THE DEVELOPMENT OF AN INTEGRATED INFORMATION SYSTEM FOR IRRIGATION WATER MANAGEMENT USING THE WAS, SWB AND RISKMAN COMPUTER MODELS

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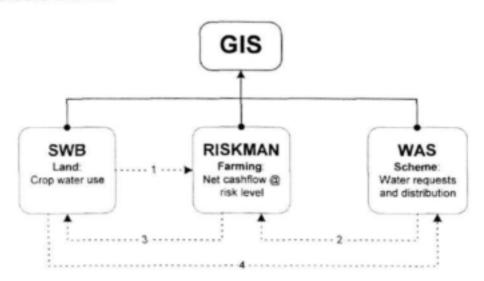
Introduction

The development of an integrated information system using the Water Administration System (WAS), Soil Water Balance model (SWB) and RiskMan computer models is about further development and implementation of research from three different research projects (WRC Report no's 531/1/95, 753/1/99 and 894/1/02). All three models make extensive use of databases and the idea of this project was to consolidate the information into an integrated information system that links to a geographical information system. This will provide a tool that can be used by individual farmers, the irrigation scheme management and agricultural advisors to minimize water losses and maximize efficient water use on scheme and farm level.

The WAS model is used by irrigation schemes for the administration of water and for the calculation of water releases into canals to satisfy a certain demand. WAS keeps an archive on crops planted, yields and water usage for an irrigation scheme that can be imported into the RiskMan model.

The SWB model is used by agricultural advisors that provide a service to farmers for irrigation scheduling. If weather stations are installed on an irrigation scheme, SWB will be able to calculate irrigation schedules for every farmer on the irrigation scheme provided that all the soil and crop data are available. SWB can be used to calculate crop yields for different water application scenarios that can be accessed directly by the RiskMan model. SWB can also automatically create a water order that can be changed if necessary and used by farmers to order water on a weekly basis.

The RiskMan model can be used by irrigation schemes to provide a service that all farmers can use to do on farm planning to make the best economical decisions. The RiskMan model can directly access relevant information from the SWB model, the WAS model or both.

The geographic information system (GIS) can be used by irrigation schemes to extract data from the three different databases and display it in a useful format on a map of the specific scheme. This information is very useful for planning and management purposes. Information that can be displayed are canal networks, sluices, pipes, canal structures, plot sizes, crops planted and total planted areas.

Referring to the previous figure irrigation scheduling data from SWB such as water use and crop yields can be accessed and used by RiskMan (link 1). In the same way can historical yields and water use records saved in WAS be used by Riskman (link 2). Once a crop has been decided upon using the RiskMan model, the day-to-day irrigation scheduling of that crop can be done using SWB (link 3). Recommendations from SWB can be converted into a water order that can be used in the WAS model (link 4).

Two irrigation schemes were identified at the start of the project for the implementation and testing of the integrated information system. The first scheme was Loskop irrigation board and the second one was Orange-Riet Government irrigation scheme. Two automatic weather stations were funded by the project that were installed at each scheme to collect weather data that could be used with the Soil Water Balance (SWB) model for irrigation scheduling services.

Aims

1. The main aim of this project is to integrate the Water Administration System (WAS), the Soil Water Balance (SWB) model and the RiskMan model in such a way that they can be used as tools on an irrigation scheme to:

   - Minimize water distribution losses.
   - Maximize efficient water use on farm level by means of irrigation scheduling.
   - Incorporate risk in crop and cash flow planning.

2. Develop a geographical information system that can be used on an irrigation scheme with WAS, SWB and RiskMan.

3. Investigate suitable modifications to WAS and SWB to compliment RiskMan as a planning tool and pending the outcome make necessary modifications.

4. Investigate the implementation of WAS, SWB and RiskMan models on a suitable irrigation scheme where it can be tested as an integrated system.

5. Implement and refine WAS, SWB and RiskMan as an integrated system on a suitable irrigation scheme.

Results

The integration of WAS, SWB and RiskMan was successful. Modifications were made to WAS, SWB and RiskMan to make the integration possible. The different models can be used alone or where necessary read information directly from the other models. WAS saves crop survey data that can be accessed by RiskMan. SWB can create simulated crop yield records that can be accessed by RiskMan. SWB can generate water request forms that can be used by WAS. Once a farmer has used RiskMan to decide on the best crops to plant, SWB can be used for the day-to-day irrigation scheduling.

The geographic information system was developed and is implemented at Loskop and Orange-Riet successfully. The canal networks of both schemes are captured and it is possible to query the different databases and display the information on the GIS map.

The GIS map consists of different layers that can be enabled or disabled depending on the amount of detail the user wants to see. The layers that were created for both schemes are a canal network layer, a farms layer and a river layer. The user can add additional layers and edit the objects on any layer such as lines, areas and points. The GIS program has a built in help file that gives the basic information on how to operate the program.

Modifications were made to WAS and SWB to compliment RiskMan as a planning tool. The modifications can be summarized as follows:

   - It is now possible to generate a water request form with SWB that is compatible with WAS. On farm water losses such as storage and conveyance losses are calculated by SWB and added to the total volume needed for irrigation. Although SWB will calculate the values of the water order form, the farmer will still be able to modify these values.

- Historical crop and yield records can be captured in WAS and these can be accessed by RiskMan.

Long-term simulations can be run with SWB that will produce yields for different water applications. These yields generated by SWB in scenario mode are accessible by RiskMan.

The implementation of WAS at Loskop and Orange-Riet was very successful. Both schemes use WAS extensively for accounting and water distribution purposes. A complete database of all irrigators with relevant information exists on both schemes. Canal network data were captured for both schemes. The necessary modifications were made to the databases that make historical crop survey records available to the RiskMan model.

The implementation of SWB at Loskop was very successful. Farmers and advisors in the area are actively scheduling with SWB. Valuable feedback was received from the Loskop area that was used to debug and improve the SWB model. The implementation of SWB at Orange-Riet is however still ongoing because the project team could not manage to find suitable farmers or advisers that were prepare to use SWB for the duration of the project. This could be because of the current user base of other irrigation scheduling services and the lack of manpower to give support should a farmer decide to use SWB.

The implementation of the RiskMan model at Orange-Riet was very successful and a few farmers cooperated with the project team to make real data available that was used to test the RiskMan model. The implementation of the RiskMan model at Loskop was however unsuccessful. Although a group of farmers were prepared to work with the project team a working solution did not realize during the research period. This is a problem that is not easily overcome as it must be realized that the irrigation scheme personnel and the farmers first priority is not the research project but the work at hand.

The implementation of the GIS program at Loskop and Orange-Riet was very successful. The GIS maps of Loskop and Orange-Riet have been completed and the personnel are able to do their own editing of the maps with the GIS program. The data querying facility of the GIS program is currently very basic, but that is something that will definitely improve once the users get to know more about the new technology and define their own needs.

Automatic weather stations have been installed successfully at Loskop and Orange-Riet and are fully operational. Both weather stations can be accessed remotely using cell phone communication. SWB has been installed at both schemes where weather data can be imported into the separate databases. The management at both schemes has committed themselves to make weather data available to farmers and advisors in the best possible way.

Conclusions

Although the project team did not implement all the modules of the integrated information system on both irrigation schemes successfully, it managed to transfer new technology to both of the schemes that will definitely grow and make a difference in there daily operations. Some of the technologies are new and it will take some time before the majority of farmers will accept it. This project has definitely proved that a visual tool such as the GIS program is easily accepted by irrigation schemes and has great potential in managing irrigation schemes and communicating information. The GIS program was the only program that was used without much persuasion by both irrigation schemes.

The current project has shown that the implementation of the integrated system at two very similar irrigation schemes produced different outcomes. What is important to one scheme is not necessary important to the other. An irrigation scheme might just not be ready to implement the complete system but can take advantage of the parts that it can use. The integrated information system cannot be forced onto an irrigation scheme. It is therefore important to do the implementation in stages and in manageable pieces. Factors that have an effect on the success rate are available resources such as hardware and personnel. Experience has shown that once a user started using a model successfully they seldom go back to the old methods.

Recommendations

It is recommended that the integrated information system should be introduced to other irrigation schemes and water management offices in South Africa. Further implementation will help to identify shortcomings that can be corrected to ensure a product that is actually used in the field.

The use of the two weather stations currently installed at Loskop and Orange-Riet should be expanded. A possibility is to make the data available on the Internet.

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Introduction

The development of an integrated information system using the WAS, SWB and RiskMan computer models is about further development and implementation of research from three different research projects (WRC Report no's 367/1/93, 347/1/96 and 476/1/96). All three models make extensive use of databases and the idea of this project is to consolidate the information into an integrated information system that is linked to a geographical information system. This will provide a tool that can be used by individual farmers, irrigation scheme management and agricultural advisors to minimize water losses and maximize water use efficiency on irrigation scheme and farm level.

The WAS model can be used by irrigation schemes for the administration of water and for the calculation of water releases into canals to satisfy a certain demand. WAS can keep an archive on crops planted, yields and water usage for an irrigation scheme that can be imported into the RiskMan model.

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The RiskMan model can be used by irrigation schemes to provide a service that all farmers can use to do on farm planning of different crop combinations at specified risk levels to make the best economical decisions. The RiskMan model can directly access relevant information from the SWB model, the WAS model or both.

The geographic information system (GIS) can be used by irrigation schemes to extract data from the three different databases and display it in a useful format on a map of the specific scheme. This information is very useful for planning and management purposes. Information that can be displayed is canal networks, sluices, pipes, canal structures, plot sizes, crops planted and planted areas.

The WAS, SWB and RiskMan models originated at universities where they have also been used as teaching aids. WAS is also used as part of the water distribution course that is given by the Department of Water Affairs and Forestry. The integrated system will therefore be a good teaching aid for people that are employed in this field.

The figure below displays schematic representation of the data flow between the different models. Irrigation scheduling data from SWB such as water use and crop yields can be accessed and used by RiskMan (link 1). In the same way can historical yields and water use records saved in WAS be used by Riskman (link 2). Once a crop has been decided upon using the RiskMan model, the day-to-day irrigation scheduling of that crop can be done using SWB (link 3). Recommendations from SWB can be converted into a water order that can be used in the WAS model (link 4).
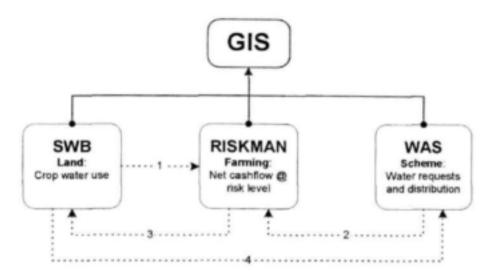
Figure 1 Data flow diagram

The following are the aims of this project:

- The main aim of this project is to integrate the Water Administration System (WAS), the Soil Water Balance (SWB) model and the RiskMan model in such a way that it can be used as a tool on an irrigation scheme to:

  - Minimize water distribution losses.
  - Maximize water use efficiency at farm level by means of irrigation scheduling.
  - Do on farm planning of cash flow at specified risk levels to make the best economical decisions.

- Develop a geographical information system that can be used on an irrigation scheme with WAS, SWB and RiskMan.

- Investigate suitable modifications to WAS and SWB to compliment RiskMan as a planning tool and pending the outcome make the necessary modifications.

- Investigate the implementation of WAS, SWB and RiskMan models on a suitable irrigation scheme where they can be tested as an integrated system.

- Implement and refine WAS, SWB and RiskMan as an integrated system on a suitable irrigation scheme.

1   Soil Water Balance (SWB)

1.1   Purpose

Soil Water Balance (SWB) is a real-time, irrigation scheduling computer model (Annandale et al., 1999a). It is based on the improved generic crop version of the soil water balance model described by Campbell and Diaz (1988). The purpose of SWB and its main features can be summarized as follows:

- SWB was developed as an irrigation-scheduling tool that should help crop producers in saving water, energy and fertilizer.

- SWB simulates the crop growth and soil water balance at field scale, with the purpose of giving recommendations on irrigation timing and amounts. The model can also calculate the salt balance. This feature is, however, recommended only for research purposes.

- SWB is mainly used as a real-time irrigation-scheduling tool. For this purpose, weather and irrigation data need to be entered in the model on a daily basis. However, SWB can also be used for scenario modelling and as a planning tool.

- SWB is a daily time step model. Weather and irrigation data need therefore to be entered on a daily basis to get a real-time recommendation on irrigation timing and amount.

- SWB is a mechanistic model giving a detailed description of the soil-plant-atmosphere continuum. The mechanistic nature makes it universally valid and deficit irrigation strategies, where water use is supply limited, can also be more accurately described.

- SWB can run in three modes (levels of operation):

  - Irrigation mode is the most basic mode of SWB. The irrigation mode is meant to be used real-time by farmers whose management (field) and soil input data have been previously set up by irrigation consultants.
  - Consultant mode is the second level (mode) of SWB. The consultant mode is meant to be used by irrigation consultants, and farmers who run SWB independently.
  - Researcher mode is the most complex mode of SWB. The researcher mode is meant to be used only for research purposes and, due to its complexity, it is not recommended to be used by irrigation consultants and farmers.

The SWB model can be set to run the following procedures:

- One-dimensional canopy radiation interception and cascading water redistribution procedure for field crops.

- Two-dimensional cascading water redistribution procedure for hedgerow tree crops irrigated with localized irrigation.

- One-dimensional finite-difference water movement procedure for field crops. This procedure is recommended only for research purposes.

- Two-dimensional canopy light interception and finite-difference water movement procedure for hedgerow tree crops irrigated with localized irrigation. This procedure is recommended only for research purposes.

Two types of models can be run to simulate the above ground part of the soil-plant-atmosphere system:

- A mechanistic crop growth model simulating dry matter accumulation and leaf area development. This is then used to calculate canopy cover.

- A FAO-based model that calculates canopy cover from the FAO crop factor.

When using the two-dimensional canopy radiation interception and finite-difference water movement procedure for hedgerow tree crops, leaf area density needs to be entered as input.

SWB is a generic crop model and simulates the soil water balance of any crop provided that either specific crop growth parameters or FAO crop factors are known. Specific crop growth parameters and FAO crop factors are already included in the database of SWB for a wide range of species (Annandale et al., 1999a).

The SWB model uses a multi-layer soil water balance by splitting the soil profile into 11 layers. This allows more accurate predictions of water redistribution and crop water uptake, and variations in soil properties can also be taken into account.

Mechanistic models have been out of reach of irrigators in the past, due to the specialist knowledge required to run these models. This high management cost was drastically reduced by packaging the SWB model in an extremely user-friendly format, eliminating the need for a detailed understanding of the intricacies of the soil-plant-atmosphere continuum.

SWB performs the calculation of the water balance and crop growth using three units, namely weather, soil and crop.

Weather unit:

The weather unit of SWB calculates the Penman-Monteith grass reference daily evapotranspiration according to the recommendations of the Food and Agriculture Organization (FAO) of the United Nations (Allen et al., 1998).

Soil unit:

In the soil unit of SWB, potential evapotranspiration is divided into potential evaporation and potential transpiration by calculating canopy radiant interception from simulated leaf area (Ritchie, 1972), from FAO crop factors or from leaf area density, depending on the type of aboveground model used. Potential evaporation and potential transpiration represent the upper limits of evaporation and transpiration and these processes will only proceed at these rates if atmospheric demand is limiting. Supply of water to the soil surface or plant root system may, however, be limiting. This is simulated in the case of soil water evaporation, by relating evaporation rate to the water content of the surface soil layer. In the case of transpiration, a dimensionless solution to the water potential based water uptake equation is used. This procedure comes up with a root density-weighted average soil water potential which characterizes the water supply capabilities of the soil-root system. This solution has been shown to work extremely well by Annandale et al. (2000). If actual transpiration is less than potential transpiration, the crop has undergone stress and leaf area development will be reduced in the mechanistic crop growth model. The multi-layer soil component of the model ensures a realistic simulation of the infiltration and crop water uptake processes. A cascading or finite-difference soil water balance is used once canopy interception and surface runoff have been accounted for.

Crop unit:

If the mechanistic crop growth model is used, SWB calculates crop dry matter accumulation in direct proportion to transpiration corrected for vapour pressure deficit (Tanner and Sinclair, 1983). It also calculates radiation-limited growth (Monteith, 1977) and takes the lower of the two. This dry matter is partitioned to roots, stems, leaves and grain or fruits. Partitioning depends on phenology calculated with thermal time and modified by water stress.

The crop growth model of SWB requires specific crop growth parameters. These can be determined using weather, soil and growth analysis data. In the absence of such time consuming and therefore expensive growth analysis data, a simpler modeling approach is required. An FAO-based crop factor procedure was developed and combined with the mechanistic SWB model, thereby still allowing evaporation and transpiration to be modeled separately as supply- and demand-limited processes (Jovanovic and Annandale, 1999). The FAO model was mainly developed in order to include more crops in the SWB crop database by making use of the database of basal crop coefficients, growth periods, root depths, crop heights, stress factors and potential yields available in FAO publications (Allen et al., 1998). The crop factor model does not grow the canopy mechanistically and therefore the effect of water stress on canopy size is not simulated. The simpler crop factor model should, however, still perform satisfactorily if the estimated canopy cover closely resembles that found in the field. The FAO model estimates crop yield under water stress conditions as a function of the stress factor for the specific crop stage and potential yield.

If the two-dimensional canopy radiation interception and finite-difference water movement procedure is used, the partitioning of potential evapotranspiration at the soil surface into potential evaporation and potential transpiration is calculated as a function of solar orientation. Some input parameters describing the canopy of hedgerow trees are also required. These parameters are row direction and canopy size, shape and leaf area density.

1.2   Application areas

The SWB model was mainly developed for irrigation scheduling under full and deficit irrigation. In particular, deficit irrigation strategies can be accurately simulated with the mechanistic crop growth model. The main target group includes farmers as well as irrigation officers and consultants. Several commercial farmers and irrigation officers are already using or are planning to use SWB for real-time irrigation scheduling. Small-scale commercial farmers are also potential users, as well as small-scale subsistence farmers, provided irrigation officers advise them.

Several other applications of SWB are possible.

Crop growth and water use under saline soil conditions can be simulated using the cascading, one-dimensional water movement procedure. Salt movement is simulated assuming complete mixing of rainfall and/or irrigation water with the soil solution. Chemical precipitation/dissolution of lime and gypsum is calculated on a daily time step per soil layer, using the model published by Robbins (1991). No toxic ion effect is included in the model. SWB can be used to investigate crop response to soil salinity under different weather and management conditions (Jovanovic and Annandale, 1998).

The SWB model can be used for long-term simulation of soil water and salt balance with generated weather data. The model can be set up to simulate the succession of crops for a user-specified cropping system. Weather data are generated with CLIMGEN, a weather generator developed by G.S. Campbell (Washington State University) and based on the work of Richardson and Wright (1984). SWB can be used to predict the sustainability of irrigation with saline water. In particular, it was used to assess the long-term (many decades) environmental impact of irrigation with gypsiferous mine effluent on soil and water resources (Annandale et al., 1999b). SWB is currently being used to schedule pivot irrigations for several crops, in the Water Research Commission project entitled "Modeling and monitoring crop production, soil properties and drainage water under centre pivot irrigation with gypsiferous mine water".

Although it was mainly developed for real-time irrigation management, the SWB model can also be used for planning and design of irrigation systems if historic weather data are entered in the model. The Paradox database makes it easy to store and handle long series of weather data.

The SWB model can be used as a teaching tool. In particular, the model was demonstrated to students with diverse academic backgrounds and career orientations at the Department of Plant Production and Soil Science, University of Pretoria. The aims of the classroom demonstrations were to familiarize the students with crop and soil water balance modeling, to strengthen their understanding of some of the theoretical principles explained during the course, and to help them in developing problem solving skills. The classroom demonstration of the SWB model was easy to set up, required only a computer and data projector, and it can be easily used in other environments. SWB can be used for theoretical lessons, as well as to create homework assignments. The method can also be beneficial for model developers to test the user-friendliness of models. The classroom demonstration of the SWB model was well received by the students. The model proved to be a useful tool for providing instruction to university students (Jovanovic and Annandale, 2000; Jovanovic et al., 2000).

The SWB model can be used as a tool to improve the use of energy and water resources in hedgerow orchards. This can be done by performing sensitivity analyses on the following input factors used in the two-dimensional canopy radiation interception and finite-difference water movement simulation: row width, row orientation, canopy height, canopy width, stem height, leaf area density, emitter spacing, wetted diameter of emitters, as well as the fraction of roots in the wetted and non-wetted portions of the ground. The results of the sensitivity analyses should indicate the best practices for establishment of the orchard (row width and row orientation), pruning (canopy height and width, stem height and leaf

area density) and irrigation water management (emitter spacing and wetted diameter of emitters), in order to maximize canopy radiation interception as well as rainfall and irrigation water use efficiency.

1.3   Benefits

The major benefit in the use of the SWB model lies in the accuracy of estimation of crop water requirements (amount and timing of irrigation). In large areas of South Africa, irrigation is required in order to achieve optimal yields. Optimization of irrigation water management is necessary for structural (irrigation system design), economic (saving of water and energy), and environmental reasons (risks of salinization, fertilizer and nutrient leaching). Crop water requirements need to be accurately quantified to improve the efficiency of irrigation water management. It is recognized that the best estimates of crop water use result from direct measurements, but this is not always feasible on large scale. The next most accurate approach would be one that integrates our understanding of the soil-plant-atmosphere continuum as mechanistically as possible. Taking the supply of water from the soil-root system, and the demand from the canopy-atmosphere system into account is essential to properly describe crop water use. The FAO Penman-Monteith reference crop evaporation (Allen et al., 1998) together with a mechanistic crop growth model, which uses soil water and grows a realistic canopy and root system provides the best possible estimate of the soil water balance. This was evaluated in a previous Water Research Commission project for a wide range of species (Annandale et al., 1999a).

The user-friendliness, matched to accuracy, makes SWB an ideal computer tool for technology application as the user generally does not need a detailed understanding of the soil-plant-atmosphere continuum in order to operate the model. Several other crop growth and soil water balance models are available. These have been developed with different levels of complexity depending on the specific requirements. Most of the existing models, however, either are crop specific or do not simulate daily crop water use. Some models are relatively simple to use for planning purposes, but do not allow real-time scheduling. Other models describe accurately the complexity of natural processes. This makes them suitable for research purposes, but they are not applicable in practice due to the large amount of input data required and lack of a user-friendly interface. A user-friendly model like SWB can make accurate, high technology approaches to irrigation scheduling feasible on farm. This approach can both reduce the costs and increase the benefits of irrigation scheduling. The grower, however, needs to be convinced that it is important to manage irrigations.

A mechanistic, and therefore universally valid, approach to estimating crop water use, like in SWB, has several advantages over the more empirical methods often used. Using thermal time to describe crop development removes the need to use different crop factors for different planting dates and regions. Splitting evaporation and transpiration solves the problem of taking irrigation frequency into account. Deficit irrigation strategies, where water use is supply limited, can also be more accurately described.

In practice, the SWB model is not meant to completely replace field measurements of soil water content. It should, however, facilitate management by making field visits less frequent. SWB, as any other model, is very unlikely to simulate a value for a parameter that is exactly equal to the measurement. For this reason, the update simulation feature was included in the model. Simulated values of fractional interception and volumetric soil water content can be updated real-time with measured data.

The recommendations feature of SWB facilitates real-time decisions on irrigation timing and amounts on farm level. SWB can, however, also be used for strategic planning at the farm level. The large number of crops included in SWB makes it suitable for planning cropping systems and target yields. This, matched to accurate predictions of crop water requirements, could be used to establish optimal seasonal and short-term (one week) irrigation strategies. For this purpose, however, the model needs to be linked to an economic model like RiskMan and a water supply management model like WAS.

The SWB model is suitable for water management under micro-irrigation. Distribution of water and energy is not uniform in widely spaced, micro-irrigated crops. This is particularly true for hedgerow fruit crops, where radiant energy may limit evaporation in the shaded row, whilst dry soil may limit the process between the rows. This is taken into account in the two-dimensional procedure of SWB. It was also essential to take into account the limited volume of soil wetted under micro-irrigation or its capacity

will easily be exceeded with a standard one-dimensional approach, leading to undesirable over-irrigation in the wetted zone, and possibly crop stress due to a too long irrigation interval.

Another benefit of SWB is that it uses a crop parameter, weather, field, irrigation water and soil database in Paradox, which negates the need to make several ASCII files in a text editor to handle each simulation. This, together with the fact that several fields can be simulated simultaneously, makes it an ideal tool for the large-scale farmer or irrigation consultant.

1.4   Features

The SWB model is written in Delphi 5 (Inprise Corp.) and uses a Paradox database. Version 1.0 is available for use with Windows 95 on an IBM-PC or compatible computer. The minimum requirement is 16 Mb RAM. The time required to complete a seasonal simulation is 3 to 5 s on a Pentium 166.

SWB makes extensive use of graphics with the soil water balance presented at the end of the simulation. SWB also generates printable graphs on which the components of the soil water balance and crop growth parameters are plotted for the simulated period.

SWB displays hints with ranges for input data, checks the ranges of input data, and generates error messages and warnings when operational errors are committed (e.g. input data out of range are entered). This should prevent accidental typing errors and errors in units.

Help files can be called by clicking on the help option or icon in the main menu. The help topics are written in HelpScribble and they describe how to operate the model (enter input data, run simulations, and generate results and recommendations). They also describe most of the technical procedures used by SWB to estimate crop growth and calculate the soil water balance, as well as recommended ranges for input data and general information. The help file makes extensive use of links and bitmaps with hotspots in order to access related topics. This should facilitate the operational and technical understanding of SWB. Context sensitive help can be accessed from any menu of SWB by pressing F1 on the keyboard.

The following special features are included in the model:

- A stand-alone ETo calculator that allows one to calculate the FAO Penman-Monteith grass reference evapotranspiration without running SWB.

- Soil water deficit can be calculated from measurements with the neutron water meter using the neutron probe scheduler as a stand-alone tool. Data from the soil database of SWB can also be imported into the neutron probe scheduler form. Water content calculated in this form can be sent to the measured values database, or can be used to update simulations. Volumetric soil water content calculated from neutron water meter measurements can also be displayed graphically.

- Soil water deficit can be calculated from measurements with tensiometers using the tensiometer scheduler as a stand-alone tool. Water content calculated in this form can be sent to the measured values database, or can be used to update simulations. Volumetric soil water content and soil matrix potential can be graphically displayed. The assumptions used to calculate soil water deficit from tensiometer measurements are explained in the help file.

- Soil water deficit can be calculated from measurements of gravimetric soil water content using the gravimetric scheduler as a stand-alone tool. Water content calculated in this form can be sent to the measured values database, or can be used to update simulations. Volumetric soil water content calculated from gravimetric measurements of soil water content can be displayed graphically.

- Volumetric soil water content at field capacity and permanent wilting point can be calculated from the percentage silt and clay, using the field capacity and wilting point calculator. This calculator uses empirical equations calibrated for soils in the Free State (Bennie et al., 1988).

- Simulated values of fractional interception of radiation and volumetric soil water content can be updated real-time with measured data. In order to facilitate the estimation and update of fractional interception of radiation (canopy cover), a database of photos of crops at different phenological stages was included in the help file.

- Recommendations for irrigation scheduling are generated and can be printed in SWB.

- A database of specific crop growth parameters and FAO crop factors is included in SWB (Annandale et al., 1999a). If parameters for particular crops and cultivars are, however, not available, these need to be determined in the field.

- An address database can be used to keep record of the users of SWB.

- Weather data can be imported into SWB from comma delimited, tab delimited or space delimited files. The order in which the data appear in the imported file can be specified, so standardization of data files is not important. The user can also set up ranges of the imported weather data. While importing weather data, the program checks for data out of range.

- SWB calculates parameters of the statistical analysis between measured and simulated data. This should allow quick, efficient and quantitative evaluation of the model's accuracy. Standard errors of measured data can also be entered in the model and error bars displayed in the output graphs.

1.5 Links with RiskMan and WAS

The link from SWB to RiskMan is through a yield summary that is generated by SWB for different water application scenarios. This summary is saved in a Paradox table that is directly accessible from RiskMan. An example of a crop yield summary is shown in the following figure.

Field	Crop	End date	Irrig (mm)	Precip (mm)	Simulated (t/ha)	Measured (t/ha)
A1	MAIZE	01./01./1990	970.0	0.0	14.0	
A1	MAIZE	01./01./1991	860.0	0.0	12.2	
A1	MAIZE	01./01./1992	727.0	0.0	10.1	
A1	MAIZE	01./01./1993	634.0	0.0	8.7	
A1	MAIZE	01./01./1994	525.0	0.0	6.6	
A1	MAIZE	01./01./1995	410.0	0.0	4.5	
A1	MAIZE	01./01./1996	281.0	0.0	2.2	
A1	MAIZE	01./01./1997	260.0	0.0	1.8	
A1	WHEAT	01./01./1990	660.0	0.0	7.8	
A1	WHEAT	01./01./1991	555.0	0.0	6.2	
A1	WHEAT	01./01./1992	468.0	0.0	5.5	
A1	WHEAT	01./01./1993	350.0	0.0	4.3	
A1	WHEAT	01./01./1994	322.0	0.0	4.0	
A1	WHEAT	01./01./1995	271.0	0.0	3.2	
A1	WHEAT	01./10/1996	191.0	0.0	2.1	
A1	WHEAT	01./01./1997	144.0	0.0	1.5	

Figure 1 Crop yield summary

The link from SWB to WAS is through a water order form that can be generated by SWB and then captured in WAS. The water request is generated using the recommendation calculated by SWB and is shown in the figure below. This water order form can be printed and used by a farmer to order water on a weekly basis.

Every field in SWB can be linked to a sluice number that is used on the water order form. The user needs to specify the current water year. The water order form defaults to an original water request but the user has the option to change this to an additional water request or a cancellation of water. The water type defaults to quota water but the user can change it to extra, surplus or flexi water. The discharges calculated by SWB are not fixed and can be changed by the user if necessary.

Figure 2 Water request form

2   RiskMan

2.1   Purpose

The RISKMAN model can be used by irrigation schemes to provide a service to assist farmers to do on farm planning, by means of supporting risk management at enterprise as well as whole farm level, in order to make the best economical decisions possible. To assist with data input into RISKMAN, relevant information can directly be accessed from the SWB model, the WAS model or both.

Risk is regarded to be present in every situation where the results of decisions are not yet known during the decision-making process. Risk management comprises choices between alternative actions that may reduce the exposure to unfavorable financial outcomes as a result of uncertain farming results.

From a risk-management point of view, computer models that treat irrigation requirements, yield/production and product prices as constant values have limited application potential. The main aim with the development of RISKMAN is to provide risk-management information to bridge the gap between theory and practice at whole farm level, and to provide reliable and relevant information on which decisions can be based. In addition to this, the system is user friendly, practically oriented and flexible, which should ensure wide applicability.

The purposes of RISKMAN can be summarized as follows:

- To provide support for risk management at enterprise as well as whole farm level.

- As a decision support system this model will facilitate and improve risk management and would make it possible to take risk into consideration.

- Serves as an aid in decision analyses, which is meant to support and not to replace the decision-maker in risk management.

- Serves as a planning aid by enabling the farmer to simulate the effect of price and production risk on the performance of his farming operation, in advance, in order to evaluate alternative farm or production plans. Therefore, farm plans may be adjusted or other alternatives may be considered.
- Take production, price, irrigation quantities, interest rate variability as well as hail damage into account separately or jointly.

- Production, price and irrigation quantities can have up to 5 types of data inputs according to the type of data available, namely constant (fixed), single values, cumulative, triangular or normal distributions.

- Take the user's attitude toward risk into account, namely risk-seeking, risk-neutral or risk-averse.

- Simulated risk for any three-production systems with the purpose to help the farmer decide what the best production system is according to his circumstances, and also provides recommendations as output.

2.2   Application areas

The flexibility of RISKMAN guarantees various fields of application regarding short-term risk analyses. Although the end beneficiary is the farmer, various users can benefit by the type of results offered by the analyses in RISKMAN. Some of the application areas include:

- Consultants, to advise farmers according to their circumstances and needs.

- On irrigation schemes in conjunction with the SWB and WAS models.

- Various agribusinesses. All the firms that provide farm inputs, from financial institutions to co-operations, have interest in the welfare of the farming community, especially regarding the risk associated with various activities or enterprises. Therefore, RISKMAN will aid in their analyses, from repayment of loans to the affordability of inputs.

- Small-scale producers are not excluded from the benefits of RISKMAN. Due to the flexibility built into the program small-scale farming operations can also be simulated.

- Utilized as a research tool by institutions and people with interest in economic variables at whole farm level, policy evaluation like interest rates, as well as the effect of contract prices on production.

- Used as a teaching tool. In particular to demonstrate risk to strengthen understanding of some of the theoretical principals explained during a course, and to help them in developing problem solving skills.

Several other applications of RISKMAN regarding farm planning are possible, namely:

- At whole farm level, by simulating price and production risk, various types of farmers can use RISKMAN to evaluate alternative production plans. Not only is variability due to price and production fluctuations taken into account, but also irrigation cost deviations as a result of different water applications are calculated.

- Whether or not to fixed on price, for instance a harvest time day price as opposed to a contracted price.

- Used to recommend the best production system according to the decision-makers attitude toward risk, and whether or not the FARM need will be satisfied.

- Financial risk. What if the interest rate increases, for example the risk of financing an irrigation system with a loan can be estimated.

Whether or not the user must insure against hail damages.

2.3   Benefits

The RISKMAN model makes theoretical and time-consuming risk analyses of short-term farm plans something of the past. Although some calculations are complicated to assure an economic well-founded program the data requirements is simple.

The main benefits of RISKMAN can be summarized as follows:

- The simulation of risk and definition of variables as different distributions.

- Sets of simulated irrigation quantities and yield levels, imported from SWB, can be used in the model to take production risk into account. The reliability of these simulated values is vested in the accuracy of the inputs and assumptions made in the model.

- By making use of inter alia time-series analyses and subjective probabilities, cumulative probability distributions can be compiled and used to reflect price risk.

- The consequences of day to day changes in economic parameters on economic results like product prices, can immediately be calculated by decision-makers. This will assist everyone involved in the fast changing and dynamic farming sector.

- The influence of variable interest rates on economic performance can also be evaluated.

- Alternative production plans, including alternative crop rotation systems as well as risk-management strategies at enterprise level, like for instance insurance against hail damage, can be evaluated.

- The reporting capability of RISKMAN makes it easy to generate cumulative distributions and do recommendation, according to risk preference.

With accurate input RISKMAN is a valuable instrument to facilitate risk management. As a support system in decision-making, RISKMAN provide users with the opportunity to facilitate this management process. Some of the benefits of the various inputs needed are:

- RISKMAN is not data intensive.

- Input data was limited to available farm level data.

- Secondary data sources like enterprise budgets will also ease the data burden.

Linking up with other models like WAS, SWB, FARMS[1] and IRRICOST[2] not only reduce the duplication of data input, but also have the advantage of utilizing generated data.

2.4   Features

The RISKMAN model is written in Delphi 5 (Inprise Corp) and uses a Paradox database, which makes it easy to store and handle long series of simulated data. This feature also enables decision-makers to do risk analyses for several farmers with a single program.

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[1]. A management decisions support system at whole farm level.
[2]. Estimate fixed and variable irrigation costs of different irrigation system types.

The RISKMAN model is not dependent on other modules, but has the advantage to link with other models and import data from them, for instance:

- Simulated irrigation quantity and yield values, as well as field ID and crop enterprise lists from the SWB model.

- If the WAS model is installed on the computer, the RISKMAN model can also be linked to its InterBase file, where measured (historical) irrigation quantity and yield data can be imported from.

- A summary of farming costs from the FARMS model (dynamic decision support model at whole farm level).

- Estimated fixed and variable irrigation costs from IRRICOST (irrigation cost estimation model).

The output of RISKMAN facilitates:

- In the model risky variables are treated as distributions and the output of the model can therefore also be presented as distributions for each risk variable. Consequently the whole distribution of each variable is taken into account.

- RISKMAN calculates various statistical parameters for the simulated data. This should allow quick, efficient and quantitative evaluation of the model's accuracy.

- Unlike traditional economic analyses that yield a single statistic, RISKMAN generated the whole distribution of the farm's total gross margin and net cash flow.

- Alternative management strategies can be evaluated at enterprise level and the dominant production system can also be identified according to the users risk preference, by means of stochastic dominance with respect to its function, as a recommendation.

- Extensive use of graphics, with each distribution presented as output at the end of the simulations.

The following special features are included in the RISKMAN model:

- An address database can be used to keep record of the users.

- Complicated calculations that are almost impossible to do by hand.

- To safeguard the user against faulty data input, the model uses referential integrity.

Flexibility and user friendliness enjoyed high priority in the development of RISKMAN. Users can obtain assistance and training by means of the help lines and error messages are displayed in certain cases.

2.5   Links with WAS and SWB

The Water Administration System (WAS) model is able to store sets of historic irrigation quantity and yield production values in a table. These values can be imported by the RISKMAN program, if the "Uses WAS" checkbox is checked on the *File | Option* form in RISKMAN, by clicking on the WAS icon at the top of the Crop enterprise form. The RISKMAN program will then run queries for all the crop enterprises in the table to locate the corresponding data in WAS. The values obtained through these queries are then inserted as a series of single values for both the irrigation quantities and yield productions. The average calculated from the single values will also be inserted as the basic or constant value of the variable.
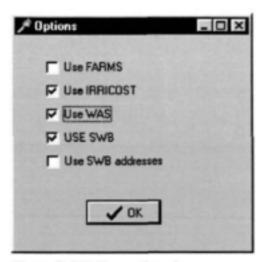
Figure 3 RiskMan options form

Instead of historical values, the Soil Water Balance (SWB) program simulates yield and irrigation quantity data if used in scenario mode. If the SWB program is installed and running on the same computer as the RISKMAN program and the "Use SWB" checkbox is checked, the user will be able to import sets of data from the SWB program into various forms and tables. The SWB model has several links with RISKMAN, namely:

- On the *General farm information | Land* form the user can utilize the field ID list of the particular water scheme on which the SWB program is running, by double clicking in the field ID cell where the user wants to insert a new field ID or to edit an existing one. The user can then double click on the chosen field ID.

- The same procedure can be followed on the *Crop enterprise | Enterprise info* form. In order to enter a crop enterprise name from the list of available enterprises of the particular water scheme, on which the SWB is running, double click in the crop enterprise cell, and again on the chosen enterprise.

- To import simulated irrigation quantities and yield values from the SWB program, click on the SWB icon at the top of the Crop enterprise form. By clicking on this icon, and with the help of some queries, all the enterprises whose field ID and crop enterprises values are identical in both RISKMAN and SWB, will be inserted as single values for both the irrigation quantities and yield productions. The average calculated from the single values will also be inserted as the basic or constant value of the variable.

If "Use SWB Addresses" checkbox is marked, the SWB address database will be linked to the RISKMAN program; otherwise the address database of RISKMAN will be used.

Initially the FARMS model was developed. This model was very data intensive. It was decided to develop a separate model RISKMAN, with the option to import data from the FARMS, SWB, WAS and IRRICOST programs/models.

The FARMS system was developed as a decision support system for assistance during the management process at whole farm level. This was evaluated in a previous Water Research Commission project for a wide range of specied. RISKMAN is based on the research done by Meiring (1994) and use procedures developed by King (1979).

The FARMS system consists out of three simulation models, Farms, IrriCost and RISKMAN. Farms is a comprehensive planning model for simulating the economic and financial results on a monthly basis for the next two seasons. This planning tool serves as an aid for decisions from enterprise level up to whole farm level. The analysis of the economics of irrigation, including detail cost calculations for various irrigation systems, is further expanded by the incorporation of the IrriCost model in the system. The important third module of the system is RISKMAN, which incorporates production and price risk in economic analyses.

In most cases the prices obtained for products, as well as weather or rainfall variability, which results in yield variation, were indicated as the most important risks. The question whether the yield of crops must be adjusted to accommodate hail damage or not is also handled. However, the nature of a farm business, as well as its locality, has an influence on the importance of risk. Therefore it is important to make available a tool or instrument with enough flexibility to be utilised by every farmer.

- Risk analyses by using data intensive complicated models, can accordingly be replaced by true to life simulations of various performance criteria, like farm profit income, incorporating price and production risk.

The user-friendliness makes RISKMAN an ideal computer tool for technology app. As the user generally does not need a detailed understanding of risk procedures. As a decision support system this model will facilitate and improve risk management and would make it possible to take risk into consideration.

RISKMAN depends on a database that is built up by sets of data that can be edited and are easily accessible.
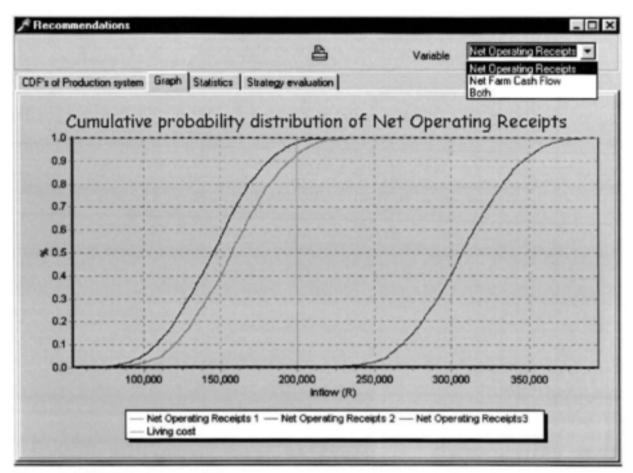
Figure 4 RISKMAN recommendations

3 Water Administration System (WAS)

3.1 Purpose

The Water Administration System (WAS) is a database that is used as a management tool for irrigation schemes and water management offices that want to manage their water accounts and water supply to their clients through canal networks, pipelines and rivers.

WAS replaces the old manual water distribution system that was commonly used on government irrigation schemes. Its water distribution module can handle canal networks and river systems and has extensive water loss control capabilities.

WAS replaces the financial system with a fully auditable debit system that integrates with the water administration and water request modules in WAS. The debit system has extensive reporting capabilities that give management better control over their user accounts.

3.2 Application areas

WAS is used for the efficient administration of irrigation schemes and water management offices that includes:

- A database of all the users that are managed by a specific office and their details such as addresses, scheduled areas, water quotas etc.

- A database of all the canal networks and river systems that are managed by a specific office.

- A water distribution system that calculates water releases for canal networks and river systems taking lag times and different water losses into account.

- A full debit system that integrates with the water distribution modules in WAS and that manages all the water accounts.
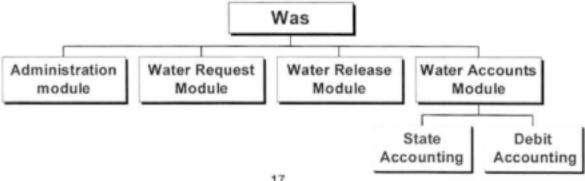
3.3 Benefits

The main benefit of using WAS is the fact that you have a completely integrated system that manages administration, water distribution and accounts in a single package. WAS uses a relational database that can manage large amounts of data efficiently and saves everything in a single file. Experience has shown that the database is robust, works well over a network, is easy to install and has a low maintenance requirement. The reporting capabilities of WAS makes it easy to generate water distribution and financial reports. The main benefits can be summarized as follows:

- The different modules in WAS are completely integrated which makes it possible to cross-reference relevant information where necessary.

- All data is archived in a single database that makes it possible to access old records quickly without having to resort to a manual filing system. Only one file needs to be backed up for protection against any loss of data.

- WAS can export specified information to an external file that can be copied and used to import the same information into any other WAS database.

- WAS generates a range of reports that simplifies the management of a scheme or office and improves productivity in and outside the office.

- WAS ensures better financial control with an integrated debit system.

- WAS minimizes water losses with an improved water distribution system.

3.4 Features

The WAS model is written in Delphi 5 (Inprise Corp.) and uses an Interbase database to store all data. Interbase is a relational database management system (RDBMS) that provides rapid transaction processing and data sharing in a single- or multi-user environment. The Interbase database has a small footprint and experience has shown that it is robust and easy to install and to maintain. It is also an open source client server database and therefore requires no licensing fees. WAS requires at least a 486-PC running Windows 95/98/NT. At least 32Mb memory must be available to run the program, but 64 MB is recommended.

WAS consists of four modules that are integrated into a single program that can be used on a single PC or in a multi-user environment. These modules can be implemented partially or as a whole, depending on the requirements of the specific scheme or office. The four modules are:

Administration module

This module is used to administrate the details of all water users or accounts on an irrigation scheme. The water administration module is common to all the other modules. The following information is managed through the water administration module:

- Irrigation scheme details.
- Financial model setup.
- List of irrigation schemes and water years.
- Owner, tenants and postal addresses.
- Water quota allocations.
- Scheduled areas.
- Household and livestock pipes installed.
- LRA – List of ratable areas.
- Crop survey information such as crops planted, areas planted, water applied and crop yield information.
- List of plots to which the water delivery has been stopped with reasons why. This list is used in the water request module to automatically block the capturing of any weekly water requests.

Information captured in the administration module is used extensively in the other modules.

Water request module

This module is used to administrate water requested by farmers on an irrigation scheme. It is also used to capture date and time based in- and outflows on river systems. Reports that can be printed, include a water balance sheet for each farmer or user, a water usage report and the percentage water used report of water allocated. The following information is managed through the water request module:

- Weekly based quota allocations.
- Weekly based water requests that are divided into original, additional and cancellation request types. The water requests are also classified as quota, extra surplus and flexi water types. Weekly based water requests are normally used for canal systems where the water distribution is done on a weekly basis.
- Weekly based water transfers between plots. Links can be created between master plots with extensions that allow for automatic water transfers between a master plot and an extension. There is no limit to the number of extensions that can be linked to a master plot.
- Weekly or monthly based metered volumes.
- Date and time based inflows and outflows that are normally used for river systems.
- Measurement stations readings with linked discharge tables.
- Water balance statements and reports.

Water accounts module

This module links with the administration and the water request modules and administrates all water accounts for an irrigation scheme or water management office. The user can choose between two major accounting systems. The first is the current Department of Water Affairs and Forestry accounting system and the second is a full debit system. The Department of Water Affairs and Forestry accounting system manages the following:

- Preliminary or first invoice for irrigation water use.
- Final or second invoice for irrigation water use.
- Monthly invoices for industrial water use.
- Payments on all invoices.
- Report on outstanding balances.

This accounting system is not auditable, and parts of it are still done manually. The debit accounting system on the other hand is fully auditable and manages the following:

- Monthly invoices for irrigation and industrial water use.

- Computer receipts.
- Computer journals.
- Computer invoices.
- Hand receipts.
- Hand journals.
- Hand invoices.
- Audit trail reports.
- Age analysis reports.
- Reconciliation reports.
- List of industrial levies.
- Printing invoices on pre-printed stationery.

Water release module

This module links with the water request module and calculates water releases for the main canal and all its branches taking lag times and any water losses into account. A schematic layout of the total canal network or river system is captured with detail such as the cross-sectional properties, positioning of sluices or pumps, canal slopes, structures and canal capacities. Discharges are converted to the corresponding measuring plate readings where needed. Water distribution sheets and water loss analysis reports can be printed for canal systems.

Some of the other features are:

- WAS can do complicated water release calculations that are impossible to do by hand.
- WAS can analyze canal and river reaches in detail.
- WAS can draw canal and river cross-sections and longitudinal profiles.
- WAS can calculate the reference evapotranspiration (ETo) from weather station data that is used to calculate the evaporation and transpiration losses for water distribution.
- WAS has the capability to link a different weather station to every reach in a canal or river that allows for different evaporation and transpiration losses for every reach.
- WAS can be installed on a network that makes it possible for people to work on a single database simultaneously.
- WAS uses referential integrity to safeguard the user against faulty data input.

3.5 Links with RiskMan

The link from WAS to RiskMan is through a crop survey table that is captured in WAS. This table is directly accessible from RiskMan. An example of the table in WAS is shown in the figure below. The crop survey table can archive an unlimited number of records that is linked to a specific irrigation scheme and plot.
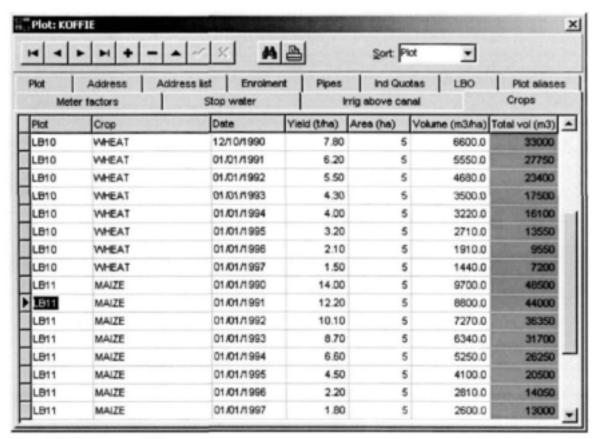
Figure 5 Crop survey list

4 Geographic Information System (GIS)

4.1 Purpose

The geographic information system (GIS) is designed to link to the WAS, RiskMan and SWB databases and display relevant information on a map. The GIS program is also developed as an editing tool to create and edit maps to be used with the different databases.
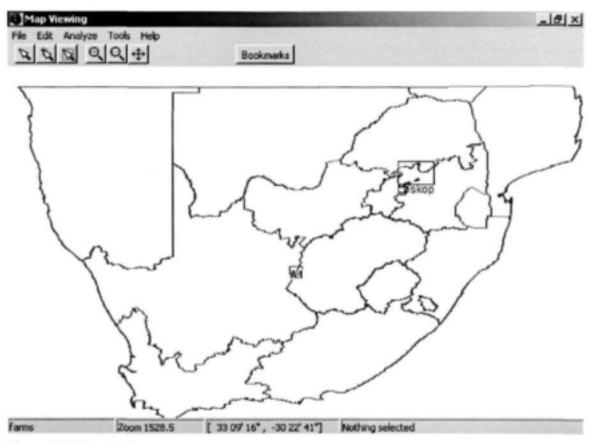
Figure 6 GIS main form

4.2 Application areas

The GIS can mainly be used by irrigation schemes as a management tool to display relevant information from the WAS, RiskMan and SWB databases on their irrigation scheme map.

4.3 Benefits

The main benefit of using a geographic information system is the fact that data can be displayed spatially on a map. This gives the user a much better understanding of the data and a tool to analyze the data in different ways. As a management tool it is much easier to do planning on a map and to communicate information to subordinates.

4.4 Features

The GIS program is written in Delphi 5 (Inprise Corp.) and uses MapInfo MapX ActiveX (OCX) control for the mapping technology. The program has the capability to link to Paradox and Interbase databases and display relevant information on a map. The GIS provides standard tools including:

- Navigation tools (Zoom-in, Zoom-out, Pan, Center) that let the user change the scale and or position placing of the map.
- A labelling tool that lets the user click a map feature to label it.
- A set of selection tools that give the user various ways to select map features.
- A thematic mapping tool that is used to analyze a point and ranges of data.
- A map layer tool that is used to create different layers to display specific information. The user can show or hide layers depending on the detail that needs to be seen.
- An editing tool to create lines, join lines and split lines.

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- Bookmark tool that is used to save and retrieve different views of a map.

4.5   GIS integration of RiskMan, WAS and SWB

The GIS program has the ability query the RiskMan, WAS and SWB databases and display the relevant information on a map. Two types of data can be displayed, the first type is point data and the second type is range data. The range type displays data for different ranges in user specified colors. The following two figures display parts of the Loskop and Orange-Riet GIS map respectively.
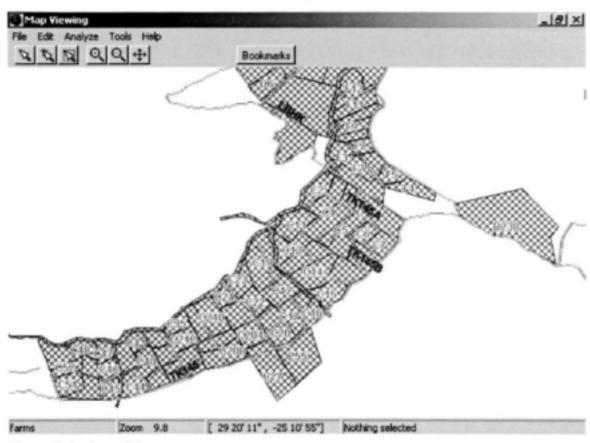
Figure 7 Loskop GIS map
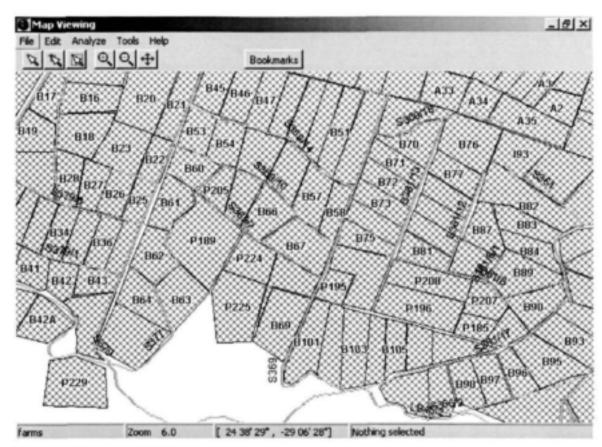
Figure 8 Orange-Riet GIS map

5   Discussion

The development of an integrated information system using the WAS, SWB and RiskMan computer models provide an irrigation scheme with an extensive suite of tools to improve irrigation scheme management, minimize water distribution losses, deliver an irrigation scheduling service to farmers and supply a tool that can be used by farmers to do on farm planning to make the best economical decisions and minimize risk.

The success of any project can be measured according to the initial aims and how well they were met. Two irrigation schemes were identified at the start of the project to implement and test the integrated information system. The first scheme was Loskop irrigation board and the second one was Orange-Riet Government irrigation scheme. Two automatic weather stations were funded by the project and the idea was to install one at each scheme to collect weather data that could be used with the Soil Water Balance (SWB) model for irrigation scheduling services.

The following paragraphs discuss the success of the project according to the initial aims.

Aim 1
The main aim of this project is to integrate the Water Administration System (WAS), the Soil Water Balance (SWB) model and the RiskMan model in such a way that they can be used as tools on an irrigation scheme to:

- *Minimize water distribution losses.*
- *Maximize efficient water use at farm level by means of irrigation scheduling.*
- *Do on farm planning to make the best economical decisions.*

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The integration of WAS, SWB and RiskMan were successful. Modifications were made to WAS, SWB and RiskMan to make the integration possible. The different models can be used alone or where necessary, information can be read directly from the other models. WAS saves crop survey data that can be accessed by RiskMan. SWB can create simulated crop yield records that can be accessed by RiskMan. SWB can generate water request forms that can be used by WAS. Once a farmer has decided on the best crops to plant, SWB can be used for the day to day irrigation scheduling.

Aim 2
Develop a geographical information system that can be used on an irrigation scheme with WAS, SWB and RiskMan.

The geographic information system was developed and is implemented at Loskop and Orange-Riet successfully. The canal networks at both schemes are captured and it is possible to query the different databases and display the information on the GIS map.

The GIS map consists of different layers that can be enabled or disabled depending on the amount of detail the user wants to see. The layers that were created for both schemes are a canal network layer, a farms layer and a river layer. The user can add additional layers and edit the objects on any layer such as lines, areas and points. The GIS program has a built in help file that gives the basic information on how to operate the program.

Aim 3
Investigate suitable modifications to WAS and SWB to compliment RiskMan as a planning tool and pending the outcome make necessary modifications.

Modifications were made to WAS and SWB to compliment RiskMan as a planning tool. The modifications can be summarized as follows:

- It is now possible to generate a water request form with SWB that is compatible with WAS. On-farm water losses such as storage and conveyance losses are calculated by SWB and added to the total volume needed for irrigation. Although SWB will calculate the values of the water order form, the farmer will still be able to modify these values.
- Historical crop and yield records can be captured in WAS that can be accessed by RiskMan.
- Long-term simulations can be run with SWB that will produce yields for different water applications. These yields generated by SWB in scenario mode are accessible by RiskMan.

Aims 4 & 5
Investigate the implementation of WAS, SWB and RiskMan models on a suitable irrigation scheme where it can be tested as an integrated system.

Implement and refine WAS, SWB and RiskMan as an integrated system on a suitable irrigation scheme.

Orange-Riet Government irrigation scheme and Loskop irrigation board were selected for the implementation of the integrated information system.

The implementation of WAS at Loskop and Orange-Riet was very successful. Both schemes use WAS extensively for accounting and water distribution purposes. A complete database of all irrigators with relevant information exists on both schemes. Canal network data were captured at both schemes. The necessary modifications were made to the databases that make historical crop survey records available to the RiskMan model.

The implementation of SWB at Loskop was very successful. Farmers and advisors in the area are actively scheduling with SWB. Valuable feedback was received from the Loskop area that was used to debug and improve the SWB model. The implementation of SWB at Orange-Riet was however not successful. This could be because of the current user base of other irrigation scheduling services and the lack of manpower to give support should a farmer decide to use SWB.

The implementation of the RiskMan model at Orange-Riet was very successful and a few farmers cooperated with the project team to make real data available that was used to test the RiskMan model. The implementation of the RiskMan model at Loskop was, however, unsuccessful. Although a group of farmers were prepared to work with the project team a working solution did not realize during the research period. This is a problem that is not easily overcome as it must be realized that the irrigation scheme personnel and the farmers first priority is not the research project, but the work at hand.

The implementation of the GIS program at Loskop and Orange-Riet was very successful. The GIS maps of Loskop and Orange-Riet have been completed and the personnel are able to do their own editing of the maps with the GIS program. The data querying facility of the GIS program is currently very basic, but that is something that will definitely improve once the users get to know more about the new technology and define their own needs.

The automatic weather stations have been installed successfully at Loskop and Orange-Riet and are fully operational. Both weather stations can be accessed remotely using cell phone communication. SWB has been installed at both schemes where weather data can be imported into the separate databases. The management at both schemes has committed themselves to make weather data available to farmers and advisors in the best possible way.

6   Conclusions

Although the project team did not implement all the modules of the integrated information system on both irrigation schemes successfully, it managed to transfer new technology to both of the schemes that will definitely grow and make a difference in their daily operations. Some of the technologies are new and it will take some time before the majority of farmers will accept it. This project has definitely proved that a visual tool such as the GIS program is easily accepted by irrigation schemes and has great potential in managing irrigation schemes and communicating information. The GIS program was the only program that was used without much persuasion by both irrigation schemes.

The current project has shown that the implementation of the integrated system at two very similar irrigation schemes produced different outcomes. What is important to one scheme is not necessary important to the other. An irrigation scheme might just not be ready to implement the complete system but can take advantage of the parts that it can use. The integrated information system cannot be forced onto an irrigation scheme. It is therefore important to do the implementation in stages and in manageable bits. Factors that have an effect on the success rate are available resources such as hardware and personnel. Experience has shown that once a user starts using a model successfully they seldom go back to the old methods.

7   Recommendations

It is recommended that the integrated information system should be introduced to other irrigation schemes and water management offices in South Africa.

The use of the two weather stations currently installed at Loskop and Orange-Riet should be expanded. A suggestion is to make the data available on the Internet.

8 References

ALLEN RG, PEREIRA LS, RAES D and SMITH M (1998) Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No. 56. FAO, Rome, Italy.

ANNANDALE JG, BENADÉ N, JOVANOVIC NZ, STEYN JM and DU SAUTOY N (1999a) Facilitating Irrigation Scheduling by Means of the Soil Water Balance Model. Water Research Commission Report No. 753/1/99, Pretoria, South Africa.

ANNANDALE JG, JOVANOVIC NZ, BENADÉ N and TANNER PD (1999b) Modeling the long-term effect of irrigation with gypsiferous water on soil and water resources. *Agriculture, Ecosystems and Environment* **76** 109-119.

ANNANDALE JG, CAMPBELL GS, OLIVIER FC and JOVANOVIC NZ (2000) Predicting crop water uptake under full and deficit irrigation: An example using pea (*Pisum sativum* cv. Puget). *Irrig. Sci.* **19** 65-72.

BENADÉ N, ANNANDALE JG and VAN ZIJL H (1997) The development of a computerized management system for irrigation schemes. Water Research Commission Rep. No. 513/1/95, Pretoria, South Africa.

BENNIE ATP, COETZEE MJ, VAN ANTWERPEN R, VAN RENSBURG LD and DU T. BURGER R (1988) 'n Waterbalansmodel vir besproeiing gebaseer op profielwatervoorsieningstempo en gewaswaterbehoeftes. Waternavorsingskommissie Verslag No. 144/1/88, Pretoria, South Africa.

CAMPBELL GS and DIAZ R (1988) Simplified soil-water balance models to predict crop transpiration. In: Bidinger FR and Johansen C (eds.) *Drought research priorities for the dryland tropics*. ICRISAT, India.

JOVANOVIC NZ and ANNANDALE JG (1998) Soil and aerial environment affects crop salt tolerance - a modelling study. *Applied Plant Science* **12(2)** 39-42.

JOVANOVIC NZ and ANNANDALE JG (1999) An FAO type crop factor modification to SWB for inclusion of crops with limited data: Examples for vegetable crops. *Water SA* **25(2)** 181-190.

JOVANOVIC NZ and ANNANDALE JG (2000) SWB (Soil Water Balance): A computer tool for teaching future irrigation managers. *J. Nat. Resour. Life Sci. Educ.* **29** 15-22.

JOVANOVIC NZ, ANNANDALE JG and HAMMES PS (2000) Teaching crop physiology with the Soil Water Balance (SWB) model. *J. Nat. Resour. Life Sci. Educ.* **29** 23-30.

MONTEITH JL (1977) Climate and efficiency of crop production in Britain. *Philos. Trans. R. Soc. London*, Ser. B **281** 277-294.

RICHARDSON CW and WRIGHT DA (1984) WGEN: A Model for Generating Daily Weather Variables. US Dept. of Agriculture, Agricultural Res. Services.

RITCHIE JT (1972) Model for predicting evaporation from a row crop with incomplete cover. *Water Resour. Res.* **8** 1204-1213.

ROBBINS CH (1991) Solute transport and reactions in salt-affected soils. In: *Modeling Plant and Soil Systems*. Agronomy Monograph No. 31, ASA-CSSA-SSSA, 677 S. Segoe Rd., Madison, WI 53711, pp. 365-395.

TANNER CB and SINCLAIR TR (1983) Efficient water use in crop production: research or re-search? In: Taylor HM, Jordan WR and Sinclair TR (eds.) *Limitations to efficient water use in crop production*. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, Wisconsin.

APPENDIX A

SWB

User's Manual

Soil Water Balance (SWB)

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3. Potatoes South Africa
4. Langeberg Foods

DISCLAIMER

Extreme attention to detail has been given to ensure that calculation procedures in this model are sound. Nevertheless, the authors, the University of Pretoria and the Water Research Commission will not accept liability for any damage or loss suffered as a result of the use of this model.

TABLE OF CONTENTS

1.1 Mechanistic irrigation scheduling

The best estimates of crop water use result from direct measurements, but this is not always feasible on large scale. The next most accurate approach would be one, which integrates our understanding of the soil-plant-atmosphere continuum as mechanistically as possible. Taking the supply of water from the soil-root system, and the demand from the canopy-atmosphere system into account is essential to properly describe crop water use. The FAO Penman-Monteith reference crop evaporation (Smith *et al.*, 1996) together with a mechanistic crop growth model, which uses soil water and grows a realistic canopy and root system provides the best possible estimate of the soil water balance. This approach has been out of reach of irrigators due to the specialist knowledge required to run the models. This high management cost can be drastically reduced by packaging the model in an extremely user-friendly format, eliminating the need for a detailed understanding of the intricacies of the soil-plant-atmosphere continuum. The benefits are increased too, because of the accuracy of the mechanistic, and therefore universally valid, estimation procedure.

1.2 The SWB (Soil Water Balance) irrigation scheduling model

Soil Water Balance (SWB) is a user-friendly irrigation scheduling model. It is based on the improved generic crop version of the soil water balance described by Campbell and Diaz (1988). A brief description follows with more detail given in Chapter 4 (Technical manual).

SWB is a mechanistic, real time, generic crop, soil water balance, irrigation scheduling model. It gives a detailed description of the soil-plant-atmosphere continuum, making use of a weather, soil and crop databases.

SWB performs the calculation of the water balance and crop growth using three units, namely weather, soil and crop.

Weather unit:

The weather unit of SWB calculates the Penman-Monteith grass reference daily evapotranspiration according to the recommendations of the Food and Agriculture Organization (FAO) of the United Nations (Smith *et al.*, 1996; Smith, 1992a).

Soil unit:

In the soil unit of SWB, potential evapotranspiration is divided into potential evaporation and potential transpiration by calculating canopy radiant interception from simulated leaf area (Ritchie, 1972). This represents the upper limits of evaporation and transpiration and these processes will only proceed at these rates if atmospheric demand is limiting. Supply of water to the soil surface or plant root system may, however, be limiting. This is simulated in the case of soil water evaporation, by relating evaporation rate to the water content of the surface soil layer. In the case of transpiration, a dimensionless solution to the

water potential based water uptake equation is used. This procedure comes up with a root density weighted average soil water potential which characterizes the water supply capabilities of the soil-root system. This solution has been shown to work extremely well by Annandale et al. (1996). If actual transpiration is less than potential transpiration the crop has undergone stress and leaf area development will be reduced. The multi-layer soil component of the model ensures a realistic simulation of the infiltration and crop water uptake processes. A cascading soil water balance is used once canopy interception and surface runoff have been accounted for.

Crop unit:

In the Crop unit, SWB calculates crop dry matter accumulation in direct proportion to transpiration corrected for vapour pressure deficit (Tanner and Sinclair, 1983). It also calculates radiation limited growth (Monteith, 1977) and takes the lower of the two. This dry matter is partitioned to roots, stems, leaves and grain or fruits. Partitioning depends on phenology calculated with thermal time and modified by water stress.

SWB also includes a model based on the FAO crop factor approach (Smith, 1992b). This model can be used to calculate the soil water balance.

1.3 Why SWB?

A mechanistic, and therefore universally valid, approach to estimating crop water use, like that described here, has several advantages over the more empirical methods often used. Using thermal time to describe crop development removes the need to use different crop factors for different planting dates and regions. Splitting evaporation and transpiration solves the problem of taking irrigation frequency into account. Deficit irrigation strategies, where water use is supply limited, can also be more accurately described.

Extensive use is made of graphics with the soil water balance presented at the end of the simulation. Valuable information on the components of the soil water balance with the deficit to field capacity and recommendations for the next irrigation are also given.

SWB uses a crop parameter, weather, field, water and soil database which negates the need to make several ASCII files in a text editor to handle each simulation. This, together with the fact that several fields can be simulated simultaneously, makes it an ideal tool for the large farmer or irrigation consultant.

User-friendly models can make accurate, high technology approaches to irrigation scheduling feasible on farm. This approach can both reduce the costs and increase the benefits of irrigation scheduling. The grower, however, needs to be convinced that it is important to manage irrigations.

1.4 How to use the User's Guide and Technical Manual?

A brief user's guide is presented in Chapter 2 (User's guide).

Special features of SWB are shown in Chapter 3 (Special features).

A detailed, technical description of both crop growth and FAO-based model (Weather, soil and crop units), follows in Chapter 4 (Technical manual).

Since SWB is a generic crop growth model, parameters specific for each crop have to be known. SWB includes a database of parameters for a large number of crops. If parameters for particular crops and cultivars are, however, not available, these need to be determined in the field.

Guidelines for the determination of specific crop growth parameters required by the crop growth model are given in Chapter 5 (Guidelines for the determination of specific crop growth parameters).

Guidelines for the determination of the parameters required by the FAO model are given in Chapter 6 (Guidelines for the determination of the FAO model parameters).

1.5 How to operate SWB?

Question: How to install SWB?

Answer: Select Setup from the CD drive.

The set-up program will automatically create an SWB shortcut icon on your Windows desktop.

The program runs in Windows 95 on an IBM-PC or compatible computer. The minimum requirement is 16 Mb RAM. The time required to complete a seasonal simulation is 3 to 5 s on a Pentium 166. The program is supplied in executable code on 3.5-inch disks or CD, with a quick reference User's guide and Technical manual.

Question: How to run SWB?

Answer: Double click on the SWB shortcut icon in the Windows desktop.

Question: What are the modes of SWB?

Answer: SWB can run in three modes (levels of operation):

1)   **Irrigation**
This is the most basic mode of SWB. **When the program is installed from the CD, SWB runs in Irrigation mode.** The following operations can be performed in the Irrigation mode: run simulations, enter real-time weather and irrigation data at the end of the simulation, see results and recommendations. In order to run a simulation, however, management (field) and soil input data need to be entered. The Irrigation mode is meant to be used real-time by farmers whose management (field) and soil input data have been previously set up by irrigation consultants.

2)   **Consultant**
This is the second level (mode) of SWB. The Consultant mode performs the same operations as the Irrigation mode. In addition, the following operations can

be performed in the Consultant mode: enter input data for management (field) and soil, use special features of SWB (ETo calculator, enter measured data, neutron probe scheduler, tensiometer scheduler, gravimetric scheduler, field capacity and permanent wilting point calculator, update simulations, generate or change specific crop growth parameters and FAO crop factors, import weather data). The Consultant mode is meant to be used by irrigation consultants and farmers who run SWB independently.

3) **Researcher**

This is the most complex mode of SWB. The Researcher mode performs the same operations as the Irrigation and Consultant modes. In addition, the following operations can be performed in the Researcher mode: run long-term simulations, see yield summary for long-term simulations, run salt balance simulations, run the two-dimensional canopy radiation interception model, run the one- and two-dimensional finite-difference water movement model, run hourly simulations. The Researcher mode is meant to be used only for research purposes and, due to the complexity, it is not recommended to be used by irrigation consultants and farmers.

Question: How to change mode of SWB?
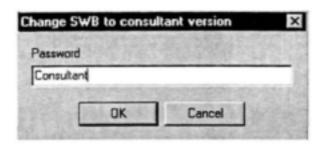
Answer: When first installed, SWB runs in Irrigation mode. To change mode, double click on the Soil Water Balance (Irrigation) bar below the logo in the Main Menu.

Soil Water Balance (Irrigation)

Choose Consultant or Researcher mode.

Enter the password in the corresponding block. The password is Consultant for the **Consultant** mode, and **Researcher** for the Researcher mode. **The passwords are case sensitive.**

Change SWB to consultant version

Password

Consultant

OK   Cancel
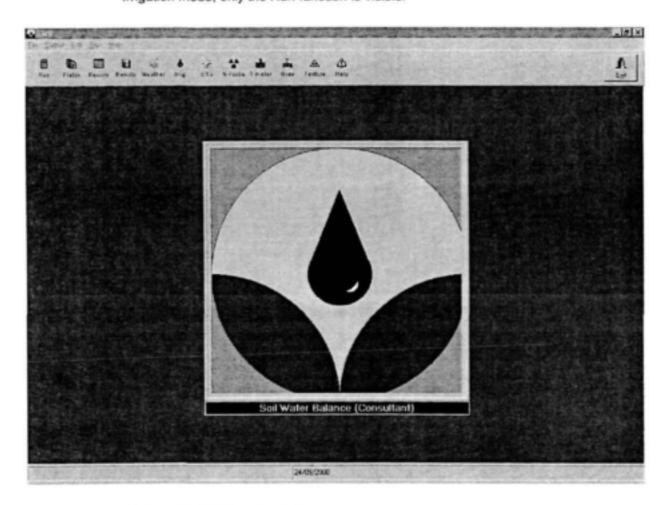
To change back to the Irrigation mode, double click on the Soil Water Balance bar below the logo in the Main Menu.

Question: What are the functions of SWB?

Answer: The various functions of SWB can be accessed from the Main Menu. When SWB is in Irrigation mode, only the Run function is visible.

Click on the Help icon for help.

Help

Question: What input data do I need to enter?

Answer: SWB requires weather, management, irrigation and soil data to run simulations.
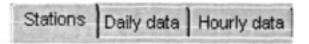
Weather input data:

1.   Click on the Weather icon in the Main Menu.

2.   The Weather stations table will appear.
3.   Edit the Weather stations table.
(Press F1 on the keyboard for context sensitive help)
4.   Click on the appropriate weather station.
5.   Click on the Daily data page to enter daily weather data.
(Do not use the Hourly data page)

6.   The Daily weather data table will appear.
7.   Edit the Daily weather data table.
(Press F1 on the keyboard for context sensitive help)

Management (field) input data:

1.   Click on the Fields icon in the Main Menu.
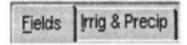
2.   The Fields form will appear.
3.   Edit the Field form. (Press F1 on the keyboard for context sensitive help)

Irrigation input data:

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1.   Click on the Irrig icon in the Main Menu.

2.   The Field table will appear.
3.   Click on the appropriate field.
4.   Click on the Irrig & Precip page to enter daily rainfall and irrigation data.

5.   The Daily rainfall and irrigation data table will appear.
6.   Edit the Daily rainfall and irrigation data table.
       (Press F1 on the keyboard for context sensitive help)

Soil input data:

1.   Select Edit|Irrigation schedule|Soil data in the Main Menu.
2.   The Soil form will appear.
3.   Edit the Soil form. (Press F1 on the keyboard for context sensitive help)

Question: How to run simulations?

Answer: 1.   Click on the Run icon in the Main Menu.

2.   The Run form will appear.
3.   Edit the Run form.
       (Press F1 on the keyboard for context sensitive help)
4.   Click on the Run button to run simulations.

Question: How to see results of the simulation?
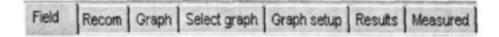
Answer: 1. Click on the Results icon of the Main Menu.

Results

2. Click on the appropriate field in the Field page.

Field	Recom	Graph	Select graph	Graph setup	Results	Measured

3. Output results can be seen both in graphical and numerical format. Select the appropriate Results data page to be seen.
(Press F1 on the keyboard for context sensitive help)

Question: How to see recommendations?

Answer: 1. Click on the Recom icon in the Main Menu.

Recom

2. The Recommendations table will appear. (Press F1 on the keyboard for context sensitive help)
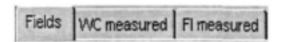
Question: How to update simulations real-time?

Answer: Computer models operated from offices are not supposed to completely substitute field measurements. They could, however, facilitate management by making field visits less frequent. SWB, as any other model, is very unlikely to simulate a value for a parameter, which is exactly equal to the measurement. There are several reasons why an estimation procedure may perform poorly. Insect or herbicide damage may for example delay canopy development. As this is not accounted for in the model a larger canopy and drier profile than actually exists will be forecast. For this reason, the update simulation feature was included in the model. It is possible to enter measured soil water and/or canopy

cover at any stage during the season and the model will bring the simulation in line.

1. Select Edit|Irrigation schedule|Update WC/FI in the Main Menu.
2. The Fields table will appear.
3. Click on the appropriate field.
4. Select the WC measured page to enter measured data of volumetric soil water content.
5. Select the FI measured page to enter measured data of fractional interception of radiation (canopy cover). (Press F1 on the keyboard for context sensitive help)

Fields	WC measured	FI measured

In order to facilitate the estimation and update of canopy cover, a database of photos of crops at different canopy cover fractions was included in the help file. Measured values of fractional interception of radiation are reported for each photo. An example is shown in the Figure below. The database of photos of crops can be accessed as follows:

1. Press F1 on the keyboard, or click on the Help icon in the Main Menu to access the help file.
2. Select Index in the Help window.
3. Select Crops from the Index list.

Fractional interception of radiation (canopy cover) = 0.40
Crop height = 45 cm
(Location: Roodeplaat, Pretoria; Season: summer 1996/97; Soil: clay loam)

Question: How to change/add crop parameters?

Answer: 1.   Select Edit|Irrigation schedule|Crop parameters|Growth model in the Main Menu to edit specific crop growth parameters for the crop growth model. (Press F1 on the keyboard for context sensitive help)

2.   Select Edit|Irrigation schedule|Crop parameters|FAO in the Main Menu to edit FAO crop factors for the FAO model. (Press F1 on the keyboard for context sensitive help)

Question: How to import weather data from spreadsheet files?

Answer: Weather data can be imported into SWB from comma delimited, tab delimited or space delimited files. The order in which the data appear in the file can be specified, so standardization of data files is not important. Ranges of the imported weather data can also be set up by the user. While importing weather data, SWB checks for data out of range.

1. Click on the Weather icon in the Main Menu to access the Weather station data table.

2. Click on the Import daily weather data icon to import weather data. (Press F1 on the keyboard for context sensitive help)

Question: How do I use other databases?

Answer:
1. Copy a new database in a new folder on the C: drive.
2. Run the Beadmin.exe file of SWB.
3. Click once on SWB in the Databases root of the Databases option in All Database Aliases.
4. Change PATH to the new folder where the new database has been stored.

Question: How do I copy databases?

Answer: Databases can be copied or overwritten by copying or overwriting *.db, *.px, *.X?? and *.Y?? files.

1.6 Troubleshooting

Question: How to call for help?

Answer: The on-line Help file can be accesses by clicking on the Help icon in the Main Menu.

The help topic related to the current screen can be accessed by pressing F1 on the keyboard.

Question: Why the mass balance error appears when I update the soil water content?

Answer: The update of the soil water content is not accounted for in the calculation of the mass balance error. Whenever an update of the soil water content is entered, a mass balance error will appear in the Soil Water Balance graph.

The mass balance error is primarily calculated to check possible numerical errors in the simulation. Another purpose of the mass balance error calculation is to verify the correctness of model predictions and to quantify the error committed by the model.

Question: How do I rebuild corrupted databases?

Answer:
1. Run the Tutil.exe file of SWB.
2. Select SWB from the Alias Name drop down list.
3. Choose the *.db database file to verify or rebuild from the Table Name drop down list.
4. Verify the *.db database file by clicking once on the Verify button.
5. Rebuild the *.db database file by clicking once on the Rebuild button.

Question: Error message: " is not a valid integer value

Answer: This problem may occur when a simulation is run, if Windows 95 did not shut down properly during the previous session.
Delete the SWB32.INI file in the C:\WINDOWS\ folder.

Question: Error message: " is not a valid floating point value

Answer: This problem may occur when the user selects to display an output graph, if Windows 95

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did not shut down properly during the previous session.
Delete the SWB32.INI file in the C:\WINDOWS\ folder.

Question: Whom to contact in case of trouble?

Answer: Contact: Dr JG Annandale
                                Dept. Plant Production and Soil Science
                                University of Pretoria
                                0001, Pretoria
                                South Africa

                                Tel.: (27) (12) 420 3223
                                Fax: (27) (12) 420 4120
                                E-mail: jannanda@postino.up.ac.za

Suggestions for improvements to SWB will be welcomed by the authors.

SPECIAL FEATURES

In an attempt to enhance the value of the scheduling program several features have been incorporated.

1.7 ETo calculator

A stand-alone ETo calculator allows one to calculate the FAO Penman-Monteith grass reference evapotranspiration (ETo) without running SWB. The procedure for the calculation of ETo with the ETo calculator is the same as that used for model predictions (see Chapter 4.1, Weather unit).

1.   Click on the ETo icon in the Main Menu to access the ETo calculator.
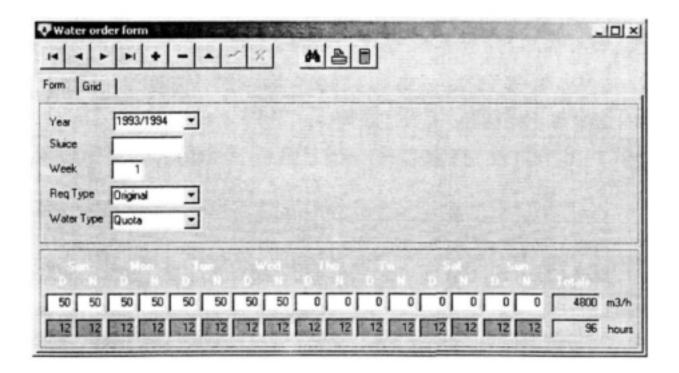
2.   The ETo calculator form will appear.
3.   Enter input data in the corresponding blocks.
      (Press F1 on the keyboard for context sensitive help)
4.   Click on the Calc button to calculate ETo.

1.8 Water request form

A water request can be generated by SWB based on the recommendation. The user needs to specify the current water year. The water order form defaults to an original water request but the user has the option to change this to an additional water request or a cancellation of water. The water type defaults to quota water but the user can change it to extra, surplus or flexi water. The discharges calculated by SWB are not fixed and can be changed by the user if necessary.

1. Click on the Recom icon in the Main Menu to access the recommendations.
2. The recommendations form will appear.
3. Move to the recommendation record under concern.
4. Click on the water requests button

1.9 Neutron probe scheduler

Soil water deficit can be calculated from measurements with the neutron water meter using the neutron probe scheduler as a stand-alone tool.

1. Click on the N-Probe icon in the Main Menu to access the Neutron probe scheduler.
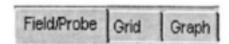
2. The Neutron probe scheduler form will appear.

3. Enter input data in the corresponding blocks. (Press F1 on the keyboard for context sensitive help).

   Volumetric soil water content and standard error of the measurement are calculated for a maximum of 11 soil layers.

   Data from the soil database of SWB can be imported into the Neutron probe scheduler by clicking on the Get soil properties icon.

4.   Select the Graph page to display volumetric water content in the soil profile graphically, as well as the calculated soil water deficit to field capacity. (Press F1 on the keyboard for context sensitive help)

| Field/Probe | Grid | Graph |

Water content calculated in the Neutron probe scheduler can be sent to the measured values database by clicking on the Send values to measured table icon.

Water content calculated in the Neutron probe scheduler can used to update simulations by clicking on the Update simulated water content icon.

1.10 Tensiometer scheduler

Soil water deficit can be calculated from measurements with tensiometers using the Tensiometer scheduler as a stand-alone tool. The assumptions used to calculate soil water deficit from tensiometer measurements are explained in the help file.

1.   Click on the T-Meter icon in the Main Menu to access the Tensiometer scheduler.

T-meter
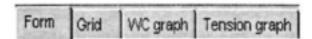
2.   The Tensiometer scheduler form will appear.
3.   Enter input data in the corresponding blocks. (Press F1 on the keyboard for context sensitive help)
     Volumetric soil water content and standard error of the measurement are calculated for a

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maximum of seven depths.

4. Select the WC graph page to display volumetric water content in the soil profile graphically, as well as the calculated soil water deficit to field capacity.

| Form | Grid | WC graph | Tension graph |

5. Select the Tension graph page to display the tension graph. (Press F1 on the keyboard for context sensitive help)

Water content calculated in the Tensiometer scheduler can be sent to the measured values database by clicking on the Send values to measured table icon.

Water content calculated in the Tensiometer scheduler can used to update simulations by clicking on the Update simulated water content icon.

1.11 Gravimetric scheduler

Soil water deficit can be calculated from gravimetric measurements of soil water content using the Gravimetric scheduler as a stand-alone tool.
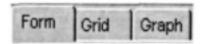
1. Click on the Grav icon in the Main Menu to access the Gravimetric scheduler.

Grav

2. The Gravimetric scheduler form will appear.
3. Enter input data in the corresponding blocks. (Press F1 on the keyboard for context sensitive help)

Volumetric soil water content and standard error of the measurement are calculated for a maximum of six depths.

4. Select the Graph page to display volumetric water content in the soil profile graphically, as well as the calculated soil water deficit to field capacity. (Press F1 on the keyboard for context sensitive help)

| Form | Grid | Graph |

Water content calculated in the Gravimetric scheduler can be sent to the measured values database by clicking on the Send values to measured table icon.

Water content calculated in the Gravimetric scheduler can used to update simulations by clicking on the Update simulated water content icon.
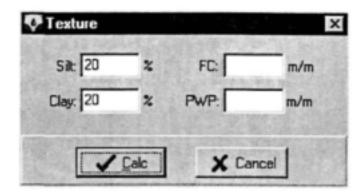
1.12 Field capacity and wilting point calculator

Volumetric soil water content at field capacity and permanent wilting point can be calculated from texture analysis using the Field capacity and wilting point calculator as a stand-alone tool. The calculator uses the empirical equations recommended by Bennie et al. (1988) for soils in the Free State.

1. Click on the Texture icon in the Main Menu to access the Field capacity and wilting point calculator.

Texture

2. The Field capacity and wilting point calculator form will appear.

3.   Enter % silt and clay in the corresponding blocks.
4.   Click on the Calc button to calculate the volumetric soil water content at field capacity (FC) and permanent wilting point (PWP).

1.13 Address database

An Address database can be used to keep record of the users of SWB.

Select Edit|Address & Tel no's in the Main Menu to access the Address database.

1.14 Statistical analysis

Measured data can be plotted as points in the output graphs which gives a very good idea of how well the simulation is performing. This feature makes it relatively easy to select reasonable parameters for new crops from growth analysis, soil water and weather data.

Select Edit|Irrigation schedule|Measured data in the Main Menu to enter measured data and standard errors of the measurement. (Press F1 on the keyboard for context sensitive help)

SWB calculates parameters of the statistical analysis between measured and simulated data. The parameters of the statistical analysis are:
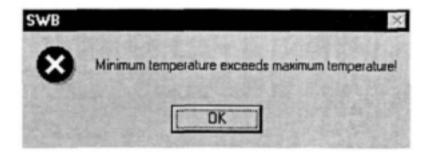
     i)   Number of observations (N);
     ii)   Coefficient of determination (r^2);
     iii)   Index of agreement of Willmot (D);
     iv)   Root mean square error (RMSE); and
     v)   Mean absolute error (MAE).

These were recommended by de Jager (1994) to assess model accuracy. He also recommended as model prediction reliability criteria that r^2 and D should be > 0.8, whilst MAE should be < 20%.

The parameters of the statistical analysis are shown in the output graphs. This should allow quick, efficient and quantitative evaluation of model performance. Standard errors of measured data can also be displayed in the output graphs.

1.15 Hints and error checking

SWB displays hints with ranges for input data, checks the ranges of input data, and generates error messages and warnings when operational errors are committed (e.g. input data out of range are entered). This should prevent accidental typing errors and errors in units. The example in the Figure below shows the error message that pops up on the screen when a minimum temperature greater than the maximum temperature is entered for the same day in the Weather database.

TECHNICAL MANUAL

1.16 Weather unit

1.16.1 Introduction

The aim of this Section is to calculate potential evapotranspiration (PET) from available meteorological input data (Smith et al., 1996; Smith, 1992a). Daily Penman-Monteith grass reference evapotranspiration (ETo) and PET are calculated in the **Weather unit** and used in the **Soil unit** to compute actual transpiration (T) and evaporation (E).

The **Weather unit** includes the procedure for initializing weather parameters, and five functions where the following parameters are calculated:

i) R_a - Extraterrestrial radiation (MJ m^{-2} day^{-1});
ii) VPD - Vapour pressure deficit (kPa);
iii) R_n - Net radiation (MJ m^{-2} day^{-1});
iv) ETo - FAO reference evapotranspiration (mm day^{-1}); and
v) PET - Potential evapotranspiration (mm day^{-1}).

An additional **Weather day step** function is performed on a daily basis.

The procedure **Initialize weather** converts the weather station latitude (Lat) from degrees into radians, and calculates atmospheric pressure (P_a) from altitude, as follows:

$$P_a = P_0 \left[(T_0 - \alpha \, Alt) / T_0 \right]^{g / (\alpha \, Rg)}$$
(Burman et al., 1987)

Alt   -   Altitude (m)
P_0 -   Standard atmospheric pressure at sea level (101.3 kPa)
T_0 -   Standard temperature at sea level (293 K)
g   -   Gravitational acceleration (9.8 m s^{-2})
Rg   -   Specific gas constant for dry air (286.9 J kg^{-1} K^{-1})
α -   Adiabatic lapse rate (K m^{-1})

The adiabatic lapse rate is assumed to be 0.0065 K m^{-1} for saturated air. Alt is an input parameter linked to a particular weather station.

The functions for calculating R_a, VPD, R_n, ETo, PET and weather day step will be treated separately in the following Sections.

1.16.2 Extraterrestrial radiation

Potential solar radiation is calculated as a function of Lat (input value) and day of year (DOY), as follows:

$$R_a = 118.08 \, D_{rel} / \pi \, [\omega_s \sin(Lat)\sin(Dec) + \sin(\omega_s)\cos(Lat)\cos(Dec)]$$

R_a is in MJ m^{-2} day^{-1}, whilst the constant 118.08 represents the solar constant in MJ m^{-2} day^{-1}. D_{rel} is the relative distance of the earth from the sun, a function of DOY:

$$D_{rel} = 1 + 0.033 \cos(2\pi \, DOY / 365)$$

ω_s is sunset hour angle (rad), a function of latitude and solar declination (Dec):

$$\omega_s = \arccos[-\tan(Lat) \tan(Dec)]$$

For the Southern hemisphere, solar declination is calculated as follows:

$$Dec = -0.409 \sin(2\pi / 365 \, DOY - 1.39)$$
(Duffie and Beckman, 1980)

whilst for the Northern hemisphere the sign of the equation is changed.

1.16.3 Vapour pressure deficit

Vapour pressure deficit is calculated adopting the following equation:

$$VPD = [e_s(T_{max}) + e_s(T_{min})] / 2 - e_a$$

where e_s is saturated vapour pressure (kPa), a function of maximum (T_{max}) and minimum air temperature (T_{min}), and e_a is the actual vapour pressure (kPa).

Saturated vapour pressure is estimated from air temperature (T_a), as follows:

$$e_s = 0.611 \exp[17.27 \, T_a / (T_a + 237.3)] \hspace{3cm} \text{(Tetens, 1930)}$$

Actual vapour pressure is an input variable. If not available, it is calculated from measured minimum (RH_{min}) and maximum relative humidity (RH_{max}), and if that is not available, from measured wet bulb (T_w) and dry bulb temperature (T_d).

Vapour pressure can be calculated as a function of percent relative humidity as follows:

$$e_a = [e_s(T_{min}) \, RH_{max} / 100 + e_s(T_{max}) \, RH_{min} / 100] / 2$$

and from psychrometer readings with:

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$$e_a = e_s(T_w) - 0.0008 (T_d - T_w) P_a \qquad \text{(Bosen, 1958)}$$

If not available for use in Kc_{max} (FAO maximum crop coefficient), RH_{min} is calculated as a function of T_{max} and T_{min} for use in the weather modified PET calculation:

$$RH_{min} = e_s(T_{min}) / e_s(T_{max})$$

If no atmospheric vapour measurements are available, SWB assumes T_{min} reaches dew point, and e_a is set to $e_s(T_{min})$.

VPD is used in the calculation of ETo and water limited dry matter production.

1.16.4 Net radiation

In this Section, the R_n value is calculated to be used for computing the Penman-Monteith reference evapotranspiration, as follows:

$$R_n = R_{ns} - R_{nl}$$

R_{ns} -   Short-wave net radiation $(MJ\ m^{-2}\ day^{-1})$
R_{nl} -   Long-wave net radiation $(MJ\ m^{-2}\ day^{-1})$

Assuming the albedo of the reference crop is 0.23, R_{ns} is:

$$R_{ns} = 0.77 R_s$$

R_s -   Solar radiation $(MJ\ m^{-2}\ day^{-1})$

R_s is an input value in $MJ\ m^{-2}\ day^{-1}$. In the absence of measured data, SWB calculates R_s after Allen (1995), as follows:

$$R_s = 0.17 P_a / P_0 (T_{max} - T_{min})^{0.5} R_a$$

T_{max} and T_{min} are in °C and they represent the minimum required input data for calculating R_s. Kelvin air temperatures are used to calculate net terrestrial radiation:

$$R_{nl} = f_c \, \varepsilon \, \sigma \, (T_{max}^4 + T_{min}^4) / 2$$

with f_c, the cloudiness factor

$$f_c = 1.35 R_s / R_{so} - 0.35 \qquad \text{(Doorenbos and Pruitt, 1992)}$$

R_{so} is the short-wave radiation during bright sunshine $(MJ\ m^{-2}\ day^{-1})$:
$$R_{so} = 0.75 R_a$$

The factor "0.75" represents the maximum clear sky transmissivity of the atmosphere. ε is the clear sky

emissivity of the earth's surface:

$$\varepsilon = 0.34 - 0.14 \, e_a^{0.5}$$

<div align="right">(Doorenbos and Pruitt, 1992)</div>

and σ is the Stefan-Boltzmann constant (4.9×10^{-9} MJ m^{-2} K^{-4}).

1.16.5 FAO reference evapotranspiration

The Penman-Monteith ETo is calculated according to the FAO procedure, as recommended by Smith *et al.* (1996). The following equation is adopted:

$$ETo = [0.408 \, \Delta \, (R_n - G) + \gamma \, 900 / (T_{avg} + 273) \, U_2 \, VPD] / [\Delta + \gamma \, (1 + 0.34 \, U_2)]$$

with Δ the slope of the saturation vapour pressure curve in kPa °C^{-1}

$$\Delta = 4098 \, e_s / (T_a + 237.3)^2$$

and G the soil heat flux (MJ m^{-2} day^{-1}) calculated from today's (DOY) and yesterday's (DOY-1) average air temperatures (T_{avg})

$$G = 0.38 \, [T_{avg}(DOY) - T_{avg}(DOY-1)]$$
(Wright and Jensen, 1972)

where

$$T_{avg} = (T_{max} + T_{min}) / 2$$

γ is the psychrometer constant (kPa °C^{-1}) calculated as

$$\gamma = 0.00163 \, P_a / \lambda$$

with λ the latent heat of vaporization (MJ kg^{-1})

$$\lambda = 2.501 - 2.361 \times 10^{-3} \, T_{avg}$$

U_2 is wind speed measured at 2 m height (m s^{-1}).

U_2 is a weather data input value. If it is not available, SWB assumes an average U_2 of 2 m s^{-1}. Smith *et al.* (1996) recommended an average U_2 of 3 m s^{-1} for windy, and 1 m s^{-1} for low wind conditions. If wind speed (U) is not measured at 2 m height, the logarithmic wind speed profile function is applied to calculate U_2, as follows:

$$U_2 = U \, 4.87 / \ln(67.8 \, H_U - 5.42)$$
(Allen *et al.*, 1989)

H_U -   Height at which wind speed is measured (cm)

1.16.6 Potential evapotranspiration

Potential evapotranspiration is used to determine actual transpiration and evaporation in the **Soil unit**. Crop PET is calculated as a function of the reference evapotranspiration and Kc_{max}, as follows:

$$PET = ETo\ Kc_{max}$$

Kc_{max} represents the maximum value for the FAO crop coefficient (Kc) following rain or irrigation. It is calculated according to the procedure recommended by Allen et al. (1996), and identified as the maximum of the following two calculations:

$$Kc_{max} = 1.2 + [0.04(U_2-2)-0.004(RH_{min}-45)]\ (Hc\ /\ 3)^{0.3}$$

$$Kc_{max} = Kcb + 0.05$$

Hc	-	Crop height (m)
Kcb	-	FAO basal crop coefficient

The upper limit of Kc_{max} is set at 1.45. The calculation of Hc and Kcb is shown in the **Crop unit**.

1.16.7 Weather day step

The **Weather day step** function is executed on a daily basis until the present day, or until crop maturity. This function identifies the day of year and reads precipitation (P) and irrigation (I) input data. It remembers the average air temperature of the previous day (T_{avg}(DOY-1)), used to estimate soil heat flux in Section 4.1.5 (FAO reference evapotranspiration).

The **Weather day step** function reads the following variables:

- FAO basal crop coefficient, Kcb;
- Crop height, Hc;
- Maximum daily temperature, T_{max};
- Minimum daily temperature, T_{min};
- Incoming solar radiation, R_s;
- Actual vapour pressure, e_a;
- Wind speed measured at 2 m height, U_2;
- Height at which wind speed is measured, H_U;
- Daily minimum relative humidity, RH_{min};
- Daily maximum relative humidity, RH_{max};
- Dry bulb temperature, T_d; and
- Wet bulb temperature, T_w.

Kcb and Hc are calculated in the **Crop unit**. T_{max} and T_{min} **are essential input values**. H_U input value is needed if U is not measured at 2 m height. If measured input data are not available, SWB calculates R_s, e_a, U_2 and RH_{min}, as described in the previous Sections.

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1.17 Soil unit

1.17.1 Introduction

The aim of this Section is to simulate the dynamics of water movement in the soil profile in order to determine soil water availability to the crop. Water movement is simulated with a cascading model. This divides the soil profile into a number of layers. Each layer has its own physical properties:

- Soil matric potential, Ψ_m (J kg^{-1});
- Volumetric soil water content, θ;
- Volumetric soil water content at field capacity, θ_{fc};
- Volumetric soil water content at permanent wilting point, θ_{pwp};
- Campbell's "a" and "b" parameters of the log-log water retention function; and
- Bulk density, ρ_b (Mg m^{-3}).

θ_{fc}, θ_{pwp}, ρ_b and initial θ are input values. Soil water movement is calculated in the **Soil unit** and includes three procedures:

- i)   Calculation of soil layer thickness (dz);
- ii)   Soil parameters initialization; and
- iii)   Soil day step calculation.

In addition, two separate functions are used to calculate:

- i)   Soil water storage; and
- ii)   Allowable depletion.

SWB firstly calculates the thickness of each soil layer (i), using the following equation:

$$dz_i = z_i - z_{i-1}$$

z   -   Layer depth (m)

Layer depth (distance between the lower boundary of the layer and the soil surface) is an input value.

In the procedure that initializes soil water parameters, SWB reads input values of initial θ, θ_{fc}, θ_{pwp} and ρ_b for each of the layers. For uniform profiles only one set of layer values needs to be entered.

Volumetric soil water content at saturation (θ_{sat}) is calculated using the following equation:

$$\theta_{sat} = 1 - \rho_b / 2.65$$

where 2.65 represents the average density of soil particles.

Campbell's "a" and "b" coefficients of the water retention function are calculated for each layer, as follows (Campbell, 1985):

$$b = \ln(\Psi_{pwp} / \Psi_{fc}) / \ln(\theta_{fc} / \theta_{pwp})$$

$$a = \exp(\ln(-\Psi_{pwp}) + b \ln(\theta_{pwp}))$$

Ψ_{pwp} -   Soil matric potential at permanent wilting point $(J\ kg^{-1})$
Ψ_{fc} -   Soil matric potential at field capacity $(J\ kg^{-1})$

Ψ_{pwp} and Ψ_{fc} are input parameters. Hillel (1982) recommended values of -1500 J kg^{-1} for Ψ_{pwp} and -10 J kg^{-1} for Ψ_{fc}.

Volumetric water content at permanent wilting point is then recalculated as the lower limit of crop water uptake for a specific plant:

$$\theta_{pwp} = \exp(-\ln(-3\ \Psi_{lm} / (2\ a)) / b)$$

Ψ_{lm} -   Leaf water potential at maximum transpiration rate $(J\ kg^{-1})$

Ψ_{lm} is a crop specific parameter.

Air dry volumetric soil water content (θ_{ad}) is calculated as follows (Campbell and Stockle, 1993):

$$\theta_{ad} = 0.3\ \theta_{pwp}$$

θ_{ad} is used to set the lower limit of water loss through evaporation from the soil surface. As SWB assumes evaporation occurs from the top soil layer, θ_{ad} is only calculated for this layer.

The soil day step procedure is performed on a daily basis. It includes five more procedures which are performed in the following order:

i)   Amount of precipitation intercepted by the canopy, I_c;
ii)   Runoff, R;
iii)   Infiltration and redistribution;
iv)   Evaporation; and
v)   Transpiration.

SWB provides options to determine the soil water balance if either sprinkle/flood/pivot or localized irrigations are performed. In the case of sprinkle/flood/pivot irrigation, the model simulates even wetting of the soil surface. When irrigations are performed with drip or micro-irrigators, SWB calculates the soil water balance for both irrigated and non-irrigated volumes of soil. The irrigated fraction of the surface (f_i, portion of wetted area) is chosen in the field input table (ratio of wetted diameter and lateral spacing).

SWB simulates one-dimensional water movement in the soil for both sprinkle/flood/pivot and localized irrigation. The calculation of the soil water balance components is discussed in the following Sections.

1.17.2 Canopy interception

Amount of rainfall and irrigation are two of the required inputs of SWB. Interception of precipitation and irrigation (P + I) by the crop canopy is calculated only on days when rainfall and/or sprinkle/pivot irrigation occur.

The amount of water intercepted by the canopy is assumed to be equal to the interception of radiation by the canopy, including both photosynthetically active and senesced leaves (FI_{evap}), multiplied by a canopy storage parameter. The FI_{evap} calculation is shown in the **Crop unit**, whilst canopy storage is a crop specific parameter. The amount of precipitation penetrating the canopy and reaching the soil surface is reduced by the amount of water intercepted by the canopy.

If the amount of precipitation is lower than potential interception, it is assumed that all precipitation is intercepted by the canopy, and no rainfall and/or sprinkle/pivot irrigation water reaches the soil surface.

1.17.3 Runoff

Runoff is calculated on days when rainfall and/or irrigation occur. R is calculated adopting a semi-empirical algorithm based on the assumption that once precipitation is greater or equal to a value representing initial infiltration and surface storage, R increases with increasing precipitation.

Runoff is assumed to be 0 if

$$P + I \leq 0.2\,S$$

S   -   Runoff curve number (mm)

S is an input parameter giving an indication of the storage of surface. If rain plus irrigation exceeds 20% of S, runoff is calculated according to the following relation:

$$R = (P + I - 0.2\,S)^2 / (P + I + 0.8\,S)$$
(Stewart *et al.*, 1976)

Surface runoff is then subtracted from the rainfall and/or irrigation water allowing the remainder to infiltrate into the soil.

1.17.4 Infiltration and redistribution

The model distributes water from rainfall and irrigation by filling soil layers to saturation, starting from the

top of the profile and moving downwards. In the case of drip or micro irrigated fields, the water redistribution is calculated for both irrigated and non-irrigated portions of the ground.

SWB updates soil layer water content on a daily basis. Layer soil water deficit (SWD) is calculated as a function of θ using the following expression:

$$SWD = (\theta_{fc} - \theta)\, \rho_w\, dz$$

ρ_w — Density of water $(1000\ kg\ m^{-3})$

If the amount of water penetrating a soil layer is larger than $\theta_{sat} - \theta$ for that layer, θ is set to θ_{sat}. The amount of water penetrating the deeper layer (D_i) is then reduced by "$(\theta_{sat} - \theta)\, \rho_w\, dz$". If the amount of water penetrating a soil layer is smaller than $\theta_{sat} - \theta$ for that layer, θ is increased by "$D_i / \rho_w\, dz$" and D_i is set to 0 for the next soil layer.

Drainage is calculated when θ exceeds θ_{fc} for the particular layer using the following equation:

$$Dr = Df\, (\theta - \theta_{fc})\, \rho_w\, dz + D_i$$

where Df is a drainage factor (soil input parameter).

1.17.5 Evaporation

The actual partitioning between evaporation and transpiration depends on the available energy reaching the crop canopy and soil surface and the resistances to water transport (Ritchie, 1972; Norman and Campbell, 1983).

Water loss by evaporation is assumed to occur only from the top soil layer.

The expression for potential evaporation (PE) is given by:

$$PE = (1 - Fl_{evap})\, PET \qquad\qquad \text{(Reddy, 1983)}$$

PET is calculated in the **Weather unit**, whilst Fl_{evap} in the **Crop unit**.

Evaporation proceeds at the potential rate until θ_{pwp} is reached (atmospheric evaporative demand limited). If water content decreases in the top soil layer below θ_{pwp}, then evaporation becomes supply limited (Campbell, 1985):

$$E = PE\, ((\theta - \theta_{ad}) / (\theta_{pwp} - \theta_{ad}))^2$$

According to this equation, actual evaporation from the soil surface decreases by reducing the layers water content.

Water content in the top soil layer is reduced by the amount of water evaporated from the soil surface, on

a daily basis.

If the calculated θ is below θ_{ad}, θ is assumed to be equal to θ_{ad}. E is then calculated as follows:

$$E = (\theta - \theta_{ad})\, \rho_w\, dz$$

Two possible cases are simulated when drip/micro irrigations are performed:

i)   If the canopy cover fraction (FI_{evap}) is larger than the irrigated surface fraction (f_i), evaporation is simulated only from the non-irrigated portion of the ground; and

ii)   If $FI_{evap} < f_i$, evaporation from the irrigated, non-shaded area is added to the evaporation from the non-irrigated surface layer.

1.17.6 Transpiration

Water loss by transpiration is calculated on days when root depth (RD) and fractional interception of radiation by photosynthetically active leaves (FI_{transp}) are greater than 0. SWB assumes that layer water uptake is weighted by root density when soil water potential is uniform. No root water uptake is calculated for the uppermost soil layer which is reserved for evaporation.

Soil matric potential is calculated daily as a function of the actual soil water content, using the following equation (Campbell, 1985):

$$\Psi_m = a\, \theta^{-b}$$

By plotting Ψ_m and θ on a log-log scale and fitting a straight line to the data, it is possible to derive Campbell's "a" and "b" values from the intercept and the slope of the relationship.

Reduction in Ψ_m closes stomata and decreases transpiration and dry matter production. Transpiration is therefore computed as a function of Ψ_m. The following equation is applied to each layer in the soil profile, in order to calculate water loss by transpiration as a fraction of soil volume:

$$\text{Loss} = (FI_{transp}\, Tr_{max}\, f\, (\Psi_x - \Psi_m) / (0.67\, \Psi_m)) / (\rho_w\, dz)$$

Tr_{max}	-	Maximum transpiration rate (mm day^{-1})
f	-	Layer root fraction
Ψ_x	-	Xylem water potential (J kg^{-1})

Tr_{max} is a crop specific parameter. The factor "f" is computed for each soil layer, according to the following expression:

$$f = dz\, (2\, (RD-z) + dz) / RD^2$$
(Campbell and Diaz, 1988)

In the layer where z is larger than RD, the factor "f" is calculated as follows:

$$f = ((RD - z + dz) / RD)^2$$

Ψ_x is calculated using the expression:

$$\Psi_x = \Psi_{lm} (\Psi_{avg}^* + 0.67\, T^*)$$

where

$$\Psi_{avg}^* = \Psi_{avg} / \Psi_{lm}$$

Ψ_{avg} –   Root weighted average soil matric potential $(J\ kg^{-1})$

$$\Psi_{avg} = \Sigma\, f_i\, \Psi_{mi}$$

The subscript "i" indicates the soil layer.

T^* is the dimensionless actual water uptake. T^* is chosen as the minimum between the dimensionless root uptake rate (U^*) and the maximum dimensionless loss rate (E^*):

$$U^* = 1 - 0.67\, \Psi_{avg}^*$$

$$E^* = PET / Tr_{max}$$

The factor "0.67" takes into account the resistances which water flow encounters in the path from the soil toward the leaf. The major resistances are in the endodermis, where water enters the root steele and in the leaf, at the bundle sheath. For typical plants growing in moist soil, the potential drop across the endodermis is 60-70% of the total (Campbell, 1985). In this model, root resistance is assumed to be two thirds of total plant resistance, with leaf resistance the remaining third. Xylem resistance is assumed to be negligible as water flows in cell walls and xylem vessels without crossing membranes. Soil resistance is also considered negligible.

Water uptake is calculated only when

$$\Psi_{avg}^* = \Psi_{avg} / \Psi_{lm} < 1.5$$

If the ratio between root weighted average soil matric potential and leaf water potential at maximum transpiration rate exceeds 1.5, actual crop transpiration is assumed to be 0. Under this condition, the xylem water potential is equal to the root weighted average soil matric potential ($\Psi_x = \Psi_{avg}$) and no water flow through the plant occurs.

Actual water content is reduced in each soil layer by the amount of water absorbed by the roots. The lower limit of θ is θ_{pwp}. If the difference between actual water content and water loss by transpiration is smaller than the water content at permanent wilting point (θ - Loss < θ_{pwp}), θ is set equal to θ_{pwp} and the water taken up by the roots is:

$$Loss = \theta - \theta_{pwp}$$

Finally, water losses by transpiration are converted into mm units and cumulated for each soil layer to

determine daily T in mm.

For localized irrigation (micro/drip), a root density factor can be specified in the field input data table. This factor indicates the fraction of total roots in the wetted and non-wetted volumes of the soil. For example, a factor of "1" indicates that all roots are in the wetted volume of the soil, whilst a factor of "0.5" indicates that the root are evenly spread in the wetted and non-wetted volumes of the soil.

A dimensionless daily water stress index (SI) is calculated as follows:

$$SI = T / (FI_{transp} PET)$$

PET is calculated in the **Weather unit**, whilst FI_{transp} in the **Crop unit**. SI is used to simulate partitioning of daily dry matter production to different plant organs under water stress conditions (**Crop unit**).

1.17.7 Soil water storage

Soil water storage is calculated on a daily basis as the sum of the water content in mm in each soil layer. This is subtracted from profile water content at field capacity to determine profile deficit. In the case of drip/micro irrigation, root zone deficit is calculated only for the fraction of irrigated ground.

1.17.8 Allowable depletion

Allowable depletion level (ADL) in the root zone is calculated on a daily basis. ADL is calculated in mm for each soil layer where the root system is present, as follows:

$$ADL = (\theta_{fc} - \theta_{pwp}) \rho_w \, dz$$

Soil layer ADL values are cumulated to calculate ADL in the root zone. For the layer not completely explored by roots, ADL is calculated as follows:

$$ADL = - (z - RD) (\theta_{fc} - \theta_{pwp}) \rho_w$$

In this way, ADL is reduced by the amount of available water $((\theta_{fc} - \theta_{pwp}) \rho_w \, dz)$ below the root zone.

SWB uses allowable depletion in the soil water balance graph and recommendations to guide irrigation timing.

1.18 Crop unit

1.18.1 Introduction

The aim of this Section is to simulate crop growth. The **Crop unit** includes three procedures:

i)	Initialization;
ii)	Planting; and
iii)	Day step calculation.

Crop initialization sets initial values of several crop parameters to zero. Crop height requires a starting value > 0 and this is set to 0.001 m.

The procedure for crop planting is initiated once a valid planting date has been identified. Top dry matter (TDM) is set to TDM at emergence (crop specific parameter). For most crops, TDM at emergence is estimated to be equivalent to seed mass density. Initial root dry matter (RDM) is calculated as:

$$RDM = f_r\ TDM\ /\ (1 - f_r)$$

f_r -   Fraction of dry matter partitioned to the roots (crop specific parameter).

Initial leaf area index (LAI) is calculated as follows:

$$LAI = SLA\ TDM$$

SLA   -   Specific leaf area $(m^2\ kg^{-1})$

SLA is a crop parameter which describes the leaf morphology of a specific crop.
The crop day step procedure is performed on a daily basis. It includes the following calculations:

i)	Growing day degrees (GDD);
ii)	Fractional interception of radiation (FI);
iii)	Crop height (Hc);
iv)	Dry matter production increment (DM_i);
v)	Harvestable dry matter increment (HDM_i);
vi)	Partitioning of DM_i into plant organs;
vii)	Partitioning of DM_i under conditions of water stress;
viii)	Leaf area index (LAI); and
ix)	Rooting depth (RD).

The simulation of crop growth is discussed in the following Sections.

1.18.2 Growing day degrees

Crop development is simulated using thermal time, an approach suggested by Monteith (1977). The calculation of growing day degrees (GDD) starts after crop planting. GDD are accumulated daily using the following expression:

$$GDD = GDD + GDD_i$$

GDD_i - Growing day degrees increment

Growing day degrees increment is calculated as follows:

$$GDD_i = T_{avg} - T_b$$

T_b - Base temperature (°C)

T_b is a crop specific parameter.

When the average daily temperature is below the base temperature, GDD_i is set to 0.

If $T_{avg} > T_{cutoff}$, then:

$$GDD_i = T_{cutoff} - T_b$$

where T_{cutoff} is an optimal temperature for crop development in °C (crop specific parameter).

The succession of phenological stages is simulated using day degree requirements for emergence (EMDD), completion of vegetative growth (FLDD), transition period between vegetative and reproductive growth (TransDD) and maturity (MTDD).

1.18.3 Fractional interception of radiation

Fractional interception of radiation is used to determine the portion of radiation available for crop transpiration and evaporation from the soil surface. The two parameters calculated in this Section are:

$$FI_{transp} = 1 - e^{(-K \, LAI)}$$

$$FI_{evap} = 1 - e^{(-K \, (LAI + yLAI))}$$

K - Canopy radiation extinction coefficient (crop specific parameter)
yLAI - Leaf area index of senesced (yellowed) leaves

FI_{transp} is the amount of radiation intercepted by the canopy and used for photosynthesis and transpiration. The amount of radiation penetrating the canopy and used for evaporation from the soil surface is given by "$1 - FI_{evap}$".

1.18.4 Crop height

Crop height is used in the calculation of potential evapotranspiration in the **Weather unit**.

Hc is assumed to be 0.001 until emergence. After emergence, it increases linearly until the end of the transition period between vegetative and reproductive growth, when it reaches its maximum (Hc_{max}, crop specific parameter). SWB calculates Hc daily, using the following equation:

$$Hc = 0.001 + (GDD - EMDD) (Hc_{max} - 0.001) / (FLDD + TransDD - EMDD)$$

After the transition period between vegetative and reproductive stage has been completed, crop height remains equal to Hc_{max}.

1.18.5 Daily dry matter production increment

SWB calculates DM_i on a daily basis, after crop emergence and before the crop reaches maturity. DM_i is calculated as either water supply or radiation limited.

Water supply limited DM_i ($kg\ m^{-2}$) is predicted using the relationship between dry matter accumulation and transpiration (Tanner and Sinclair, 1983):

$$DM_i = DWR\ (T / VPD)$$

DWR - Dry matter-water ratio (Pa)

VPD is in Pa and T in mm.

Under conditions of radiation limited crop growth, DM_i is calculated using the equation recommended by Monteith (1977):

$$DM_i = E_c\ T_f\ FI_{transp}\ R_s$$

E_c -   Radiation conversion efficiency ($kg\ MJ^{-1}$)
T_f -   Temperature factor for radiation-limited crop growth

where

$$T_f = (T_{avg} - T_b) / (T_{lo} - T_b)$$

T_{lo} -   Temperature of optimum light-limited growth (°C)

The upper limit of T_f is set at 1, when $T_{avg} > T_{lo}$.

Daily dry matter increment is chosen as the minimum of the water supply and radiation limited DM_i.

1.18.6 Daily harvestable dry matter increment

SWB assumes that, after flowering, DM_i is firstly partitioned to reproductive sinks, then to the other plant organs. The calculation of daily harvestable dry matter increment is therefore the first in the series of calculations carried out to determine dry matter partitioning to plant organs.

On the day when flowering stage commences, initial harvestable dry matter (HDM) of the crop is calculated as follows:

$$HDM = Transl \ SDM$$

Transl	-	Factor determining translocation of dry matter from stem to grain
SDM	-	Stem dry matter $(kg \ m^{-2})$

Transl is a crop specific parameter.

During the flowering stage, the following equation is used to calculate the daily harvestable dry matter increment:

$$HDM_i = rpf \ DM_i$$

rpf	-	Reproductive partitioning fraction

where
$$rpf = (GDD - FLDD) / TransDD$$

FLDD and TransDD are crop specific parameters. The upper limit of rpf is set to 1 (all dry matter produced is partitioned to the reproductive portion). If the crop has not flowered, rpf is set to 0. Once the HDM calculation has been completed, SWB subtracts HDM_i from DM_i.

1.18.7 Partitioning of dry matter into other plant organs

SWB assumes that DM_i is firstly partitioned into roots, then into leaves and finally into the stem.

Daily dry matter increment for roots (RDM_i) is calculated as follows:

$$RDM_i = f_r \ DM_i$$

f_r is set to 0 once root depth has reached a maximum value. Maximum rooting depth (RD_{max}) is a crop specific parameter.

Canopy dry matter daily increment (CDM_i) is then calculated:

$$CDM_i = (1 - f_r) \ DM_i$$

Daily increment of leaf dry matter (LDM_i) is calculated as follows:

$$LDM_i = f_l \ CDM_i$$

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f_l -   Fraction of top dry matter partitioned into leaves

f_l is calculated as a function of canopy dry matter (CDM):

$$f_l = 1 / (1 + PART\ CDM)^2$$

PART is the stem-leaf partitioning factor (crop specific parameter).

The daily increment of stem dry matter (SDM_i) is then calculated as follows:

$$SDM_i = CDM_i - LDM_i$$

HDM_i is finally added to CDM_i in order to include grain dry matter into CDM.

1.18.8 Partitioning of dry matter under conditions of water stress

Assimilate partitioning is affected by water stress. Water stress conditions are simulated when the calculated daily water stress index is lower than the threshold (crop specific parameter). SI is calculated in the **Soil unit** as the ratio between actual and potential transpiration.

Under conditions of water stress, a half of the daily leaf dry matter increment is partitioned into roots, the other half into the stem:

$$RDM_i = RDM_i + LDM_i / 2$$

$$SDM_i = SDM_i + LDM_i / 2$$

$$CDM_i = CDM_i - LDM_i / 2$$

If the root system has already reached the maximum depth ($f_r = 0$), the daily leaf dry matter increment is fully partitioned into the stem:

$$SDM_i = SDM_i + LDM_i$$

and LDM_i becomes 0 and one stress day is accumulated.

1.18.9 Leaf area index

Once emergence has taken place, LAI daily increments (LAI_i) are calculated using the following relationship:

$$LAI_i = LDM_i\ SLA$$

LAI is then calculated by cumulating LAI, values. It represents the "green leaf" or photosynthetically active canopy, which contributes to transpiration and dry matter production.

Leaf senescence is also accounted for in SWB. This is done by tracking each individual day's LAI age (LAIage,). The age (in d °C) of each day's leaf area increment is kept track of from the day it was generated. Once the LAI, reaches a maximum age (crop specific parameter), it is classified as leaf area of "yellow/dead leaves" (yLAI,) as it stops contributing to photosynthesis and dry matter production. The green LAI value is then reduced by yLAI,. Leaf area index of senesced leaves (yLAI) is increased by yLAI,, so as to estimate shading of the soil for the evaporation calculation (**Soil unit**).

A water stress factor (wsf) is used to simulate premature leaf senescence under water stress conditions. When SI is lower than the threshold value, wsf is calculated as follows:

$$wsf = 1 / SI$$

Ageing of leaves is speeded up by multiplying the daily thermal time increment by wsf:

$$LAIage_i = wsf\ GDD_i$$

The upper limit of wsf is set to 2, indicating that the ageing of leaves under water stress conditions can be at most twice as fast as that under well watered conditions.

1.18.10 Rooting depth

Rooting depth is calculated with the following equation:

$$RD = RGR\ RDM^{0.5}$$

RGR - Root growth rate $(m^2\ kg^{-0.5})$

RGR is a crop specific parameter. RD is used in the calculation of transpiration (**Soil unit**).

1.19 FAO model

The calculation of crop growth with SWB can only be performed if the afore mentioned crop specific growth parameters are known. If growth parameters for a specific crop are not included in the SWB database, the model allows one to run the soil water balance simulation using an additional database of FAO crop coefficients (Allen *et al.*, 1996).

The FAO approach for crop water use simulations can be selected as an option. The following crop specific parameters are required:

- Length of initial (IniStage), development (DevStage), mid-season (MidStage) and late-season stage (LateStage) of the crop, in days;

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- FAO basal crop coefficient for:
    - Initial stage ($K_{cb}Ini$),
    - Mid-season stage ($K_{cb}Mid$), and
    - Late-season stage ($K_{cb}Late$);
- FAO stress factor (Ky) for initial, development, mid-season and late-season stage;
- Potential yield (Y_{pot}) in t ha^{-1};
- Crop height at initial (H_cIni) and mid stage (Hc_{max});
- Root depth at initial (RDIni) and mid stage (RD_{max});
- Maximum transpiration rate (Tr_{max}); and
- Leaf water potential at maximum transpiration (Ψ_{lm}).

The FAO approach does not calculate dry matter accumulation and canopy LAI. It is, however, used to determine FI_{transp}, FI_{evap} and RD whose values are then used in the soil water balance calculation (**Soil unit**), and Hc whose value is used in the Penman-Monteith calculation of PET (**Weather unit**). The calculation of FI_{transp}, FI_{evap}, RD and Hc using the FAO approach is carried out in the **Crop unit**.

The FAO approach, if selected, is run on a daily basis after crop planting. Crop developmental stages (initial, development, mid and late) are identified from days after planting (DAP).

During the initial stage, Kcb is assumed to be equal to $K_{cb}Ini$. Hc is assumed to be equal to H_cIni, whilst RD is equal to RDIni.

At the beginning of the development stage, the FAO basal crop coefficient is equal to $K_{cb}Ini$. During the development stage, Kcb linearly increases reaching a value equal to $K_{cb}Mid$ at the end of the stage (Doorenbos and Pruitt, 1992). The following equation is applied to calculate Kcb for the development stage, on a daily basis:

$$Kcb = Kcb + K_{cb}UpGrad \, (DAP - IniStage)$$

where $K_{cb}UpGrad$ (gradient of FAO basal crop coefficient increase during the development stage) is:

$$K_{cb}UpGrad = (K_{cb}Mid - K_{cb}Ini) / DevStage$$

Similarly, Hc is calculated adopting the following equation:

$$Hc = Hc + H_cGrad \, (DAP - IniStage)$$

where H_cGrad (gradient of crop height increase during the development stage) is:

$$H_cGrad = (Hc_{max} - H_cIni) / DevStage$$

RD is calculated as follows:

$$RD = RD + RDGrad \, (DAP - IniStage)$$

where RDGrad (gradient of root depth increase during the development stage) is:

$$RDGrad = (RD_{max} - RDIni) / DevStage$$

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During the mid-season stage, Kcb is assumed to be equal to K_{cb}Mid, crop height equal to Hc_{max} and RD equal to RD_{max}.

At the beginning of the late-season stage, the FAO basal crop coefficient is equal to K_{cb}Mid. During the late stage, Kcb linearly decreases reaching a value equal to K_{cb}Late at the end of the stage. The following equation is applied to calculate Kcb for the late stage, on a daily basis:

$$Kcb = Kcb + K_{cb}DownGrad\ (DAP - MidStage)$$

where K_{cb}DownGrad (gradient of FAO basal crop coefficient decrease during the late-season stage) is:

$$K_{cb}DownGrad = (K_{cb}Late - K_{cb}Mid)\ /\ LateStage$$

RD and Hc remain at their maximum value during the late-season stage.

The FAO model calculates potential crop transpiration (PT) using the following equation:

$$PT = Kcb\ ETo \qquad\qquad\qquad (Allen\ et\ al.,\ 1996)$$

Values of PET calculated in the **Weather unit** are used to determine Fl_{transp} which is assumed equal to Fl_{evap}, as follows:

$$Fl_{transp} = Fl_{evap} = PT\ /\ PET$$

Potential evaporation from the soil surface (PE) is then calculated as follows:

$$PE = (1 - Fl_{transp})\ PET$$

Fl_{transp} and Fl_{evap} are used in the **Soil unit** to determine actual T and E.

A subroutine for the estimation of yield with the FAO model under conditions of water stress, was included in SWB. The procedure recommended by the FAO was used to compile this procedure (Smith, 1992b). The estimated crop yield (Y) is calculated as follows:

$$Y = Y_{pot}\ (1 - Y_{red}\ /\ 100)$$

where

Y_{pot}	-	Potential yield (t ha^{-1})
Y_{red}	-	Percentage yield reduction (%)

Y_{pot} is a specific crop input parameter. Y_{red} is calculated as follows:

$$Y_{red} = 100\ (1 - Y_{rel(Init)}\ Y_{rel(Dev)}\ Y_{rel(Mid)}\ Y_{rel(Late)})$$

where

$Y_{rel(Init)}$ - Relative yield for initial stage
$Y_{rel(Dev)}$ - Relative yield for development stage
$Y_{rel(Mid)}$ - Relative yield for mid-season stage
$Y_{rel(Late)}$ - Relative yield for late-season stage

Relative yield for each stage (Y_{rel}) is calculated as a function of Ky for that particular stage and the SI:

$$Y_{rel} = 1 - Ky (1 - SI_1 \ SI_2 \ ... \ SI_{n-1} \ SI_n \ / \ n)$$

Ky for each stage and the duration of the stage in days (n) are crop specific input parameters. The subscript of SI indicates the day of the stage. SWB calculates SI on a daily basis as follows:

$$SI = T / (FI_{evap} \ PET)$$

SI therefore represents the relative transpiration of the crop (ratio of actual and potential crop transpiration). The CROPWAT model of the FAO (Smith, 1992b) uses the ratio of actual and potential evapotranspiration instead of SI, as it does not calculate soil water supply limited root uptake.

SWB calculates and outputs estimated yield (Y) and Y_{red} on a daily basis, assuming that no water stress (SI = 1) will occur from that particular day until the end of the growing season.

GUIDELINES FOR THE DETERMINATION OF SPECIFIC CROP GROWTH PARAMETERS

Examples of how to determine specific crop growth parameters for SWB are presented in this chapter.

1.20 Vapour pressure deficit corrected dry matter-water ratio

DWR is a crop specific parameter determining water use efficiency. Tanner and Sinclair (1983) recommended that the relation between dry matter production (DM) and crop transpiration should be corrected to account for atmospheric conditions, in particular for vapour pressure deficit (VPD). DWR is therefore calculated as follows:

$$DWR = (DM\ VPD) / ET$$

DM ($kg\ m^{-2}$) is measured at harvest, whilst VPD represents the seasonal average. Both VPD and DWR are in Pa. Seasonal crop evapotranspiration (ET) in mm is equivalent to $kg\ m^{-2}$.

ET is obtained using the following equation for weekly time intervals:

$$ET = P + I - R - Dr - \Delta Q$$

where R is runoff, Dr is drainage and ΔQ represents the soil water storage. All terms are expressed in mm. A positive sign for ΔQ indicates a gain in soil water storage. ΔQ can be calculated from soil water content measurements with the neutron water meter.

Daily VPD can be calculated from measurements of e_a, or RH_{max} and RH_{min}, or T_w and T_d, as described in Section 4.1.3 (Vapour pressure deficit).

Evaporation from the soil surface should not be included in the calculation of DWR, as unlike transpiration, it is not tightly linked to photosynthesis and therefore dry matter production. The portion of soil water lost by evaporation could be substantial, particularly at the beginning of the season when canopy cover is partial. For this reason, DWR values calculated as described above, should be seen as lower limits and would need to be increased to give reliable simulations in SWB.

1.21 Radiation conversion efficiency

E_c is a crop specific parameter used to calculate dry matter production under conditions of radiation limited growth (Monteith, 1977) as follows:

$$DM = E_c\ FI\ R_s$$

Figure 1 represents DM of cabbage as a function of the daily cumulative product of the fractional interception of radiation (FI) and R_s. Data were obtained in a field trial carried out at Roodeplaat, on a clay

loam soil (1996 season) (Annandale *et al.*, 1998). FI was measured with the sunfleck ceptometer and R_s with a pyranometer. E_c is the slope of the regression line forced through the origin. The high coefficient of determination (r^2) indicates that E_c is a relatively constant and predictable parameter under conditions of good water supply.
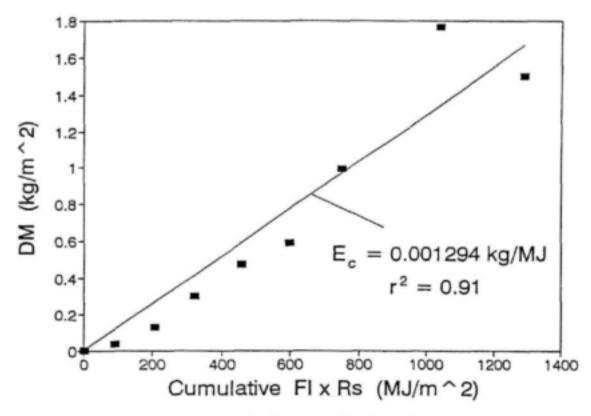
Figure 1 *Dry matter (DM) production of cabbage as a function of the cumulative product of fractional interception and solar radiation (FI x R_s). Radiation conversion efficiency (E_c) and the coefficient of determination (r^2) are shown*

1.22 Specific leaf area

SLA is a crop parameter which describes the leaf morphology of a specific crop. It can be calculated as the seasonal average of the ratio of leaf area index (LAI) to leaf dry matter (LDM):

SLA = LAI / LDM

LAI and LDM can be obtained from growth analysis. SLA is in $m^2 \ kg^{-1}$, whilst LDM is in $kg \ m^{-2}$.

Caution should be exercised in the use of seasonal average SLA as this parameter typically has a decreasing trend during the season, as shown in the example for cabbage (Figure 2).
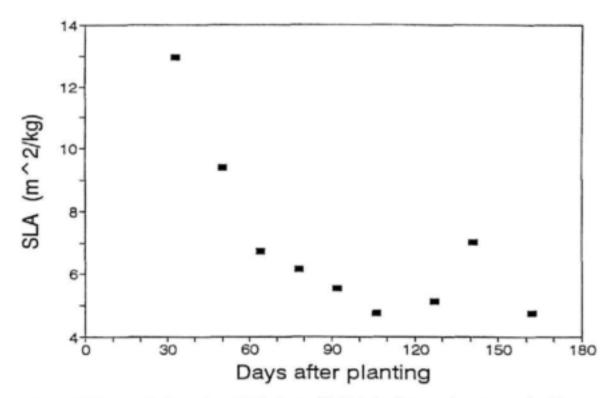
Figure 2 Measured values of specific leaf area (SLA) during the growing season of cabbage

1.23 Stem-leaf partitioning parameter

PART is a crop specific parameter which describes how much of the canopy dry matter (CDM) is

partitioned into stems and leaves. It can be calculated as follows:

$$PART = ((SLA\ CDM) / LAI - 1) / CDM$$

Figure 3 represents the correlation between CDM and "(SLA CDM) / LAI - 1" for cabbage. The slope of the regression line which is forced through the origin, represents PART in $m^2\ kg^{-1}$. CDM in $kg\ m^{-2}$ and LAI can be obtained from growth analysis. SLA can be calculated from growth analysis data (Section 5.3, Specific leaf area).
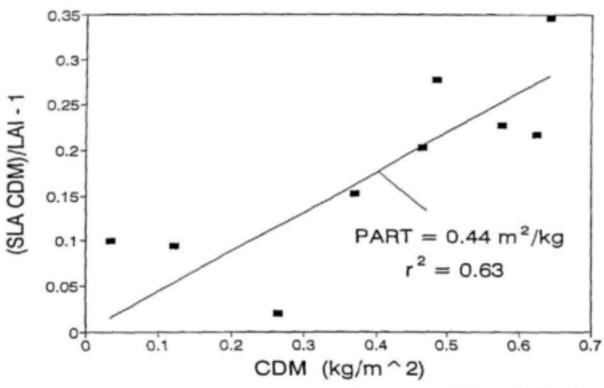
Figure 3 *Determination of the leaf-stem dry matter partitioning parameter (PART) as a function of canopy dry matter (CDM), specific leaf area (SLA) and leaf area index (LAI) for cabbage. The slope of the regression line (PART) and the coefficient of determination (r^2) are shown*

1.24 Canopy radiation extinction coefficient

The basic equation describing transmission of a beam of solar radiation through the plant canopy is similar to Bouguer's law (Campbell and van Evert, 1994):

$$FI = 1 - e^{-K \, LAI}$$

where K is the canopy extinction coefficient. K can be calculated from field measurements of LAI and FI. Guidelines for determining K in the field are given by Jovanovic and Annandale (1998). Figure 4 represents FI values as a function of LAI for cabbage. FI was measured with the sunfleck ceptometer, whilst LAI was determined from growth analysis. The calculated value of K was 1.17, and the coefficient of determination of the exponential function (r^2) was 0.81.
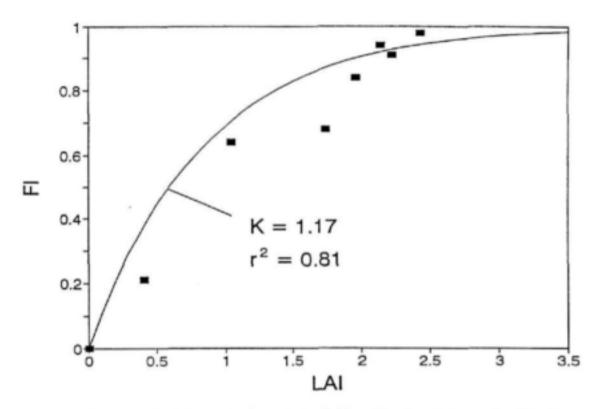
Figure 4 *Correlation between leaf area index (LAI) and fractional interception (FI) of radiation measured with the ceptometer for cabbage. Canopy extinction coefficient (K) and the coefficient of determination of the exponential regression function (r^2) are shown*

The value of K calculated from FI measurements with the ceptometer, is for photosynthetically active radiation (PAR, 0.4-0.7 μm). The canopy extinction coefficient for PAR (K_{PAR}) can be used to calculate photosynthesis as a function of intercepted PAR. The canopy extinction coefficient for total solar radiation (K_s) is, however, required for predicting radiation limited dry matter production (Monteith, 1977) and for partitioning ET into evaporation from the soil surface and crop transpiration (Ritchie, 1972). The procedure recommended by Campbell and van Evert (1994) can be used to convert K_{PAR} into K_s:

$$K_s = K_{bd} \_ a_s$$

$$K_{bd} = K_{PAR} / \_ a_p$$

$$a_s = \_ a_p a_n$$

K_{bd}	-	Canopy radiation extinction coefficient for 'black' leaves with diffuse radiation
a_s	-	Leaf absorptance of solar radiation
a_p	-	Leaf absorptance of PAR
a_n	-	Leaf absorptance of near infrared radiation (NIR, 0.7-3 μm)

The value of a_p was assumed to be 0.8, whilst a_n was assumed to be 0.2 (Goudriaan, 1977). a_s is the geometric mean of the absorptances in the PAR and NIR spectrums.

1.25 Rooting depth

Root depth can be estimated from measurements of soil water extraction with the neutron water meter. It can be assumed to be equal to the depth at which 90% of soil water depletion occurred during a given period.

1.26 Thermal time requirements

Growing day degrees daily increment (GDD_i) can be determined from daily average air temperature (T_{avg}), after Monteith (1977):

$$GDD_i = (T_{avg} - T_b) \Delta t$$

where GDD_i is in d °C, T_b is the base temperature in °C, and Δt is one day. T_b is a crop specific parameter.

When the average daily temperature is below the base temperature, GDD_i for that day is 0.

If $T_{avg} > T_{cutoff}$, then:

$$GDD_i = T_{cutoff} - T_b$$

where T_{cutoff} is an optimal temperature for crop development in °C (crop specific parameter).

GDD_i values are cumulated from planting until emergence to determine day degrees requirement for emergence (EMDD), until flowering to determine day degrees requirement for completion of vegetative growth (FLDD), and until maturity to determine day degrees requirement for maturity (MTDD)

GUIDELINES FOR THE DETERMINATION OF THE FAO MODEL PARAMETERS

Examples of how to determine FAO crop parameters for SWB are presented in this chapter.

1.27 Basal crop coefficients and growth periods

Figure 5 represents values of FI and Kcb for onions grown at Roodeplaat on a clay loam soil (1996 season) (Annandale et al., 1998). FI was measured with the sunfleck ceptometer, and a third order polynomial was fitted through the measured data points (r^2 = 0.94). Daily Kcb was calculated using the following equation:

$$Kcb = FI \, PET / ETo$$

ETo and PET were calculated as described in Sections 4.1.5 and 4.1.6 (FAO reference evapotranspiration and Potential evapotranspiration).

The following procedure can be used to estimate Kcb's for the initial, mid and late stages, and the lengths of growth stages in days (Figure 5):

i) Initial stage:	Length of stage from planting until FI = 0.1. Kcb equal to calculated daily Kcb at FI = 0.1.
ii) Crop development stage:	Length of stage from end of initial stage until FI is 90% of maximum FI.
iii) Mid-season stage:	Length of stage from end of development stage until canopy cover drops to the same value it had at the beginning of the mid-season period (90% of maximum FI). Kcb equal to average daily Kcb (Kcb = FI PET / ETo) during the mid-season stage.
iv) Late stage:	Length of stage from end of mid-season stage until end of growing season. Kcb equal to calculated daily Kcb at end of growing season.

The duration of the late stage and Kcb for the late stage cannot determined for crops harvested during the mid-season stage, before leaf senescence occurs.

Doorenbos and Pruitt (1992) stated that the beginning of the mid-season stage can be recognized in the field when the crop has attained 70 to 80% groundcover. They also stated that full groundcover occurs when the FAO crop coefficient (Kc) approaches a maximum. Many crops do not reach 70% groundcover during the growing season. The mid-season stage can therefore be assumed to start when FI becomes equal to 90% of maximum FI.

Caution should be exercised against blind acceptance of the FAO parameters as local conditions, management and cultivars are likely to influence crop growth periods and Kcb's.
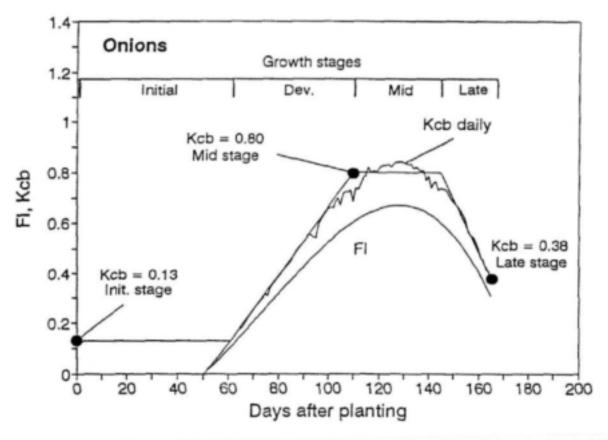
Figure 5 *Daily values of canopy cover (Fl) and basal crop coefficient (Kcb daily), and estimated Kcb values for four growth stages of onions (initial, crop development, mid-season and late-season stages)*

1.28 Initial and maximum crop height

Initial and maximum crop height can be easily measured in the field at the beginning of the growing season, and at full canopy development. Initial Hc values can be assumed to be 0.01 m for crops planted by seeding (Smith, 1992b) and 0.05 m for transplanted crops.

1.29 Initial and maximum rooting depth

Root depth can be estimated from measurements of soil water extraction with the neutron water meter. It can be assumed to be equal to the depth at which 90% of soil water depletion occurred during a given period. Initial rooting depth occurs at the beginning of the season, whilst maximum rooting depth occurs at full canopy development. Smith (1992b) recommended RD values of 0.25 m for the initial crop stage.

REFERENCES

ALLEN RG (1995) Evaluation of procedures for estimating grass reference evapotranspiration using air temperature data only. Rep. submitted to FAO/AGL, Rome.

ALLEN RG, JENSEN ME, WRIGHT JL and BURMAN RD (1989) Operational estimates of evapotranspiration. *Agron. J.* **81** 650-662.

ALLEN RG, SMITH M, PRUITT WO and PEREIRA LS (1996) Modifications to the FAO crop coefficient approach. *Proc. of the Int. Conf. on Evapotranspiration and Irrigation Scheduling*, San Antonio, Texas, USA. 124-132.

ANNANDALE JG, VAN DER WESTHUIZEN AJ and OLIVIER FC (1996) Die fasilitering van tegnologie oordrag deur verbeterde besproeiingriglyne vir groente en 'n meganistiese gewasmodeleringbenadering. Waternavorsingskommissie Verslag No.476/1/96, Pretoria, South Africa.

ANNANDALE JG, BENADÉ N, JOVANOVIC NZ, STEYN JM, DU SAUTOY N and MARAIS D (1998) Facilitating irrigation scheduling by means of the soil water balance model. Water Research Commission, Progress Report, Pretoria, South Africa.

BENNIE ATP, COETZEE MJ, VAN ANTWERPEN R, VAN RENSBURG LD and DU T. BURGER R (1988) 'n Waterbalansmodel vir besproeiing gebaseer op profielwatervoorsieningstempo en gewaswaterbehoeftes. Waternavorsingskommissie Verslag No. 144/1/88, Pretoria, South Africa.

BOSEN JF (1958) An approximation formula to compute relative humidity from dry bulb and dew point temperatures. *Monthly Weather Rev.* **86**(12) 486.

BURMAN RD, JENSEN ME and ALLEN RG (1987) Thermodynamic factors in evapotranspiration. In: James LG and English MJ (eds.) *Proc. Irrig. and Drain. Spec. Conf.*, ASCE, Portland, Oregon, USA, July 1987. 28-30.

CAMPBELL GS (1985) *Soil physics with Basic.* Elsevier Science B.V., Amsterdam

CAMPBELL GS and DIAZ R (1988) Simplified soil-water balance models to predict crop transpiration. In: Bidinger FR and Johansen C (eds.) *Drought research priorities for the dryland tropics.* ICRISAT, India.

CAMPBELL GS and STOCKLE CO (1993) Prediction and simulation of water use in agricultural systems. In: *International crop science I.* Crop Science of America, 677 S. Segoe Rd., Madison, Wisconsin 53711, USA.

CAMPBELL GS and VAN EVERT FK (1994) Light interception by plant canopies: efficiency and architecture. In: Monteith JL, Scott RK and Unsworth MH (eds.) *Resource capture by crops.* Nottingham Univ. Press. 35-52.

DE JAGER JM (1994) Accuracy of vegetation evaporation ratio formulae for estimating final wheat yield. *Water SA* **20**(4) 307-315.

DOORENBOS J and PRUITT WO (1992) *Crop water requirements.* FAO Irrigation and Drainage Paper No. 24. FAO, Rome, Italy.

DUFFIE JA and BECKMAN WA (1980) *Solar engineering of thermal processes.* John Wiley and Sons, New York.

GOUDRIAAN J (1977) *Crop meteorology: a simulation study.* Pudoc, Wageningen.

HILLEL D (1982) *Introduction to soil physics.* Academic Press Inc., New York.

JOVANOVIC NZ and ANNANDALE JG (1998) Measurement of radiant interception of crop canopies with the LAI-2000 plant canopy analyzer. *SA J. of Plant and Soil* **15**(1) 6-13.

MONTEITH JL (1977) Climate and efficiency of crop production in Britain. *Philos. Trans. R. Soc. London,* Ser. B **281** 277-294.

NORMAN JM and CAMPBELL GS (1983) Application of a plant-environment model to problems in irrigation. *Adv. in Irrig.* **2** 155-188.

REDDY SJ (1983) A simple method of estimating the soil water balance. *Agric. Meteor.* **28** 1-7.

RITCHIE JT (1972) Model for predicting evaporation from a row crop with incomplete cover. *Water Resour. Res.* **8** 1204-1213.

SMITH M (1992a) Expert consultation on revision of FAO methodologies for crop water requirements. FAO, Rome, Italy, 28-31 May 1990.

SMITH M (1992b) *CROPWAT - A computer program for irrigation planning and management.* FAO Irrigation and Drainage Paper No. 46. FAO, Rome, Italy.

SMITH M, ALLEN RG and PEREIRA LS (1996) Revised FAO methodology for crop water requirements. *Proc. of the Int. Conf. on Evapotranspiration and Irrigation Scheduling,* San Antonio, Texas, USA. 133-140.

STEWART BA, WOOLHISER DA, WISCHMEIER WH, CARO LH and FRERE MH (1976) Control of water pollution from cropland. Vol. 2. An overview. U.S. Department of Agriculture, Agricultural Research Service. Beltsville, Maryland, USA.

TANNER CB and SINCLAIR TR (1983) Efficient water use in crop production: research or re-search? In: Taylor HM, Jordan WR and Sinclair TR (eds.) *Limitations to efficient water use in crop production.* American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, Wisconsin.

TETENS O (1930) Uber einige meteorologische Begriffe. *Z. Geophys.* **6** 297-309.

WRIGHT JL and JENSEN ME (1972) Peak water requirements of crops in Southern Idaho. *J. Irrig. and Drain. Div. ASCE* **96**(IRI) 193-201.

APPENDIX 1

LIST OF ABBREVIATIONS AND SYMBOLS

a	-	Campbell's coefficient of the log-log water retention function
ADL	-	Allowable depletion level
Alt	-	Altitude (m)
a_n	-	Leaf absorptance of near infrared radiation
a_p	-	Leaf absorptance of photosynthetically active radiation
a_s	-	Leaf absorptance of solar radiation
b	-	Campbell's coefficient of the log-log water retention function
CDM	-	Canopy dry matter $(kg\ m^{-2})$
CDM_i	-	Canopy dry matter daily increment $(kg\ m^{-2})$
DAP	-	Days after planting
Dec	-	Solar declination (rad)
DevStage	-	Length of crop development stage (days)
Df	-	Drainage factor
D_i	-	Amount of water that penetrates the deeper soil layer (mm)
DM	-	Dry matter production $(kg\ m^{-2})$
DM_i	-	Daily increment of total dry matter $(kg\ m^{-2})$
DOY	-	Day of year
Dr	-	Drainage (mm)
D_{rel}	-	Relative distance of the earth from the sun
DWR	-	Dry matter-water ratio (Pa)
dz	-	Soil layer thickness (m)
E	-	Actual evaporation (mm)
e_a	-	Actual vapour pressure (kPa)
E_c	-	Radiation conversion efficiency $(kg\ MJ^{-1})$
EMDD	-	Emergence day degrees
e_s	-	Saturated vapour pressure (kPa)
ET	-	Evapotranspiration (mm)
ETo	-	FAO reference evapotranspiration (mm)
E^*	-	Maximum dimensionless loss rate
f	-	Layer root fraction
f_c	-	Cloudiness factor
f_i	-	Irrigated fraction of the surface ground (fraction of wetted area)
FI	-	Fractional interception of radiation
FI_{evap}	-	Fractional interception of radiation by photosynthetically active and senesced leaves
FI_{transp}	-	Fractional interception of radiation by photosynthetically active leaves
f_l	-	Leaf partitioning factor
FLDD	-	Day degrees at end of vegetative growth
f_r	-	Fraction of dry matter partitioned to roots
G	-	Soil heat flux (°C)
g	-	Gravitational acceleration $(9.8\ m\ s^{-2})$

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GDD	-	Growing day degrees
GDD_i	-	Growing day degrees daily increment
Hc	-	Crop height (m)
H_cGrad	-	Gradient of crop height increase during the development stage
H_cIni	-	FAO initial crop height (m)
Hc_{max}	-	Maximum crop height (m)
HDM	-	Harvestable dry matter (kg m^{-2})
HDM_i	-	Harvestable dry matter daily increment (kg m^{-2})
H_U	-	Height at which wind speed is measured (m)
I	-	Irrigation amount (mm)
I_c	-	Amount of precipitation intercepted by the canopy (mm)
IniStage	-	Length of crop initial stage (days)
K	-	Canopy radiation extinction coefficient
K_{bd}	-	Canopy extinction coefficient of black leaves and diffuse radiation
K_{PAR}	-	Canopy extinction coefficient of photosynthetically active radiation
K_s	-	Canopy extinction coefficient of total solar radiation
Kc	-	FAO crop coefficient
Kcb	-	FAO basal crop coefficient
K_{cb}DownGrad	-	Gradient of FAO basal crop coefficient decrease during the late-season stage
K_{cb}Ini	-	FAO basal crop coefficient for initial stage
K_{cb}Late	-	FAO basal crop coefficient for end-season stage
K_{cb}Mid	-	FAO basal crop coefficient for mid-season stage
K_{cb}UpGrad	-	Gradient of FAO basal crop coefficient increase during the development stage
Kc_{max}	-	FAO maximum crop coefficient
Ky	-	FAO stress factor
LAI	-	Leaf area index
$LAIage_i$	-	Age of leaf area index generated on day "i"
LAI_i	-	Leaf area index daily increment
Lat	-	Latitude (deg)
LateStage	-	Length of crop end-season stage (days)
LDM	-	Leaf dry matter (kg m^{-2})
LDM_i	-	Leaf dry matter daily increment (kg m^{-2})
Loss	-	Soil water loss by transpiration (fraction of soil volume)
MidStage	-	Length of crop mid-season stage (days)
MTDD	-	Maturity day degrees
n	-	Duration of the crop stage
NIR	-	Near infrared radiation (0.7-3 µm)
P	-	Precipitation (mm)
P_a	-	Atmospheric pressure for a given altitude (kPa)
PAR	-	Photosynthetically active radiation (0.4-0.7 µm)
PART	-	Stem-leaf partitioning parameter (m^2 kg^{-1})
PE	-	Potential evaporation (mm)
PET	-	Potential evapotranspiration (mm)
PT	-	Potential transpiration (mm)
P_0	-	Standard atmospheric pressure at sea level (101.3 kPa)
R	-	Runoff (mm)

R_a	-	Extraterrestrial radiation $(MJ\ m^{-2}\ day^{-1})$
RD	-	Root depth (m)
RDGrad	-	Gradient of root depth increase during the development stage
RDIni	-	Initial root depth (m)
RDM	-	Root dry matter $(kg\ m^{-2})$
RDM_i	-	Root dry matter daily increment $(kg\ m^{-2})$
RD_{max}	-	Maximum root depth (m)
Rg	-	Specific gas constant for dry air $(286.9\ J\ kg^{-1}\ K^{-1})$
RGR	-	Root growth rate $(m^2\ kg^{-0.5})$
RH_{max}	-	Daily maximum relative humidity $(\%)$
RH_{min}	-	Daily minimum relative humidity $(\%)$
R_n	-	Net radiation $(MJ\ m^{-2}\ day^{-1})$
R_{nl}	-	Long-wave net radiation $(MJ\ m^{-2}\ day^{-1})$
R_{ns}	-	Short-wave net radiation $(MJ\ m^{-2}\ day^{-1})$
rpf	-	Reproductive partitioning fraction
R_s	-	Solar radiation $(MJ\ m^{-2}\ day^{-1})$
R_{so}	-	Short-wave radiation during bright sunshine $(MJ\ m^{-2}\ day^{-1})$
r^2	-	Coefficient of determination
S	-	Runoff curve number (mm)
SDM	-	Stem dry matter $(kg\ m^{-2})$
SDM_i	-	Stem dry matter daily increment $(kg\ m^{-2})$
SI	-	Stress index
SLA	-	Specific leaf area $(m^2\ kg^{-1})$
SWB	-	Soil Water Balance model
SWD	-	Soil water deficit (mm)
T	-	Actual transpiration (mm)
T_a	-	Air temperature $(°C)$
T_{avg}	-	Daily average air temperature $(°C)$
T_b	-	Base temperature $(°C)$
T_{cutoff}	-	Cutoff temperature $(°C)$
T_d	-	Dry bulb temperature $(°C)$
TDM	-	Top dry matter $(kg\ m^{-2})$
T_f	-	Temperature factor for light limited crop growth $(°C)$
T_{lo}	-	Temperature for optimum light-limited crop growth $(°C)$
T_{max}	-	Daily maximum air temperature $(°C)$
T_{min}	-	Daily minimum air temperature $(°C)$
TransDD	-	Day degrees of transition period from vegetative to reproductive growth
Transl	-	Factor determining translocation of dry matter from stem to grain
Tr_{max}	-	Maximum transpiration rate $(mm\ day^{-1})$
T_w	-	Wet bulb temperature $(°C)$
T_0	-	Standard temperature at sea level $(293\ K)$
T^*	-	Dimensionless actual water uptake
U	-	Wind speed $(m\ s^{-1})$
U_2	-	Wind speed measured at 2 m height $(m\ s^{-1})$
U^*	-	Dimensionless root uptake rate
VPD	-	Vapour pressure deficit (Pa)
wsf	-	Water stress factor
Y	-	Crop yield $(t\ ha^{-1})$

yLAI	-	Leaf area index of senesced leaves
$yLAI_i$	-	Daily increment of leaf area index of senesced leaves
Y_{pot}	-	Potential yield $(t\ ha^{-1})$
Y_{red}	-	Percentage yield reduction (%)
$Y_{rel(init)}$	-	Relative yield for initial stage
$Y_{rel(Dev)}$	-	Relative yield for development stage
$Y_{rel(Mid)}$	-	Relative yield for mid-season stage
$Y_{rel(Late)}$	-	Relative yield for late-season stage
z	-	Soil depth (m)
α	-	Adiabatic lapse rate $(K\ m^{-1})$
γ	-	Psychrometer constant $(kPa\ °C^{-1})$
Δ	-	Slope of the saturation vapour pressure curve $(Pa\ °C^{-1})$
ΔQ	-	Soil water storage (mm)
Δt	-	Daily time step (1 day)
ε	-	Clear sky emissivity of the earth's surface
θ	-	Actual volumetric soil water content
θ_{ad}	-	Air dry volumetric soil water content
θ_{fc}	-	Volumetric soil water content at field capacity
θ_{pwp}	-	Volumetric soil water content at permanent wilting point
θ_{sat}	-	Volumetric soil water content at saturation
λ	-	Latent heat of vaporization $(MJ\ kg^{-1})$
ρ_w	-	Water density $(Mg\ m^{-3})$
ρ_b	-	Bulk density $(Mg\ m^{-3})$
σ	-	Stefan-Boltzmann constant $(4.9 \times 10^{-9}\ MJ\ m^{-2}\ K^{-4})$
Ψ_{avg}	-	Root weighted average soil matric potential $(J\ kg^{-1})$
Ψ_{fc}	-	Soil matric potential at field capacity $(J\ kg^{-1})$
Ψ_{lm}	-	Leaf water potential at maximum transpiration $(J\ kg^{-1})$
Ψ_m	-	Soil matric potential $(J\ kg^{-1})$
Ψ_{pwp}	-	Soil matric potential at permanent wilting point $(J\ kg^{-1})$
Ψ_x	-	Xylem water potential $(J\ kg^{-1})$
ω_s	-	Sunset hour angle (rad)

APPENDIX B

RiskMan

User's Manual

RISKMAN

Version 1.0

Risk Management Simulator
User's guide

Risk Management Simulator (RISKMAN)

Developer

André Meiring

Programming and User' Guide

Illze Crous

Funding

Water Research Commission

DISCLAIMER

Extreme attention to detail has been given to ensure that calculation procedures in this model are sound. Nevertheless, the authors, the University of the Free State and the Water Research Commission will not accept liability for any damages or loss suffered as a result of the use of this model.

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1. INTRODUCTION

1.1 RISK MANAGEMENT

Risk is regarded to be present in every situation where the results of decisions are not yet known during the decision-making process. Risk management comprises choices between alternative actions that may reduce the exposure to unfavourable financial outcomes as a result of uncertain farming results.

The increase in risk at farm level demands that risk management should form an integral part of the daily decision process while managing a farm business. Risk management at farm level however, is subject to constraints, firstly, because of a lack of analysis techniques that might enable one to take risk into account in decision-making, and, secondly, because of the level of sophistication and cost of the aids that are in fact available. This research was motivated by the fact that risk management on South African farms is currently constrained by the lack of instruments and aids that would render it possible to take risk explicitly and practically into account in analyses at farm level.

1.2 THE RISKMAN (RISK MANAGEMENT) SIMULATION MODEL

From a risk-management point of view, computer models that treat irrigation requirements, yield/production and product prices as constant values have limited application potential. The main aim with the development of RISKMAN is to provide risk-management information to bridge the gap between theory and practice at whole farm level.

Flexibility and user friendliness enjoyed high priority in the development of RISKMAN. Users obtain assistance and training by means of the help lines and error messages are displayed in certain cases. RISKMAN is based on the research done by Meiring (1994) and use procedures developed by King (1979).

The nature and importance of risk demands a comprehensive approach involving aspects such as identifying the sources of risk, measurement of risk, attitudes toward risk and risk management as an integral part of decision analyses. In the management process at enterprise level the most efficient enterprise or combination of enterprises must be chosen and then also managed efficiently. The farmer often has various sources of data at his disposal, but the format in which the information is available limits its usefulness and the data therefore require further processing.

In most cases the prices obtained for products, as well as weather or rainfall variability, which results in yield variation, were indicated as the most important risks. The question whether the

yield of crops must be adjusted to accommodate hail damage or not is also handled. However, the nature of a farm business, as well as its locality, has an influence on the importance of risk. Therefore it is important to make available a tool or instrument with enough flexibility to be utilised by every farmer.

The output of *RISKMAN* facilitates the management process at enterprise level by providing several tables with information regarding the planned enterprise combinations and management methods. Alternative management strategies can be evaluated at enterprise level. Since risk results are simulated as distribution of specific performance criteria, the distributions are also presented graphically.

The reliability of these simulated values is vested in the accuracy of the inputs and assumptions made in the model. With accurate input *RISKMAN* is a valuable instrument to facilitate risk management. As a support system in decision-making, *RISKMAN* provide users with the opportunity to facilitate this management process.

1.3   WHY RISKMAN?

The purpose of the program is to provide support for risk management at enterprise as well as whole farm level. The model was primarily developed with a view to provide reliable and relevant information on which decisions can be based. In addition to this, the system is user friendly, practically oriented and flexible, which should ensure wide applicability. As a decision support system this model will facilitate and improve risk management and would make it possible to take risk into consideration.

RISKMAN enables farmers, consultants and researchers to do various analyses and can be used for the following:

- Sets of simulated irrigation quantities and yield levels are used in the model to take production risk into account. By making use of *inter alia* time-series analyses and subjective probabilities, cumulative probability distributions can be compiled and used to reflect price risk.

- By using *RISKMAN*, alternative production plans, including alternative crop rotation systems, as well as insurance against hail damage can be evaluated.

- The model user can compare alternative risk-management strategies at enterprise level. In the model risky variables are treated as distributions and the output of the model can therefore also be presented as distributions. The simulation of risk and definition of variables as different distributions were made possible by using *RISKMAN*.

- The influence of variable interest rates on economic performance can also be evaluated.

1.4   HOW TO USE THE USER'S GUIDE?

A brief discussion to familiarise the user with the overall structure of the program and the mechanics of running it is presented in Chapter 2 (Getting started).

Chapter 3 introduces the user to *RISKMAN* and how to manage the database of farmers' information. The file menu also controls the main procedures of the program (File menu).

Guidelines for the required data input are given in Chapter 4. Data is divided into four groups, *e.g.* General farm information, Fixed obligations, Crop enterprise and Livestock enterprise. The use of tables for entering and editing data, as well as a technical description of subjective probabilities and correlation's is fully discussed here (Data menu).

Chapter 5 handles the input on the Run form that consists of the production and the risk management strategies. Since *RISKMAN* is a simulation model, parameters for each enterprise have to be known. The main purpose for this component is to calculate the net operating receipts (NOR) and net farm income (NFI) of the three production systems (Run menu).

In Chapter 6 the power of this model is illustrated by the extent and nature of it's output. The tables contain different sets of information that can be used to support decision making at enterprise level. This outputs acts as support to the economic aspects of the enterprise decision as well as whole farm planning (Output menu).

2. GETTING STARTED

The program is supplied on 3.5-inch disks or CD, with a User's guide.

2.1 HARDWARE REQUIREMENTS

The program runs in Windows 95 or later version on an IBM-PC or compatible computer. The minimum requirement is 16 Mb RAM, 10Mb of disk space and a SVGA monitor with 1Mb VGA card. 32Mb of RAM and a printer attached to your computer is recommended but optional.

2.2 HOW TO INSTALL RISKMAN?

1. From the Windows START menu choose **RUN**.

2. Select Setup from the CD drive or from disk no 1 and press Enter or OK.

3. By default *RISKMAN* will be placed in a directory called *RISKMAN* on the hard disk, usually the C drive. Change the disk and directory name if required and click on OK.

4. The installation program will ask for your name or company name. Enter your name and press OK to proceed.

5. The install program will copy and expand all the files on the installation Disks.

6. On completion the installation program will create the Windows program items in the program folder which contains the *RISKMAN* folder.

2.3 HOW TO RUN RISKMAN?

The use of the program is discussed in detail in Chapters 3, 4, 5 and 6. The main steps to follow are indicated in figure 2.2. *The steps are:*

1. Left click on the **Start** button and point to **Programs**, a sub-menu will appear. Move the mouse cursor to the *FARMS* group, again a sub-menu will open. Left click on *RISKMAN*.

2. The introductory screen is displayed while *RISKMAN* is being loaded.

3. The Main menu will then appear with only the **File** and **Help** components active. Commands shown in grey are inactive.

4. Left click on the **File menu**, and then again on **Open**. Then highlight a farmer's name in the database, and click on the OK button. The farmer's data set in the database is now active.

5. Next use the **Data** option on the Main menu. Start at the top with General farm information through to Livestock enterprise. Change the data to suit your farm information.

6. After all the data is entered, go to **Run** on the Main menu and edit the strategies to suit your needs.

7. After the program has been run and all the calculations completed, you can go to **Output** and to evaluate the results.

8. By using the Exit option under the **File** menu, the user can exit the *RISKMAN* program.
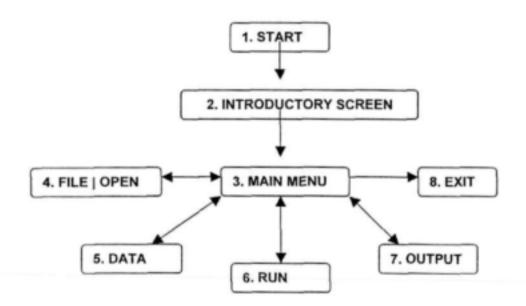
FIGURE 2.1   PROGRAM FLOW DIAGRAM OF *RISKMAN*.

2.4   TERMINOLOGY AND GENERAL CONTROL KEYS

Link Type

The following link types are supplied for a shortcut to other datastes:

FARMS   Firm-level Agricultural Management System

IRRICOST   Irrigation cost system calculation model

WAS   Water Administration System

SWB   Soil Water Balance

Alt and Menu Characters

Menu and sub-menu access is available by holding the Alt key down and pressing the underlined character.

Esc

The Esc key may be used at any time to exit a table editing function, an active dataset or lookuplist or to exit the form.

TAB

The TAB key may be used to advance the cursor one field at a time.

Shift TAB

Hold the shift key down and press TAB to move the cursor back one field at a time.

[...]	If the user double click in the field with this button, a pick list will appear for the user to choose from.
⬇	A dropdown list will appear when the user click on this arrow or in the case of dates, a calendar will appear.
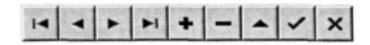
2.5   DATA ENTRY AND EDITING PROCEDURES

While entering data, you can edit the current or previous entries. The <↑> up arrow and <↓> down arrow keys can be used to move the cursor to a field to be edited. Use the <BACKSPACE>, <INS>, <DEL>, <←> and <→> keys to make corrections.

Use of the function and editing keys is the same for all data entry screens in *RISKMAN*. When data input is out of an allowable range, an error message will appear.

A database navigator is used to move through the data in a dataset and perform operations on the data, such as inserting a blank record or posting a record. When the user chooses one of the navigator buttons, the appropriate action occurs on the dataset the navigator is linked to. For example, if the user clicks the Insert button, a blank record is inserted in the dataset.

Each table has a navigation bar across the top. If the user pause for a moment over a button a hint with the buttons function will be visible for a few seconds. A Navigator bar may show any or all of the following buttons (listing the actions available in order from left to right): -

⏮	◄	►	⏭	+	−	▲	✓	✕

Button Purpose

First	Sets the current record to the first record in the dataset, disables the First and Previous buttons, and enables the Next and last buttons if they are disabled.
Previous	Sets the current record to the previous record and enables the Last and Next buttons if they are disabled.
Next	Sets the current record to the next record and enables the First and Prior buttons if they are disabled.
Last	Sets the current record to the last record in the dataset, disables the Last and Next buttons, and enables the First and Prior buttons if they are disabled.
Insert	Inserts a new record before the current record, and sets the dataset into Insert and Edit states.
Delete	Deletes the current record and makes the next record the current record.
Edit	Puts the dataset into Edit state so that the current record can be modified.
Post	Writes changes in the current record to the database.
Cancel	Cancels edits to the current record, restores the record display to its condition prior to editing, and turns off Insert and Edit states if they are active.

The use of the navigation buttons is the same for all database entries.

3. FILE MENU

This chapter introduces the user to the File menu option in *RISKMAN*. The File menu enables the user to open and close the farmers database, as well as to change the options, handle the addresses and telephone numbers, change the printer setup and exit from the *RISKMAN* program.

3.1 OPEN DATASET

File | Open dataset

Before any data can be viewed or edited, a farmer's data set has to be opened. Only after a farmer has been chosen, the Data, Run and Output menu options will be active.

On the Open form, the user can open a data set, click on the Insert button to create a new data set or click on the Delete button to delete a data set.

3.1.1 Open a Farmer

A list of all the available farmers are shown in a table. Select the farmer you want to work with, by highlighting it, and click OK. The chosen farmer's dataset will then be activated. The table consists out of the following two fields, namely:

Identification Number
This identification number is used to identify the farmer. This number must be unique in the database. The field can save up to 13 characters.

Description
A good description of the farmer must be entered here in order to help the user identify a specific farmer.
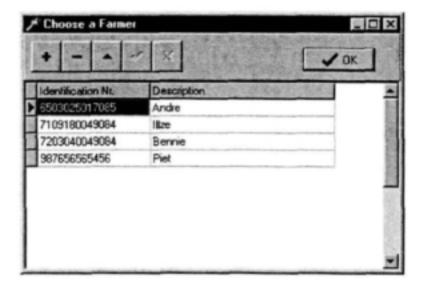
Figure 3.1 The open farmer window.

The Open screen is shown in figure 3.1.

3.1.2 Add a new Farmer

Click on the Insert button on the Open form, to enter a new set of data. A window will appear. A new data set can be created in one of three ways:

1. Import from *FARMS*: A list of all the available farmers data sets in *FARMS* will appear for the user to pick from.

2. *Copy another*: When creating a new database, an existing database has to be chosen and new name has to be given for the new database. The existing database is then used as the source and a copy will be made. The new database will have all the data that the source has and minor changes to fit the user can be made.

3. Start new.

After the user has chosen one method, place the cursor on the New farmer's data set line and enter the Description of the new farmer.

3.1.3 Delete a Farmer

This action will remove a farmer's data set permanently from your hard drive.

1) Select the farmer from the existing list of farmers in the database.

2) Click on the Delete button on the navigator bar.

3) Confirm twice that you wish to delete the dataset.

3.2 CLOSE DATASET

File | Close dataset

Close Dataset is used to exit the current dataset, returning to the opening screen with two active menu commands, namely **File** and **Help**.

3.3 OPTIONS

File | Options

This menu options help the user to indicate whether or not other programs that can be linked to *RISKMAN* are available for use by the *RISKMAN* program. Figure 3.2 opens when the Option sub-menu under the File menu is clicked.

FIGURE 3.2 THE OPTION WINDOW.

3.3.1 Use FARMS

Linking *FARMS* with *RISKMAN* has the advantage that only data input for the risk variables need to be provided in *RISKMAN* and that *FARMS* are not burdened with the additional data of risk analyses. Furthermore the risk analyses can be executed without providing all the data at enterprise level as input, because this data is imported from *FARMS*. In the model risky variables are treated as distributions and the output of the model can therefor also be presented as distributions. The simulation of risk and definition of variables as different distributions were made possible by using *RISKMAN*. The enterprise names and main products of each enterprise together with the cost and constant values can be imported from *FARMS*.

3.3.2 Use IRRICOST

IRRICOST contains a list of various irrigation systems. If the farmers' irrigation information or a similar system design is already entered in *IRRICOST*, it can be utilised by *RISKMAN* if the checkbox is checked next to "Use *IRRICOST*". The System ID, system type and the variable costs will then be imported into *RISKMAN*.

3.3.3 Use WAS

The Water Administration System (*WAS*) program can store historic irrigation quantities and yield productions. If the "Use *WAS*" checkbox is checked, the *WAS* icon will appear on the Crop enterprise form. By clicking on this icon,
a list of the irrigation quantities and yield production values can be obtained and imported as single values, if the field ID and the crop enterprise are the same for both the *WAS* and *RISKMAN* programs. The average calculated from the single values will also be inserted as the basic or constant value of the variable.

3.3.4 Use SWB

The Soil Water Balance (*SWB*) program has several links with *RISKMAN*. But instead of historic values, the SWB program can simulate data if used in scenario mode. If the "Use *SWB*" checkbox is checked, the *SWB* icon will appear on the Crop enterprise form. By clicking on this icon, all the data whose field ID and crop enterprises values are corresponding in both *RISKMAN* and *SWB* will be imported as single values, as well as the calculated average as the basic or constant value of the variable will be inserted in the table.

3.3.5 Use SWB addresses

The user has the choice whether or not to use the address list of *SWB*, by simply checking this checkbox. The address data of the *SWB* program can be utilised by the *RISKMAN* program, or the user of *RISKMAN* can enter his own address information.

3.4 ADDRESS & TEL NO'S

File | Address & Tel no's

The Address form can either contain the farmers address information of the *RISKMAN* or the *SWB* program. This feature is there to minimise the input of *RISKMAN*. *RISKMAN* can utilise the address information already entered through *SWB*, simply by checking the checkbox next to "Use *SWB* Addresses" on the *File | Options* form.

The columns of the Address grid include the following information (by scrolling from left to right):

- Surname of the user
- Name of the user
- ID number of the user
- Line 1 of postal address as entered in the Address form
- Line 2 of postal address as entered in the Address form
- Line 3 of postal address as entered in the Address form
- City of the user
- Postal Code of the user
- Home telephone number of the user (Tel no (H))
- Work telephone number of the user (Tel no (W))
- Cell phone number (Cell no)
- Fax number of the user (Fax no)
- E-mail address of the user (E-mail)

Any information about the users is optional, it does not necessarily need to be entered in the database.

3.5 PRINT SETUP

Printer

File | Print setup

Configure the print setup for the reports. Remember that you can get help on this screen by pressing <F1> or clicking the Help button while you are on the screen.

3.6 PRINT BLANK FORM

File | Print blank form

In order to gather new information from a farmer, a blank form can be printed here.

3.7 EXIT RISKMAN

Exit

File | Exit

Exit from the *RISKMAN* program.

4. DATA MENU

In this chapter all of the data input, required for cost calculations in *RISKMAN*, will be attended to. Data that is required for calculating the costs are divided into four groups, namely General farm information, Fixed obligations, Crop enterprise and Livestock enterprise. The subjective probabilities and the correlation between the random variables are also discussed in this chapter.

4.1 GENERAL FARM INFORMATION

General

Data | General farm information

The main aim with this option is to insert and edit some general farm information in *RISKMAN*. General farm information refers to the fixed cost, land (owed and rented) as well as the irrigation system of a specific farmer.

4.1.1 Fixed cost

Data | General farm information | Fixed cost

Fixed costs are the costs that are regarded as fixed irrespective of the scale or intensity of production. Farm expenses not affected by the choice of the enterprise should be included here as overhead expenses and not at enterprise level. Fixed costs are important and should be included in each analysis to reflect the actual performance of the farming operation. Figure 4.1 opens when the Fixed cost sub-menu under the Data menu is clicked.
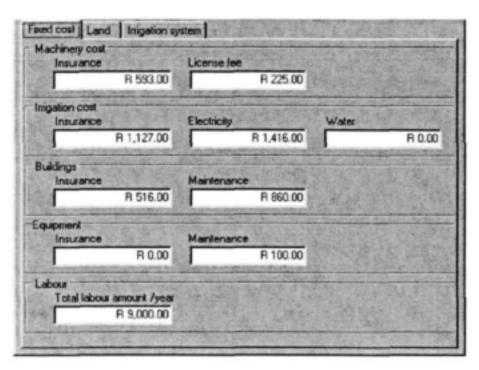
FIGURE 4.1 SCREEN OF THE FIXED COST.

Machinery

The total amount of *insurance* and *license fees* to be paid during the year of the analysis for the machinery system of the farmer.

Irrigation

The total amount of *insurance cost* on all the irrigation systems of the specific farmer, as well as the annual fixed *electricity's* and *water cost* for the service provided (monthly rental x 12).

Buildings

An estimated *insurance* and *maintenance* cost of buildings that are directly used by the crop or livestock enterprises on the farm.

Equipment

Specify the annual estimated *insurance* and *maintenance* cost of equipment that are directly associated to the enterprises on the farm.

Labour

The total amount of labour cost per year is entered here.

4.1.2 Land

Data | General farm information | Land

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A list of all the fields, owned and rented, that are available for crop and livestock production. The following information is needed:

Field ID

Used to identify the field that is being described. A Field ID must be unique, if not an error message will appear on the screen. If the *RISKMAN* program is used in conjunction with the *SWB* program (see section 3.3), a list of all the fields in the scheme will be available. The user can double click in the Field ID cell to insert or edit a Field ID, a list of all the Field ID's in the scheme will appear. Choose one by double clicking on it.

Description

Short description of the field to help recognize it.

Land type

Indicates the type of land. Double click in this field, and again on the down arrow, a dropdown list will appear that consists out of the following: Dry land, Irrigated, Grazing, Pastures and odd pieces. Choose one by clicking on the relevant type.

Field size (ha)

The area of each field that is used must be entered here. These values are used to calculate and verify feasible crop rotation systems as well as carrying capacity for livestock enterprises.

4.1.3 Irrigation system

Data | General farm information | Irrigation system

If the *IRRICOST* module (see section 3.3) of the *FARMS* system is installed on your computer, you can select an irrigation system from the list by double clicking in the System ID cell. All the relevant information of the chosen irrigation system will then be inserted into your table and the chosen system can be edited. The user can also insert or edit a system simply by clicking on the insert or edit button. If you don't irrigate you don't have to enter values under this option.

After you have entered the required data, press the post button in the navigator bar (see section 2.5).

System ID

Used to uniquely identify the irrigation system or corresponds to the specific system in the *IRRICOST* program (see section 3.3).

System type

Describe the type of irrigation system. Clicking on the down arrow provides a dropdown list and by clicking on a type of system it will be placed in the field. The dropdown list consists out of the following: Hand line, Flood, Micro, Drip, and Centre pivot.

Area (ha)

Design area of the specific irrigation system.

Variable water cost (c/mm.ha)

Variable water cost is the cost of water, calculated in cent/mm.ha or cent/10m^3.

Variable electricity cost (c/mm.ha)

Variable electricity cost is the cost of electricity (cent) calculated to irrigate one mm.ha or 10m^3 water.

Other variable cost (c/mm.ha)

Variable cost not already entered for the system, which are not fixed cost, e.g. reparations.

4.2   FIXED OBLIGATIONS

Loans

Data | Fixed obligation

Management decisions regarding new investments can only be evaluated by means of financial feasibility studies at whole farm level. This implies that the additional risk due to the cost of interest on medium- and long-term loans needs to be estimated.

First the date field must be updated to the current date for further references. Double click on the date field for editing purposes.

4.2.1   *Indicator rate*

Data | Fixed obligation | Indicator rate

The risk involved due to the cost of credit is handled in this section. The influence of fluctuations in interest rates, as well as the variation in the amounts on which interest is payable is calculated. Any reference rate, like the Prime rate can be used as the indicator rate.

Most probable annual rate

The indicator rate with the highest probability of occurrence must be entered here.

Possible annual indicator rate levels

Specify the different levels for the indicator rate that can occur during the coming year for intermediate (medium-) and long-term loans.

FIGURE 4.2 SCREEN OF THE INDICATOR RATE

4.2.2 Intermediate and Long-term

Data | Fixed obligation | Intermediate or Long-term

Details regarding intermediate and long-term fixed obligations are specified here. Since there is a connection between the movement of interest rates, all the rates are treated as possible deviations from a fluctuating so-called indicator rate.

Description

Description of the liability; usually refers to an institution.

Balance

The total outstanding loan amount.

Indicator rate +/- ?

The user has to specify a deviation (+ or -) from the indicator rate.

Interest rate

The rate at what interest on the loan is calculated.

Interest

The interest amount calculated by the *RISKMAN* program.

Fixed

Indicates whether or not the interest rate is fixed for the specific loan, in such a case interest rate fluctuations are not taken into account.

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4.3 CROP ENTERPRISE

Crop

Data | Crop enterprise

Six pages of input are required for each crop enterprise. The first page contains the enterprise information and the second page the products that are produced by the enterprise. The subjective probabilities of irrigation quantities, product's yield and prices must be entered on the next three pages that is followed by the percentage of hail damages.

The *WAS* and *SWB* buttons will be visible if the *WAS* or/and *SWB* programs are available and their check buttons are marked on the options form. Historical values can be obtained from the *WAS* model and simulated values from the *SWB* model, if the Field ID and the Crop enterprise are the same as in the Crop enterprise table. By simply clicking on the *WAS* or *SWB* button the single value and the average value will be inserted.

4.3.1 Enterprise info

Data | Crop enterprise | Enterprise info

A crop enterprise may have more than one product associated with it. Different cultivations give rise to different enterprises in *RISKMAN* due to input requirements. The same applies for the same crop enterprise on different types of land with differences in crop potential.

Field ID

Identify the field. To enter a new Field ID or to edit an existing one, double click in the cell, a window will appear with a list of all the available Field ID's of the farmer. Double click on the Field ID you choose, the window will then disappear and the chosen Field ID will then be placed into the cell. This field ID corresponds to Field ID's in *Data | General farm information | Land.*

Crop enterprise

Name of the crop enterprise. A list of crop enterprises is available in the model. To enter a new crop enterprise or to edit an existing enterprise, double click in the cell, a window will appear with a list of the crop enterprises. Double click on the enterprise you choose, the window will then disappear and the chosen enterprise will then be inserted in the cell. The user can also enter a new enterprise or edit the existing one in the field, simply by typing.

Irrigation system ID

Identification of the irrigation system concerned. To enter a new irrigation system or to edit an existing one, double click in the cell to choose an irrigation system from the list of systems

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obtained from the irrigation system inputs in the *Data | General farm information option | Irrigation system*. Double click again on the system you choose for the window to disappear and the system to be placed in the cell.

Basic irrigation

The basic irrigation requirement for the coming season also referred to as the constant. This value is treated as a constant amount in calculations.

Yield independent cost (pre-harvest costs)

Input costs that do not fluctuate according to variation in yield (seed, fertiliser, fuel, chemicals, repairs, etc), but are specified on a per hectare basis. These costs can also be obtained from the crop enterprise budgets of the *FARMS* programs output, or from the provincial enterprise budgets (COMBUD, 1999).

Yield variable cost (post-harvest cost)

Costs where the application quantities are dependent on the yield level and are thus entered as a cost per yield unit. These costs can also be obtained from the crop enterprise budgets of the *FARMS* programs, or from the provincial enterprise budgets (COMBUD, 1999).

Other cost

Costs that are used by the enterprise specifically and not taken into account anywhere else.

4.3.2 Products

Data | Crop enterprise | Products

All the different product details of each enterprise must be entered in this section.

Product name

A product's name must be entered to identify each product of the enterprise.

Main-product

Products are divided into two groups, namely Main-products and By-products. Only one product with the major contribution to income can be labeled as the main product of an enterprise, all the additional products of the specific enterprise under discussion are by-products. Indicating true in case of a main product and false otherwise.

Unit

Indicate the unit of the product, for example ton, bushels, etc.

Basic yield

Basic yield per hectare also referred to as the constant yield value to be used in economic analyses.

Basic price

The basic price per unit also referred to as the constant price value, also to be used in cases where price risk is not taken into account.

4.3.3 *Irrigation*

Data | Crop enterprise | Irrigation

RISKMAN caters for four types of subjective probabilities to quantify the risk. Enter at least one of the subjective probabilities associated with irrigation quantities. See section 4.5 for a discussion on methods for quantifying risk and how to import data from the *WAS* and *SWB* models.

4.3.4 *Yield*

Data | Crop enterprise | Yield

The input requirements for crop yield are the same as in the case of irrigation. Risk or variability can be defined by using one of the four subjective probabilities (see section 4.5). The unit of crop yield, for example ton/ha is shown on the input window. As in the case of irrigation, a series of crop yields can be imported from the *WAS* or *SWB* models.

4.3.5 *Price*

Data | Crop enterprise | Price

Price risk also accommodated the using of the four procedures to define the user's beliefs regarding the outcome of product prices.

4.3.6 *Hail damage*

Data | Crop enterprise | Hail damage

Since insurance against hail is considered an important risk-management tool the *RISKMAN* program includes an option to adjust yield distributions from hail damage. Hail is considered as a risky variable and therefore hail damage can be simulated as a distribution. A hail damage distribution can thus be considered as a loss function, which is an indication of the probability that a certain percentage damage on a specific enterprise can occur. Data about hail damage are not generally available and known, especially for a region as a whole. Historic insurance data, including hail damage, thus is an important data source, since hail damage differ from

locality to locality. Therefore, regarding risk management, it is important to estimate the economical and financial result of hail damage.

Input requirements include the minimum and maximum potential loss, as well as a distribution of yield loss due to hail with its associated probability of occurrence.

4.4 LIVESTOCK ENTERPRISE

Stock

Data | Livestock enterprise

Four pages of input are required for each livestock enterprise. On the first and second page the enterprise information and the products are handled and on the third and fourth pages the four different types of subjective probabilities can be entered for the production and price variables. With the exception of irrigation and hail damages this section do not differ from the previous section.

4.4.1 Enterprise info

Data | Livestock enterprise | Enterprise info

A livestock enterprise may have more than one product associated with it.

Livestock enterprise
Name of the livestock enterprise. To enter a new enterprise or to edit an existing enterprise, double click in the cell, a window will appear with a list of livestock enterprises. Double click on the enterprise you choose, the window will then disappear and the chosen enterprise will then be placed in the cell.

Production independent cost
Production inputs that is not production dependent and thus does not vary according to the scale of production. These costs can also be obtained from the crop enterprise budgets of the *FARMS* programs output, or from the provincial enterprise budgets (COMBUD, 1999).

Production variable cost
The application quantities of production inputs are dependent on the production level. These costs can also be obtained from the crop enterprise budgets of the *FARMS* programs output, or from the provincial enterprise budgets (COMBUD, 1999).

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Other cost

Costs that are used by the enterprise specifically and not taken into account anywhere else.

In some cases a livestock enterprise uses a part of a crop enterprise, like silage. The cost of such a crop enterprise can be entered as a cost in the livestock enterprise budget.

4.4.2 Products

Data | Livestock enterprise | Products

Product details for each enterprise must be entered.

Product name

The product's name must be entered to identify products that are produced by each enterprise.

Main-product

Products are divided into two groups, namely Main-products and By-products. There can be only be one main product in an enterprise, all the additional products of the specific enterprise under discussion are by-products. Choose the true option in the case of a main product and false otherwise.

Unit

Unit of the product, for example unit, kg, ton, etc.

Basic price

The basic price per unit is a single (constant) value.

Basic production

The basic production is a constant value, for example the average production that is expected for the next year.

4.4.3 Production

Data | Livestock enterprise | Production

The same discussion as in the case of crop enterprises is applicable, see section 4.5 for a more detailed discussion.

4.4.4 Price

Data | Livestock enterprise | Price

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Also in the case of product price, the *RISKMAN* user can apply the same principles as with crop enterprises (see section 4.5).

4.5   METHODS FOR QUANTIFYING RISK

Irrigation quantity, yield/production and price data can be introduced as input in 5 different ways depending on the method that suit the user the best.

- The first and most familiar option is to specify a constant value.

- A second option is to provide single values, for instance, as series of historic or simulated yields with the assumption that each value has an equal chance of being realised during the planned period.

- As a third input method the variable can be directly elicited as a cumulative probability distribution.

- The last two methods in which irrigation, price and yield/production risk can be defined are by providing the input as either a triangular or a normal distribution.

RISKMAN users with access to the *WAS* and *SWB* programs have the advantage to import irrigation and yield data from these two programs.

If the user has historical data available from the Water Administration System (*WAS*) program for the irrigation requirements and the yields, the user can click on the *WAS* button, and the data will be inserted as single values and the calculated average thereof as a constant.

The Soil Water Balance (*SWB*) program can simulate an array of values for irrigation requirements and yields. These values can be inserted into the *RISKMAN* program by clicking on the *SWB* button.

4.5.1   Single values

If at least 10 possible values are available or can be estimated, this option in *RISKMAN* can be utilised. The assumption is made that any one of these values has an equal chance to be realised, thus all the calculations is based on those specific values.

Minimum as well as a maximum value has to be specified to anchor the range of values that is generated from the set of single values. By clicking on the calculator icon, a minimum and maximum value are calculated for given set of single values.

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4.5.2 Cumulative distribution

The *RISKMAN* user has the task to provide values corresponding to nine levels of probability on a cumulative distribution. By matching for example 540 mm with 60 % probability, this input is interpreted as having a 60 percent chance of irrigating 540 mm or less for that enterprise. Both minimum and maximum irrigation quantities have to be specified.

4.5.3 Triangular distribution

In instances with little information the triangular distribution can be utilised as a method to include risk in economic analyses. In the case of irrigation quantity the user has to provide a low, most likely and high amounts to reflect the possible outcome of irrigation scheduling for the planned season. In the simulation of fluctuated irrigation amounts, values are generated from a triangular distribution with these three points as basis.

4.5.4 Normal distribution

By specifying an expected average value for irrigation as well as a standard deviation, a normal distribution can be used to simulate risk. A minimum and maximum amount must also be specified.

4.5 CORRELATION

Corr

Data | Correlation

The second type of risk input required by the model is the relationship between risk variables. The correlation between different crops and different risks can be provided. The correlation can also be obtained from tables provided by the government or other people.

Correlation can be positive or negative and vary between −1.0 and 1.0. Correlation coefficients from small samples should be used with great caution, however, since a very large sample is required to accurately estimate a correlation coefficient. A correlation coefficient must be entered for each sample of variables.

Just enter the correlation coefficients in the upper half of the matrix. Values in the lower left portion of the matrix are automatically set equal to the corresponding values in the upper right portion.

A random variable always has a correlation coefficient of 0 with a constant, because a constant does not vary and since a random variable is perfectly correlated with itself, the values on the diagonal is equal to one.

5. RUN MENU

The main purpose of this component is to calculate the net operating receipts (NOR) and net farm income (NFI) for three management strategies after all the data input has been entered and edited under the Data option on the main menu.

At the top of the Run window next to "Farmers ID:" the Farmers identification number will be shown. This unique number corresponds to the active farmer in the database.

The farmer's attitude towards risk, the method to quantify risk and risk-management strategies are formulated here. The farmer must also identify the variables to be included in the risk analyses and the various methods to quantify risk.

Run

5.1 GENERAL

Run | General

In figure 5.1 the first page of the window which open under the Run option is shown.
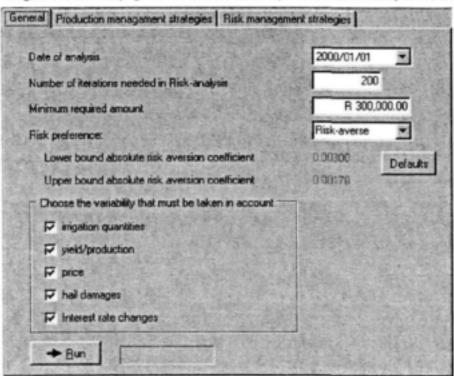
FIGURE 5.1 THE RUN WINDOW

5.1.1 Date of analysis

The date field is included to indicate to the user the analysis date of the last series of calculations.

To change the date, click on the arrow next to the date. A calendar will then appear. Use the arrows on both sides of the date to scroll the months or click on the month name in the middle for the list of all twelve months names. After the year has been highlighted, the analysis year can be scrolled by clicking on the up or down arrow next to the year. To change the day, just simply left click on the day you want with the mouse, after which the calendar will disappear and the new date will be placed in the date space.

5.1.2 Number of iterations needed in Risk-analysis

The number of iterations that have to be performed during each simulation must be indicated here. With each iteration a new set of values are being inserted into the model and all the formulas are calculated with this new values. The higher the number of iterations, the higher the chance will be that all the possible combinations of the variables are used as input, that assures that the model's output are a better reflection of the real situation.

RISKMAN allows 3000 iteration. The smaller the number of iterations the quicker the calculations will be done. The more calculations the smoother the graphs of the cumulative distributions will be.

5.1.3 Minimum required amount

This value will be shown on the recommendation graph as a vertical line and is an indication of the annual amount of money that is needed by the operator for non-farming purposes *e.g.* living expenses.

5.1.4 Risk preference

The three different production systems that the user has to enter on the Run form result in three different cumulative distribution functions. Which one does the specific decision-maker choose?

Decision-makers have three alternative attitudes towards risk, namely risk-seeking, risk-neutral and risk-averse. The type of risk attitude is not a reflection of the individual's management ability, but implies that preferences of individuals differ. Therefore, it is an oversimplification to make an assumption that one alternative should suit all decision-makers best.

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Risk seekers or takers are more adventuresome with a preference for more risky business alternatives. In comparing decisions with similar expected values, risk seekers select the alternative with some probability of a higher income, even though they must accept a higher probability to receive less income.

Risk neutral decision-makers is the class between risk averters and risk seekers. The risk-neutral individual chooses the decision with the highest expected return, regardless of the probabilities associated with alternative levels of gain and loss.

Risk averters or avoiders are characterised as more cautious individuals with preferences for less risky sources of income and investment. In general, they will sacrifice some amount of expected income to reduce the probability of low income and losses.

The user must choose the risk preference of the farmer from the dropdown list. The lower and upper absolute risk aversion coefficients will then be shown in grey. Once this information is available, it will be possible to determine which of the production management strategies can be regarded as risk efficient.

The user does not need to change the default risk aversion coefficients, but in the case of research it will be possible to change them. To alter the lower or upper absolute risk aversion coefficients, click on the default button.

The inclusion of risk preferences does not replace the decision-maker, but must be regarded as a mere tool or aid to reduce the number of possible strategies in cases of several alternatives.

5.1.5 Default button

Click on the default button to open the upper and lower bound default window of the risk preference. In this window, the program user can edit the upper and lower default bounds of risk aversion.

5.1.6 Choose the variability that must be taken into account

From a risk-management point of view, computer models that treat irrigation quantities, yields/productions and prices as constant values have a limited application potential. The gap between theory and practice are bridged by the development of *RISKMAN* which provide relevant risk-management information. It comprises the development of procedures to define irrigation quantities, yield/production and price risk, and to define risk in terms of trends concerning the most important variables at enterprise level, as well as the ability to take sources of risk such as hail and fluctuating interest rates into account. In addition to the above, alternative risk-management strategies at enterprise level are evaluated.

The user must choose which of the following variables he wants to take into account, simply by clicking their checkboxes, namely:

- *Irrigation quantities*
- *Yield / production*
- *Price*
- *Hail damage*
- *Interest rate changes*

By not marking the checkbox, the specific variable is handled as a constant value in all calculations.

5.1.7 Run button

After the user has finished updating all three pages, General, Production management strategies and Risk management strategies, click the Run button,
In order to start the calculations.

While *RISKMAN* is doing the calculations two questions will be asked to the user, namely:

- Calculate correlation-matrix from existing information? Click YES to let the program calculate the correlation coefficients among the different variables, in the case of historic values or simulated values. Click NO if you want to enter the correlation coefficients yourself from other sources or if you do not want the correlation's to be calculated.
- Show correlation matrix? Click YES if you want to see the matrix, or if you want to alter it or insert own data, or NO if you do not what the correlation-matrix to be shown.

When the calculations are done a message box will appear indicating that the calculations are completed.

See section 4.5 for a discussion on the correlation-matrix.

5.2 PRODUCTION MANAGEMENT STRATEGIES

Run | Production management strategies

The evaluation of the alternative risk-management strategies at farm level renders it possible to make an assessment of the influence of risk on the results of each strategy.

RISKMAN offers the facility to design and evaluate production management strategies. There are three tools for managing risk that can be evaluated:

a)   Diversification by means of crop rotation and utilising of livestock enterprises.

b)   Using of crop insurance against hail damage by transferring some of the yield risk to an insurer outside the operation.

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c)   Forward contracting if a farmer wants to evaluate available pre-plant contracts.

The Production management strategy page is used for inserting and editing the planned crop rotation or to include livestock enterprises in the farm plan.

5.2.1 *Crop enterprise*

The crop enterprises which are displayed are those that have already been entered through the Data menu. To insert a new crop enterprise or to edit an existing one, click on the insert or edit button.   The Crop enterprise form will then open and the user can insert or edit a crop enterprise. After completing the crop enterprise form the control will be given back to the run form with the new or altered data.

Provision is made to evaluate three different crop rotation systems at once.   Just fill in the areas allocated to each crop enterprise, make a choice if the crops are irrigated and whether or not yield must be adjusted for hail damage.   The planned areas to be planted in the three production systems are tested against the area available. If the available land is exceeded, an error message is given in a message box. The area of one of the crops then has to be decreased.

Field ID
Identify the field. This field cannot be edited.

Crop enterprise
Name of the crop enterprise. This field cannot be edited.

Season
The season in which the crop will utilise the field. To enter a season the user must click on the field and then on the arrow, a dropdown list will appear with three choices to pick from, namely both, summer or winter.

Crop rotation 1, 2 and 3 (ha)
The planned areas (ha) of all the crop enterprises of the first, second and third crop rotation system to be evaluated. The total utilised land of each crop rotation system may not exceed the total area available per season. If it does, an error message will be shown.

Irrigate
Indicate whether or not the crop is cultivated under irrigation. Click on the down arrow and choose either True or False from the dropdown list.

Hail damage
An additional risk input in *RISKMAN* concerns the question whether the yield of crops must be adjusted to accommodate hail damage or not. If that is the case the cumulative probability

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distributions of potential hail damage and the correlation of hail damage among different crops must be provided.

5.2.2 Livestock enterprise

Only livestock enterprises that have already been entered through Data are displayed. New livestock enterprises can be inserted and existing enterprises can be edited by clicking on the insert or edit buttons. The livestock enterprise form will appear so that the user can insert or edit all the information. After all the data is entered the user can close the livestock enterprise and go back to the Run form.

Livestock enterprise

Name of the livestock enterprise.

Include 1, 2 and 3

Indicate whether or not the livestock enterprise must be included in the production system, thus in the economic analyses.

5.3 RISK MANAGEMENT STRATEGIES

Run | Risk management strategies

The type of data input (method to quantify variability) for irrigation quantities, yield/production and price levels for each main product has to be indicated. The availability of the five ways to define the risk associated with each enterprise depends on the earlier data input. Whether it is constant, single, cumulative, triangular or normal distribution. For each enterprise only the type of inputs that have been entered in the crop and livestock enterprise forms will be available in the dropdown list. Choose one by clicking on it, and it will be placed into the field.

5.3.1 Crop enterprise

A list of all the available crop enterprises of the farmer is displayed.

Field ID

Identification of the field ID.

Crop enterprise

Name of the crop enterprise.

Type of irrigation input

Choose the type of irrigation input, from the types which *WAS* already inserted in earlier data input, from the dropdown list.

Type of yield input

Choose the type of yield input, from the dropdown list of available subjective input types.

Type of price input

Choose the type of price input, from the dropdown list of available subjective inputs.

5.3.2 Livestock enterprise

A list of all the available livestock enterprises of the farmer is displayed.

Livestock enterprise

Name of the livestock enterprise.

Type of production input

Choose the type of production input, from the dropdown list of available subjective inputs.

Type of price input

Choose the type of price input from the dropdown list of available subjective inputs.

6. OUTPUT MENU

The extent and nature of the program output illustrate the power of this model. The tables contain different sets of information that can be used to support management decisions at enterprise level. This outputs acts as a support to the economic aspects of enterprise management as well as whole farm planning. Since risk analyses results are best presented by means of distribution of various performance criteria, these distributions are also represented graphically.

In analyses with *RISKMAN*, risk can be determined in terms of the fluctuations as presented by cumulative distribution functions, as well as on the basis of the probability to realise a negative cash flow. Annual or seasonal production plans can in advance be evaluated.

The flexibility of the model assures an interactive approach where the decision-maker can re-evaluate plans after some adjustments have been made.

All reports are displayed on screen and can be printed by clicking on the Print button at the top of the screen.

6.1 RESULTS

Results

Output | Results

With the Result option irrigation quantities, yield/production, price and hail damage results of each enterprise are presented as cumulative distribution functions. Each distribution is also displayed graphically and the descriptive statistics calculated for each. On the basis of this data each decision-maker can make adjustments to the variables once he has studied the implications of his data input.

6.1.1 Cumulative distribution function (CDF) table

Output | Results | CDF table

A cumulative distribution function (CDF) is a mathematical relationship that indicates the probability that the outcome of a random variable will be less than or equal to any particular level or value.

In order to evaluate the different cumulative distributions associated with the risk variables for each enterprise, choose the variable whose cumulative distributions you want to see from the dropdown list at the top of the form.

In *RISKMAN*, all cumulative distribution functions (CDF's) are stored in table format. The first column contains the associated cumulative probability levels, and the next columns contains the corresponding irrigation quantity, yield/production, price, or hail damage values arranged in ascending order. CDF values for random variable levels that are not included in the table are determined by linear interpolation.

When you choose the normal data input option to describe the variability of irrigation quantity, yield/production or price distribution, its CDF is constructed from a standard normal CDF stored in the program. Under the subjective (cumulative probability) data input option, the user directly specifies eleven pairs of random variables and cumulative probability levels that form the initial CDF table. Similarly, under the triangular data entry option, one pair of CDF values is determined for each set of values.

The connection between the data you enter and the CDF table is somewhat less direct under the single value data input option. The first step in constructing a CDF from a set of single values is to construct an "empirical" CDF. This is done by sorting the single value levels and assigning a cumulative probability of i/n to each value of the risk variable, where i am its rank order and n is the number of single values. These assumptions give the empirical CDF a "step-wise" appearance and the cumulative probability increases by $1/n$ at each value level.

Statistically this CDF has the desirable property of being the minimum variance, unbiased estimator of the true CDF. In the second step of the procedure used in *RISKMAN* to construct CDF's from single value, the empirical CDF is smoothed using a centred moving average. This eliminates the over-restrictive assumptions about possible values of the random variable without, in most cases, seriously biasing the CDF representation.

6.1.2   CDF graph

Output | Results | CDF graph

The cumulative distribution functions graph page display one CDF graph at a time. The user has to pick the enterprise, as well as the type of risk variable form the dropdown lists at the top of the screen of the available enterprises and risk variables to show the graph.

6.1.3   Statistic's

Output | Results | Statistic's

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The usual statistic's of the various variables CDF's can be viewed here. For each risk variable you want to evaluate, the statistics can be picked from the dropdown list at the top of the screen. See section 6.3 for more information on the description and calculation of the statistical parameters.

6.2 RECOMMENDATIONS

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Recom

Output | Recommendations

The Recommendation option reflects the net operating receipts (NOR) and the net farm income (NFI) as cumulative probability distributions for each of the three production strategies that is compared in one run (analyses). Each distribution is also represented graphically and the descriptive statistics calculated. The user can decide whether he wants to see the net operating receipts or the net farm income simply by choosing from the dropdown list. The structure of the budgeting model is described in Appendix A.

The decision-maker can make adjustments to his production strategies on the basis of these results as presented in the distributions, and run the program again to evaluate the effect of the adjustments.

6.2.1 CDF's of production systems

Output | Recommendations | CDF's of production systems

The cumulative distribution functions of the production strategies is a mathematical relationship that indicates the probability that the outcome levels of the farm profit will be less than or equal to any particular level.

After the CDF of all the risk variables have been calculated and the correlation between the risk variables have been taken into account, the net operating receipts and net farm income are calculated for each iteration.

In *RISKMAN*, all cumulative distribution functions (CDF's) are stored in table format. The first column contains the associated cumulative probability levels, and the following columns contain the net operating receipts or net farm income levels arranged in ascending order for the three production management strategies.

6.2.2 Graphs

Output | Recommendations | Graphs

The user has the choice whether he wants to see the net operating receipts, the net farm income or both graphs, simply by clicking on the down arrow. A dropdown list will then appear for the user to choose from.

The CDF graph page on the Recommendation form will then display the CDF's graph as required for all three-production management strategies.

An additional feature of the CDF graph option is that it draws a vertical line at the minimum required amount, to help the user identify the production system most suitable for his circumstances. The production system to the right of the three will in most cases be the preferred production system.

6.2.3 Statistic's

Output | Recommendations | Statistic's

The statistic's of all three-production strategies for net operating receipts and the net farm incomes are calculated and should allow quick, efficient and quantitative evaluation of model performance. As with the CDF's, the variable you want to validate can be chosen from the dropdown list. See section 6.3 for a more detailed discussion of the statistical parameters.

6.2.4 Strategy evaluation

Output | Recommendations | Strategy evaluation

According to the farmers' risk attitude preference the model makes it possible to determine which risk-management strategies the farmer would prefer with the help of stochastic dominance with respect to a function (SDRF). SDRF is therefore applied to the distributions of net operating receipts and net farm income. In this way the farmers' preferences with regard to production plans, including crop-rotation systems and the use of crop insurance are determined.

Firstly, the information about the user's risk preferences and the lower and upper bounds used in the calculations is shown. Next, the dominance table is shown with an explanation thereof, in order to indicate to the user what production system would be the best for him, according to his risk preference.

6.3 STATISTICAL ANALYSIS

In *RISKMAN* the distributions are defined by large samples of random observations, as is the case for generated yield/production, price and irrigation levels and budgeted net cash flows, the distributions can be treated as though they were discrete rather than continuous. Density functions values are 1/n for each observation, where n is the number of observations, and the intervals can be treated as simulations. When this is done the following familiar computing formulas can be used. The formula can be seen in Appendix A.

6.4   STOCHASTIC DOMINANCE WITH RESPECT TO A FUNCTION

Stochastic dominance with respect to a function is an evaluation criterion which orders uncertain action choices for classes of decision makers defined by specified lower and upper bounds, $r_1(y)$ and $r_2(y)$, on the absolute risk aversion function. The absolute risk aversion function (Arrow, 1971; Pratt, 1964), r(y), is defined by the expression:

Where u'(y) and u''(y) are the first and second derivatives of a Von Neumann-Morgenstern utility function u(y).

$$r(y) = \frac{-u''(y)}{u'(y)}$$

A major advantage of stochastic dominance with respect to a function is that this criterion can be used to order more choices than can be done with other criteria. Furthermore, stochastic dominance with respect to a function is relatively easy to apply. A computer program which implements this solution procedure defined above has been developed by Meyer, and a modified version of that program by King (1971) is used in *RISKMAN*.

7. STATISTICS CALCULATED IN RISKMAN

Minimum

The minimum simulated value that occurs for the specific risk variable.

Maximum

The maximum simulated value that occurs for the specific risk variable.

Mean

The mean as a statistical measure of average.

$$Mx = \sum_{i=1}^{n} Xi \ / \ n$$

Standard deviation

Measure of variability around the mean. The variance is the square of the standard deviation.

$$Vx = (\sum_{i=1}^{n} Xi^{2} / n) - Mx^{2}$$

$$Sx = \sum Vx$$

Coefficient of variance

Sometimes when comparing different sets of data it can be helpful to assess their comparative relative variability rather than the absolute variability (as measured by the standard deviations).

Coefficient of skewness

$$CV = \frac{std.\ deviation}{mean} \ x\ 100$$

$$SK = \frac{3(mean - median)}{std.\ deviation}$$

Such a statistic tries to provide an impression of the general shape of the data distribution in the context of its overall symmetry.

8   STRUCTURE OF THE BUDGETING MODEL

The budgeting model in *RISKMAN* calculates before tax net flow under each set of variables for each crop and livestock enterprise and overhead costs. The crop enterprise variables consist of crop hectare levels, irrigation quantity, yield, price and hail damage; and production and price variables for livestock enterprises. Net flow can be seen as a random variable and must be calculated for all the combinations.

The net operating receipts (*NOR*) can by defined by the following expression:

$$NOR = OI - OC \tag{1}$$

where *OI* is the operating income and *OC* is the operating cost of all the enterprises on the farm.

The overall net farm income (NFI) can by defined by the following expression:

$$NFI = NOR - FC \tag{2}$$

where *NOR* is the net operating receipts *(1)* and *FC* is the fixed costs for the entire operation. *Fixed cost* includes allocated ownership cost, insurance, license fees, labour, irrigation, mechanisation and all other unallocated costs.

Operating income (*OI*) consist out of the following:

$$OI = \text{Total Gross income}$$

$$= GICrop + GIStock \tag{3}$$

where GICrops refers to the Gross income from all the crop enterprises and *GIStock* refers to the Gross income from all the livestock enterprises. Operating costs (*OC*) consist out of the following:

$$OC = CropC + StockC \tag{4}$$

where, *CropC* refers to the Operating cost from all the crop enterprises and *StockC* refers to the Operating Cost from all the livestock enterprises.

The Gross income for each crop enterprise *GICrop* are defined by the following expression:

$$GICrop_i = Area_i * Price_i * (Yield_i - Hail_i) \tag{5}$$

where, for crop enterprise i and n is the number of crop enterprises, $Area_i$ is a choice variable. Hectare for the n crop enterprises is constrained to be less than or equal to the total crop hectare for the farm. $Price_i$ is the price per unit, $Yield_i$ is the crop yield per hectare and $Hail_i$ is the hail damage.

The Gross income for each livestock enterprise GIStock are defined by the following expression:

$$GIStock_j = Price_j * Quantity_j \qquad (6)$$

where, for example j, $Price_j$ is the product price and $Quantity_j$ is the production quantity.

$CropC_i$ includes expenditures on seed, fertilizer, fuel, chemicals, hired labour, and all other costs directly allocatable to the production of a particular crop. The costs for crop enterprise i, $CropC_i$, are defined by the following expression:

$$CropC_i = Area_i * (YIC_i + (YVC_i * HarY_i)) + (IrrC * IrrAmount_i)) + Other \qquad (7)$$

where, for enterprise i, YIC_i is per hectare yield independent cost, YVC_i is the yield variable cost. $HarY_i$ is the expected yield production ($Yield_i$) minus the Hail damage ($Hail_i$). $IrrC$ is the variable irrigation cost for applying one mm of water and $IrrAmount_i$ is the variable. $OtherC$ is the other cost allocated by this enterprise, but not already included in the costs.

$StockC_j$ includes expenditures on feed, feed additives, medicine, veterinary supplies, and all other costs directly attributable to the production of a particular livestock. $StockC_j$, are defined by the following expression:

$$StockC_j = PIC_j + PVC_j + OtherC_j \qquad (8)$$

where, for enterprise j, PIC_j PVC_j and $OtherC_j$ is per unit production independent costs, production variable costs and other cost.

9. REFERENCES

ARROW, KJ. 1971. Essays in the Theory of Risk-Bearing. Chicago: Markham Publishing Company.

COMBUD, 1999. COMBUD Enterprise Budgets. Published by the Mpumalanga Department of Agriculture and Environmental Affairs. Devision of Agricultural Economics, PO Box 3, Ermelo, 2350. November 1999.

KING, RP. 1979. Operational techniques for applied decision analysis under uncertainty, D.Phil. thesis. Department of Agricultural Economics, University of Michigan, Michigan.

MEIRING, JA. 1994. Die ontwikkeling en toepassing van 'n besluitnemingsondersteuningstelsel vir die ekonomiese evaluering van risiko-bestuur op plaasvlak. Ph.D Agric. Departement Landbou-ekonomie, Universiteit van die Oranje-Vrystaat, Bloemfontein.

MEYER, J. 1977. Second Degree Stochastic Dominance with Respect to a Function. International Economic Review 18:477-87.

PRATT, JW. 1964. Risk Aversion in the Small and in the Large. Econometrica 32: 122 – 136.

APPENDIX C

WAS

User's Manual

WAS

USER'S GUIDE

Author: Dr. Nico Benadé
Date: 5 May 2001

Table of Contents

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CHAPTER 1 INTRODUCTION

1.1 PURPOSE

The Water Administration System (WAS) is designed to be a management tool for irrigation schemes and water management offices that want to manage their water accounts and supply water to clients through canal networks, pipelines and rivers.

1.2 APPLICATION AREAS

WAS is used for the efficient administration of:

- Water supplied, water requested and water used.
- Water distribution through canal networks and rivers including the calculation of lag times and different water losses.
- Water accounts.

1.3 BENEFITS

- Increased financial control
- Improved water utilisation
- Streamlining of communication
- Efficient planning and co-ordination
- User friendly and modular, i.e. easily upgraded

1.4 FEATURES

WAS consists of four modules that are integrated into a single program that can be used on a single PC or a multi-user environment. These modules can be implemented partially or as a whole, depending on the requirements of the specific scheme or office. The four modules are:

Administration module

This module is used to administer the details of all water users of an irrigation scheme. Pertinent information including owners, tenants, postal addresses, water quota allocations, hectares scheduled, household and livestock pipes installed, crops planted and crop yield are managed in this module.

Water request module

This module is used to administer water requested by farmers for an irrigation scheme. Reports that can be printed, include a water balance sheet for each farmer or user, a water usage report of users and a report of the percentage of allocated water used.
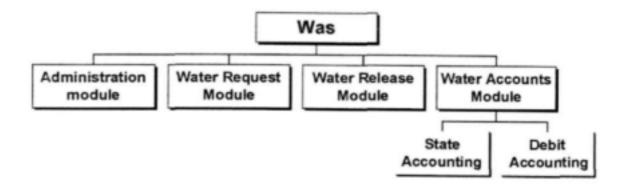
Water accounts module

This module links with the water request module and administers all water accounts for an irrigation scheme or water management office. The user can choose between two major accounting systems. The first is the current Department of Water Affairs accounting system and the second a full debit system, from which monthly reports can be printed, including accounts on pre-printed stationery, reconciliation reports, age analysis and audit trail reports.

Water release module

This module links with the water request module and calculates water releases for the main canal or river and all its branches and tributaries allowing for lag times and any water losses and accruals. A schematic layout of the total canal network or river system is captured with detail such as the cross-sectional properties, positioning of sluices or pumps, canal or river slope, structures and canal or river capacities.

Discharges are converted to the corresponding measuring plate readings where needed. Water distribution sheets and water loss analysis reports can be printed for canal or river systems.

```
                              ┌─────────────┐
                              │     Was     │
                              └──────┬──────┘
        ┌────────────────┬──────────┼──────────────┬──────────────────┐
┌───────┴────────┐ ┌─────┴──────┐ ┌──┴───────────┐ ┌┴──────────────┐
│ Administration │ │Water Request│ │Water Release │ │Water Accounts │
│     module     │ │   Module    │ │    Module    │ │    Module     │
└────────────────┘ └─────────────┘ └──────────────┘ └───────┬───────┘
                                              ┌──────────────┴──────────┐
                                        ┌─────┴──────┐          ┌───────┴────┐
                                        │   State    │          │   Debit    │
                                        │ Accounting │          │ Accounting │
                                        └────────────┘          └────────────┘
```

1.5 SPECIAL FEATURES

- WAS is user friendly with a built in context sensitive help system
- Data capturing screens are consistent and easy to use
- WAS combines water management, water distribution and an accounting system
- The database is robust and easy to maintain
- The data handling capacity is only limited to the size of the hard drive
- WAS can be used in a multi-user environment
- Extensive error checking capabilities for data capturing are standard
- Where possible data or results are represented graphically
- WAS was developed for users, by users
- Additional features are included as part of an ongoing development, installation and training programme

1.6 USER REQUIREMENTS

WAS requires at least a 486-PC running Windows 95/98/NT. At least 32Mb random access memory (RAM) must be available to run the programme, but 64 MB is recommended.

WAS is written in Delphi and uses Interbase as the underlying database. Interbase is a relational database management system (RDBMS) that provides rapid transaction processing and data sharing in a single- or multi-user environment.

1.7 WAS MENU STRUCTURE

```
                         ┌─────────────────┐
                         │      WAS        │
                         │  Menu structure │
                         └─────────────────┘
     ┌──────────┬──────────────────┬───────────────────┬──────────┐
┌─────────┐  ┌────────┐        ┌───────┐          ┌──────┐
│ Scheme  │  │ Output │        │ Input │          │ Help │
└─────────┘  └────────┘        └───────┘          └──────┘

Scheme                Output                    Input                      Help
├ Server login        ├ Water                    ├ Water                    ├ Contents
├ Server logout         ├ Balance statements       ├ Requests               ├ Search for Help On...
├ Scheme & water year   ├ Water report             ├ Transfers              ├ How to use Help
├ Empty database        ├ Water balance report     ├ Meter readings         └ About
├ Clear accounts        ├ Disposal reports         ├ Water balances
├ Import data           ├ Operator defined water reports  ├ Water quotas
├ Backup                ├ Distribution sheet       ├ Measuring stations
├ Restore               ├ % Quota used             ├ Weather stations
├ Set printer font      ├ Cut off list             ├ Opening times
├ Set date              └ Release reporting        └ Water sales
└ Exit                ├ Accounts (State)          ├ Accounts (State)
                        ├ Statements              ├ Accounts (Debit)
                        ├ Summary                   ├ Source documents
                        └ Receipts                  ├ Dates & tariffs
                      └ Accounts (Debit)            ├ Account notes
                        ├ Account queries           ├ Handing over
                        ├ Source documents          └ Water sales
                        ├ Audit trail             ├ User information
                        ├ Reports                 ├ Letters
                          ├ Age analysis          ├ Canal & river network
                          └ List of industrial levies  ├ To do list
                        ├ Month end               ├ Schemes & authorities
                          ├ Print tariffs         └ Parameters
                          ├ Print reconciliation
                          ├ Print age analysis
                          ├ Print statements
                          └ Do month end
                        ├ Reconciliation
                        ├ Tariff & dates
                        └ Invoice designer
```

Figure 1 WAS menu structure

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1.8 STARTING WAS

The name of the WAS executable file is WAS32.EXE and the database filename is WASIB.GDB. After starting WAS the following login form appears. The user needs to specify the database, user name and password. The database administrator can assist with the adding of new users to the database. WAS will start up with the previous database and user name by default.
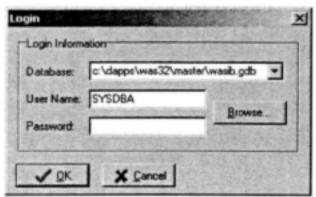
Figure 2: Login

If the server accepts the username and password, the following about form appears. The details of the developer and the institutions that funded the development of WAS appears as shown on the following about. If the login was unsuccessful, WAS will start up with most of the menu options and speed buttons disabled. The user can retry the login procedure by clicking the server login speed button at the top left of the screen or selecting **Scheme|Server login** from the main menu.
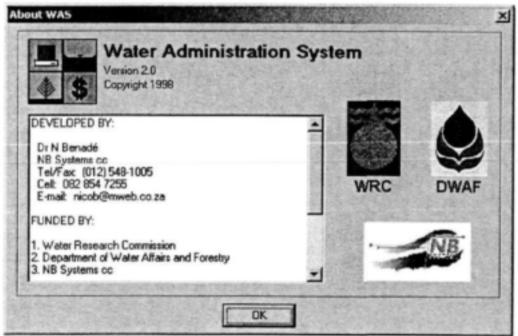
Figure 3: About WAS

The about form is followed by a popup calendar to verify the current date. It is important to specify the correct date as the financial modules and the water release module in WAS depend on it. The main form appears after the calendar and is discussed in the following paragraph.

1.9 MAIN FORM

The main form of WAS consists of a main menu, speed buttons, a picture and a message line. All the options of the different modules in WAS can be accessed through the main menu. The more frequently used options are also accessible through speed buttons at the top of the screen.

The message line at the bottom of the screen is divided into three parts. The first part displays abbreviated help messages where applicable. The second part displays the current scheme name and water year selected. The third part displays the current date.

Double clicking on the picture in the middle of the main screen will change it. The user can add more pictures by copying scanned jpg-images into the WAS folder and renaming it to the waspic1.jpg, waspic2.jpg, waspic3.jpg etc. format.

Figure 4: Main form

Speed buttons

Server Login: Log in to the server with a user name and password.

Server Logout: Log out of the server without exiting the program.

Backup: Backup the database to a specified device.

Restore: Restore the database from a previously made backup.

Select Scheme and Year: Select the default scheme and water year from a list.

User Information: Access the user information form.

Accounts: Access the accounts form.

Water Requests: Access water requests form.

Water Transfers: Access the water transfers form.

Meter Readings: Access the meter readings form.

Measuring Stations: Access the measuring stations form.

Canal Network: Access the canal or river network form.

Water Balance Statements: Access the water balance statements.

Water Balance Report: Access the water balance report.

1.10 COMMON SPEED BUTTONS AND CONTROLS

Every form in WAS makes use of speed buttons and controls to manage the application. All speed buttons in WAS have a hint that appears for a few seconds if the mouse cursor is positioned on the button. The same hint is displayed permanently on the message line at the bottom of the screen. A greyed out speed button means it is inactive.

The following paragraphs describe all the common speed buttons and controls that are used throughout WAS and the description is not repeated for every form that uses it.

A

The *find speed button* is used to find records and normally depends on the setting in the sort drop down list.

Σ

The *summation speed button* (Sigma speed button) is used for summation of data.

[print icon]

The *print speed button* is used to print various reports or graphs depending on the current form and active page.

Sort: Plot ▼

The sort drop down list is used to specify a sort order for the specific data set.

Filtered: ☐

The *filter check box* is used to filter a data set according to active record or column. In some cases it will filter according to the setting in the sort drop down list.

Week: 10 ▲▼
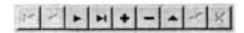
The select week box with up and down buttons is used to select the week number. The user can either type the week number manually or use the up and down buttons to increment or decrement the week number.

Close

The *close button* will close the current form or application.

1.10.1 DATABASE NAVIGATOR

A *database navigator* is used on almost every form for navigating through records and for manipulating records in WAS. The figure below displays the *database navigator* with all buttons but some of the forms only use a subset of the buttons.

[navigator buttons]

The different buttons of the database navigator are used to:

[button]

Go to the first record in the dataset. A greyed out button means the cursor is already at the first record in the dataset.

[button]

Go to the previous record in the dataset. A greyed out button means the cursor is at the first record in the dataset.

► [button]

Go to the next record in the dataset. A greyed out button means the cursor is at the last record in the dataset.

▶|

Go to the last record in the dataset. A greyed out button means the cursor is already at the last record in the dataset.

+

Insert a blank record in the dataset. An alternative is to press <Insert> on the keyboard. If the cursor is at the last record and the down arrow is pressed, the current record will be posted (saved) and a new one created. A greyed out button means the dataset is in an insert state.

−

Delete the current record in the dataset. An alternative is to press <Ctrl Delete> on the keyboard.

▲

Permit users to edit the current record. In some cases the user is prevented from editing records directly. In such cases this button must be used to put the dataset in edit state to enable editing. A greyed out button means the dataset is in an edit state.

✓

Post (save) the current record after inserting or editing. Posting of records must be done to write the data to the database on disk. The same result can be accomplished on a grid by moving off a record with the up and down arrow keys. A greyed out button means the current record is posted.

✗

Cancel: Cancels the current edit or insert state.

CHAPTER 2 WATER ADMINISTRATION MODULE

This module is used to administrate the details of all the water users or accounts on an irrigation scheme or river system. The water administration module is common to all the other modules. The following information is managed through the water administration module:

- List of irrigation schemes and water years
- Owner, tenants and postal addresses
- Water quota allocations
- Scheduling
- Household and livestock abstraction
- LRT – List of rateable taxes
- Crops planted, areas planted, water applied and crop yield information

2.1 IRRIGATION SCHEMES

WAS is capable of handling any number of irrigation schemes or water management offices in a single database. The Irrigation Schemes form is used to capture, store and manage all the information of schemes that will be part of the database. To open the Irrigation Schemes form, select **Input|Irrigation Schemes** from the main menu:
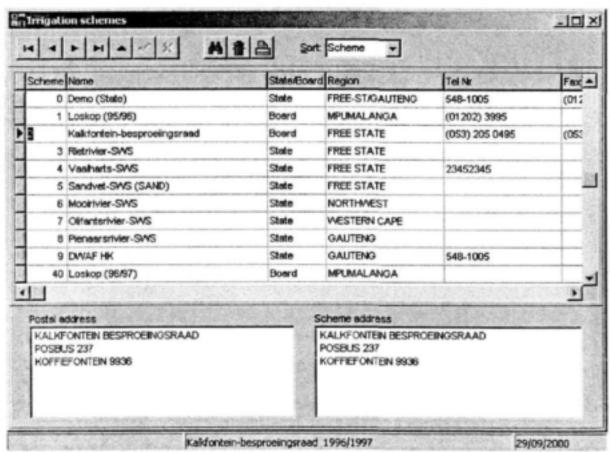
Figure 5: Irrigation Schemes

Speed buttons

Delete scheme and all associated records. A password is needed to use this option.

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The Irrigation Schemes dataset can be sorted according to:

- Name
- Scheme
- State/Board
- Region
- Application

Short descriptions of each column in the Irrigation Scheme form are as follows:

Scheme
This is a unique number for the scheme.

Name
This is the name or description of the scheme.

State/Board
Specifies whether the scheme is state owned or privately owned. This choice has no effect on the working of WAS.

Region
Specifies the region in which the scheme lies. The region is selected from a drop down list of available regions.

Tel. nr.
This is the contact telephone number of the irrigation scheme.

Fax. nr.
This is the fax number of the irrigation scheme.

VAT nr.
Should the scheme be registered for VAT, the tax number will be entered in this column.

Start month
Specifies the starting month of the water year for a specific scheme. The starting month will affect the state accounting model.

Application
Indicates the application of the water provided by a specific scheme. These are selected from a drop down list containing the following options:

- Unknown
- Irrigation
- Dom & Industrial
- Multi-Purpose
- Dom, Ind, GWS
- Water Treatment

Account
This is the accounting model used by the specific scheme. Three accounting models are provided. Details of these are given in the Accounting Module and a single selection must be made from the following:

- State
- Debit
- State/Debit

Invoice
Specifies the invoice layout template for the *debit accounting* model. The name of the template indicates the scheme that originally designed the invoice layout.

Req. Time
Specifies whether the water request time is captured on the water request form or on a canal layout form. The relevant option can be chosen from a drop down list containing the following options:

- On Canal
- On Form

Each of the selections are defined below:

On Form The water request time is captured on the water request form (**Input|Water Request Form**). In this case opening and closing times can vary from week to week.

On Canal The water request time is captured on the canal layout form. In this case, opening and closing times stay constant from week to week.

Season
A selection of a season can be made from a drop down list containing the following options:

- None
- Winter
- Summer

This is only used by schemes with different allocations for winter and summer. The water balances need to be recalculated in **Input|Water|Water Balances** when changing between seasons. The water allocations are captured in the Enrolment Page on the User Information Form **Input|User Information|Enrolment**.

2.2 SCHEME AND YEAR

The scheme and year form is used to select the current scheme and year to be worked on. In this form, a new year for a given scheme can be created or a specific year for a scheme can be deleted with all relevant data for that year.

The following information will be deleted only for the specified year:

- Water Requests
- Water Transfers
- Meter Readings
- Household and livestock abstractions
- Water balances
- Water sales
- Water accounts
- Account tariffs

To open the Select scheme and year form, select **Scheme|Scheme & water year**:

Irrigation scheme	Year
Loskop (95/96)	1997/1998
Loskop (95/96)	1998/1999
Kalkfontein-besproeiingsraad	1994/1995
Kalkfontein-besproeiingsraad	1995/1996
Kalkfontein-besproeiingsraad	1996/1997
Kalkfontein-besproeiingsraad	1997/1998
Rietrivier-SWS	1996/1997
DWAF HK	1998/1999
Demo (Debit)	1998/1999
Hartbeespoort-besproeiingsraad	1997/1998
Hartbeespoort Nuwe vore	1997/1998
Buffelspoort 1	1999/2000
Buffelspoort 2	1999/2000
Darrkom	1999/2000
HB Poort 56(3) met WNF	1999/2000
HB Poort 56(3) sonder WNF	1999/2000
Sabie rivier	1999/2000

Figure 6: Select scheme and year

Inserting a new scheme and year:
Should you insert a new scheme and year, the year will default to the following year of the selected record, but can be altered manually. Password: Superman
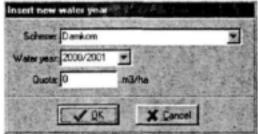
Figure 7: Insert new water year
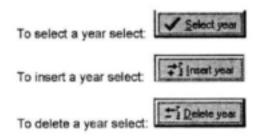
Descriptions of columns in the Irrigation Scheme form:

Irrigation Scheme
This is the name of the irrigation scheme that can be selected from a drop down list.

Year
This is the new water year that can be selected from a drop down list.

To select a year select:

To insert a year select:

To delete a year select:

A password is needed to delete a scheme or year. Password is provided by NB Systems.

2.3 PARAMETERS

The parameters form is used to create lookups for water wards, election wards and crops that can be used throughout WAS. To open the parameters form, select **Input|Parameters** from the main menu:
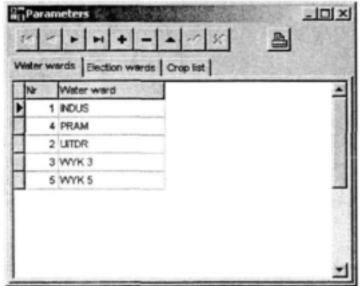
Figure 8 Parameters

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2.3.1 WATER WARDS

Nr
A specific number that is given to a water ward.

Water ward
The description of the specific water ward.

2.3.2 ELECTION WARDS

Nr
A specific number that is given to an election ward.

Election ward
Description of the specific election ward.

2.3.3 CROP LIST

Crop ID
A specific number given to a crop.

Crop name
The name or description of the crop.

2.4 USER INFORMATION
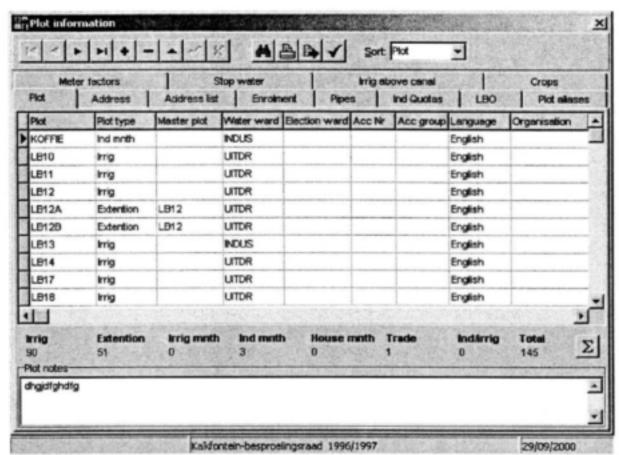
Figure 9: User information

The user information form is used to capture all the users, accounts, abstractions and other relevant information on the consumers. Every page on this form is used to capture a different set of information. A specific user must be captured before any other related information can be entered. WAS will verify that a user exists before accepting related information. Once a user is captured it can only be removed by means of a password. If a user is deleted all related information will also be deleted. To open the User information screen select **Input|User Information** from the main menu.

Speed buttons

Move user

The User Information form can be sorted according to:

- User
- Description
- User type
- Water ward
- Account no
- Account grp
- Group no
- Group order
- Licence no

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This form consists of a number of pages. A short description of each page follows:

2.4.1 USER PAGE

The user page is where all the information relating to a specific user is captured. The correct completion of this page is important as the user number is used throughout the system for identification purposes. The total number of users and different user types in the specific scheme can be calculated by pressing the summation button at the bottom of the user page.

User

This is the unique number or reference number identifying a specific user. The maximum width is 10 characters and is used for the account number. To sort in numerical order, it must be padded with zero's, 0001, 0002 etc.

User type

The user type can be selected from a drop down list. The user type affects the accounting model selected.

A choice can be made from the following user types:

- Irrig: Has enrolment (captured on the enrolment page) and is used by the state accounting model to operate two invoices per year.
- Extension: Has no enrolment and no invoice will be generated. Is used to link to a master user for automatic water transfers from the master user to the extension. Automatic transfers will only take place when water is requested on a water request form or for meter readings.
- Irrig mnth: Has enrolment (captured on the enrolment page) and is used by the debit accounting model to generate monthly invoices.
- Ind mnth: Has a quota allocation (captured on the industrial quotas page) and is used by the debit accounting model to generate monthly invoices.
- House mnth: Not used.
- Ind/Irr mnth: This is a combination of the industrial monthly and irrigation monthly type and is only used by the state accounting model.

Master user

A master user can have several extensions attached to it and is used to transfer water automatically from the master user to the extension user. If water is requested on an extension that is linked to a master user, a water transfer (**Input|Water|Water Transfer**) is automatically generated between the master and the extension user. The water balance of an extension user is normally zero and only the master user will receive an invoice. There is no limit to the number of extensions that can be attached to a master user. No water will automatically be transferred back from the extension to the master user after a water cancellation on an extension.

Water ward

Irrigation scheme or users can be divided into different water wards that can be selected from a drop down list. The available water wards in the drop down list are captured on the parameters form (**Input|Parameters**). Water wards are extensively used in the reports to group information according to a specified water ward.

Election ward

Irrigation schemes or users can be divided into different election wards that can be selected from a drop down list. The available election wards in the drop down list are captured on the parameters form (**Input|Parameters**).

Acc no

This is the account number for the specific user and it is a numerical value. The user identification string is normally used for the account number.

Acc group
A group number assigned to several accounts belonging to the same owner in order to group accounts before printing invoices.

Language
A language of preference can be selected from a drop down list. Only the invoices printed by the debit accounting model are affected.

Organisation
The organisation that is relevant to a particular user can be selected from a drop down list containing the following options:

- GWS (Government water scheme)
- Irrigation Board
- Water Board
- Municipality

Group no
The group number specifies where the specific user is situated. The Group number has an effect on the Distribution sheet (**Output|Water|Distribution sheet**) and the meter readings (**Input|Water|Measuring stations**).

Group order
The group order specifies the user sorting order within a specific group number. The Group order has an effect on the Distribution sheet (**Output|Water|Distribution sheet**) and the meter readings (**Input|Water|Measuring stations**).

Description
This column can be used for a longer description of a particular user. The user column only allows 10 characters while the description can take 30 characters.

License nr
A water registration licence number that can be linked to a specific user.

Usage
The water use type of the specific user. This type is used in the disposal report to calculate different water use totals.

2.4.2 ADDRESS PAGE

The address page is used for capturing address information for a particular user. This information is used in the accounting module selected in order for accounting or any other system generated information to be sent to the relevant user. A user must have a postal address for the month end procedure of the debit accounting model to work.

User
This is a unique number or reference number identifying a specific user.

Type
The address type that can be selected from a drop down list. The following types are available:

- Owner
- Postal
- Tenant

Name
This is the name of the user.

Surname
This is the surname of the user.

ID no
This is the identification number of the person.

Address, city & code
Address details of the user.

Tel No
Telephone number of the specific user.

Contract expiry date
This is the date when the contract between an owner and a tenant will expire. The date can be selected from a pop-up calendar.

2.4.3 ADDRESS LIST PAGE

This is a spreadsheet view of the address information. This information can be edited from both the Address Page and the Address List Page.

2.4.4 ENROLMENT PAGE

The enrolment page is used to capture the enrolment information of each irrigator. This page integrates with the Accounting and Water Request modules. The total hectares enrolled can be calculated by pressing the summation button at the bottom right of the enrolment page.

User
This is the unique number or reference number identifying a specific irrigator.

Type
A user can receive water from either a river or a canal for irrigation purposes. The relevant selection can be made from a drop down list.

Enrolment (ha)
This specifies the number of hectares enrolled with the specific scheme.

Winter (m^3)
The winter quota is used when the season parameter is set to winter on the irrigation scheme form (**Input|Irrigation schemes**).

Summer (m^3)
The summer quota is used when the season parameter is set to summer on the irrigation scheme form (**Input|Irrigation schemes**).

Year

This indicates the year when the enrolment was captured or changed. If the enrolment changes a new record must be inserted with the new year value. Currently WAS cannot handle more than one enrolment change per year. The historical record of enrolment is only important if the state accounting model is used.

2.4.5 PIPES PAGE

The pipes page is used for the capturing of the pipe details for pipes installed on canal networks for household and livestock use. It is assumed that each pipe size has a fixed delivery rate, which is used for billing purposes on both accounting modules. The total number of pipes and different pipe sizes can be calculated with the summation button at the bottom of the screen.

User

This is the unique number or reference number identifying a specific user.

No

This is a unique pipe number that ranges from 1 to 9.

Type

A selection between two types of pipes can be made from a drop down list:

- House
- Livestock

Diameter

The diameter of the pipes must be specified. WAS provides for four standard pipe sizes that can be selected from a drop down list:

- 19mm
- 25mm
- 32mm
- 38mm

2.4.6 IND QUOTAS PAGE

The industrial quotas page is used to capture water quota allocations and tariffs for industrial users that receive monthly invoices from the state and the debit accounting models. The number of columns displayed will depend on the accounting model selected on the irrigation schemes form (**Input|Irrigation schemes**).

User

This is the unique number or reference number identifying a specific user.

Free vol (m³)

This is the amount of free water allocated to a specific user for the current water year. This is used by both the state and debit accounting models.

Quota vol (m³)

This is the quota of water allocated to a specific user for the current water year. This is used by both the state and debit accounting models.

Total vol (m³)

This is the total volume of free and quota water allocated to a specific user and it is calculated by WAS. This is used by both the state and debit accounting models.

Tariff ID

The Tariff ID integrates with both accounting models. When the ellipses button in the Tariff ID column is selected, a Monthly Tariff set form opens. The form that opens depends on the accounting model selected in the irrigation schemes form (Input|Irrigation schemes).

The following figure shows the monthly tariff set form for the state accounting model. The values in the VAT % to the TCTA VAT % columns can easily be duplicated by capturing the first value and then double clicking on the specific value to automatically replicate the data to the rest of the column:

Month	From Week	To Week	Issued	Payable	VAT %	Useage (c/m3)	WRF (c/m3)	CMC (c/m3)	TCTO
1	42	45	01/01/2001	31/01/2001	14.0	1.50000	2.32000	1.00000	0.0
2	46	49	01/02/2001	03/03/2001	14.0	1.50000	2.32000	1.00000	0.0
3	50	53	01/03/2001	31/03/2001	14.0	1.50000	2.32000	1.00000	0.0
4	1	6	01/04/2000	01/05/2000	14.0	1.50000	2.32000	1.00000	0.0
5	7	10	01/05/2000	31/05/2000	14.0	1.50000	2.32000	1.00000	0.0
6	11	14	01/06/2000	01/07/2000	14.0	1.50000	2.32000	1.00000	0.0
7	15	19	01/07/2000	31/07/2000	14.0	1.50000	2.32000	1.00000	0.0
8	20	23	01/08/2000	31/08/2000	14.0	1.50000	2.32000	1.00000	0.0
9	24	27	01/09/2000	01/10/2000	14.0	1.50000	2.32000	1.00000	0.0
10	28	32	01/10/2000	31/10/2000	14.0	1.50000	2.32000	1.00000	0.0
11	33	36	01/11/2000	01/12/2000	14.0	1.50000	2.32000	1.00000	0.0
12	37	41	01/12/2000	31/12/2000	14.0	1.50000	2.32000	1.00000	0.0

Print   Save

Figure 10: Monthly tariff set for the state accounting model

The following columns appear on the Monthly tariff set form:

Month
Each month is identified by the corresponding month number.

From week
This specifies the start of the week number range that links to the water request module. The week number range is used to calculate the water usage for the given range.

To week
This specifies the end of the week number range that links to the water request module. The week number range is used to calculate the water usage for the given range.

Issued
Date when the invoice will be issued.

Payable
Final date for the account to be paid.

VAT %
Current VAT rate.

Usage (c/m³)
Water tariff for water used.

WRF (c/m³)
Water Research Fund tariff on water used.

20

CMC (c/m³)
Tariff for Catchment Management Cost on water used. This cost is only payable on free water.

TCTA (c/m³)
Trans-Caledon Tunnel Authority tariff on water used.

Interest %
Interest rate on outstanding amounts.

WRF interest %
Interest rate on outstanding amounts to the Water Research Fund.

WRF VAT %
Percentage VAT on the amount payable to the Water Research fund.

TCTA VAT %
Percentage VAT on the amount payable to the Trans-Caledon Tunnel Authority.

The following columns for monthly tariffs appear in the Industrial Quotas page only when the Debit accounting model is used. A tariff can either be on a usage basis or a quota basis, but not on both.

Tariff usage (c/m³)
Monthly tariff based on the actual water used.

Tariff quota (c/m³)
Monthly tariff based on quota allocation.

WRF usage (c/m³)
Monthly tariff used to calculate the amount payable to the Water Research Commission based on actual water used.

WRF quota (c/m³)
Tariff used to calculate the amount payable to the Water Research Commission based on quota allocation.

Maint. usage (c/m³)
Monthly tariff based on the water used for maintenance.

Maint. quota (c/m³)
Monthly tariff based on quota allocation for maintenance.

TCTA usage (c/m³)
Tariff for water usage payable to the Trans-Caledon Tunnel Authority.

CMC (c/m³)
Tariff for Catchment Management Cost on water used. This cost is only payable on free water.

2.4.7 LRT PAGE

The LRT (list of rateable taxes) page is used to capture information on rateable irrigation areas of a specific scheme. WAS keeps historical LRT information on a specific farm that is linked to a date. A description of the different columns follows.

User
This is the unique number or reference number identifying a specific user.

Date
Current information date. If information changes a new record must be inserted with the new and updated information. Previous information is kept as part of the history record for a specific user.

Description
Short description of the user.

Enrolled (ha)
Number of hectares enrolled with the scheme.

Pump (ha)
Abstraction rights of a particular user in hectares.

Area (ha)
Size of the irrigated property in hectares.

Reg. Owner
Name of the registered owner of an irrigated property or authorised user.

Tenant
Name of the tenant of an irrigated property or authorised user.

Deed Nr
Registration number of ownership that appears on the owner's title deed.

Deed Date
Date on which the ownership was registered.

Date Born
Date on which the owner was born.

Share
Ownership share of the registered owner.

Size (ha)
Size of the irrigated property measured in hectares.

Water right
Water use entitlement of the specified user.

Farm name
Name of the irrigated property.

2.4.8 USER ALIASES PAGE

This page is provided for cases where the user is given an alias or another name, which is commonly used. The system automatically links the alias to the User number. If an alias is specified on this page, water requests can be captured using the alias and not the User number.

User alias
The name a user may be referred to other than the user number. The user alias must be unique within the specific scheme.

User
This is the unique number or reference number identifying a specific user.

2.4.9 METERS FACTORS PAGE

The meter factor page is used to capture meter factors that are used to convert meter readings to cubic meters. If a meter factor is specified on this page, it can automatically be accessed on the meter readings form (**Input|Water|Meter volumes**). Two water meters can be used to measure water volume to a specific user. This is relevant when the user and the authority have separate water meters. WAS will then calculate the average volume from the two meters.

User
This is the unique number or reference number identifying a specific user.

K 1
Factor that is used to convert the first meter reading to cubic meters.

K 2
Factor that is used to convert the second meter reading to cubic meters.

2.4.10 STOP WATER PAGE

The stop water page provides the operating authority with a way to stop water to a certain user when the account has not been paid. This page links to the water request form in the water request module.

User
This is the unique number or reference number identifying a specific user.

Note
A note can be captured for the attention of the operator. This note appears when water requests are captured in so as to notify the operator that no further water requests can be made.

Stop
Two options are made available on a drop down list:

- Yes: Water requests cannot be captured.
- No: Water requests can still be captured, but the user number remains on the list.

2.4.11 IRRIG ABOVE CANAL PAGE

This page refers to all the users that have permission to irrigate above a canal in the case of a canal scheme.

User
This is the unique number or reference number identifying a specific user.

Date
Date when permission was granted to irrigate above the canal.

Size (ha)
Number of hectares that are irrigated above the canal.

2.4.12 CROPS PAGE

The crops page is used to keep a record of the different crops, areas planted, the yields and water used by the different crops. This information is available to other models for risk analysis and decision-making.

User
This is the unique number or reference number identifying a specific user.

Crop
A specific crop can be selected from a drop down list. The list of available crops can be captured in the crop lookup form (**Input|Parameters**).

Date
Date when the crop was harvested or any other date linked to the specific season.

Yield (t/ha)
Crop yield, in tons per hectare.

Area (ha)
Total area planted of the specific crop.

Volume (m³/ha)
Total volume of water required per hectare to grow the specific crop.

Total Volume (m³)
Total volume of water required to grow the specific crop.

2.5 LETTERS

In this form, letters to all the users can be typed. Each letter has a specific ID. To open the Letters form, select **Input|Letters** from the main menu:
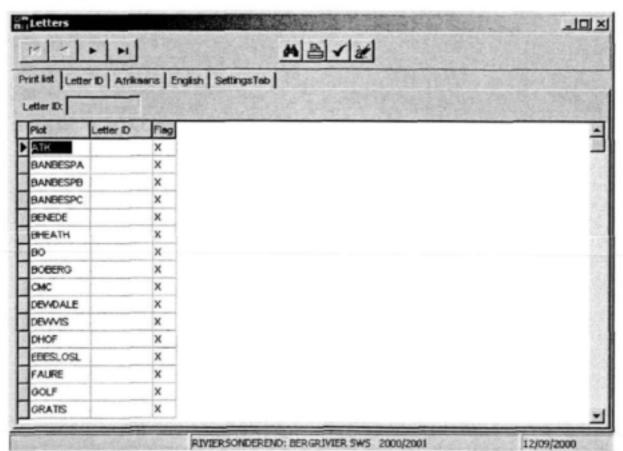
Figure 11: Letters

Speed Buttons

Initialise All

Clear All

Description of each column follows:

Print list
List of all users where a specific letter can be assigned and marked for printing.

Letter ID
Each letter has an ID to identify itself, with a description.

Afrikaans
Afrikaans version of the letter.

English
English version of the letter.

Settings Tab
In this section, the printer font, margins and contacts can be set up.

2.6 PROBLEMS

All queries and problems regarding the program or schemes, can be captured here. To open the screen, select **Input|Problems** from the main menu:

Scheme	Type	Date	Description
ERSONDEREND: BERGRIVIER SWS	WAS	28/10/1997	Aanvraag op BMei, Kwaggas, RMei, TWK, K.plaas
RIVERSONDEREND: BERGRIVIER SWS	WAS	19/03/1998	Rade saam voeg met damkomponente
RIVERSONDEREND: BERGRIVIER SWS	WAS	26/03/1998	Betekenis van Postel by adreslyste
RIVERSONDEREND: BERGRIVIER SWS	WAS	16/04/1998	Adres: Indien maatskappy wat sal die eienaar wees
ADMIN: WORCESTER KANTOOR	WAS	26/03/1998	Rekenings vir Robertson - 2 boere
BREERIVIER: GROTER BRANDVLEIDAM	WAS	28/10/1997	Bereken uitvarswater by BMei, K/Kloof, Secunda

RIVIERSONDEREND: BERGRIVIER SWS 2000/2001   12/09/2000

Figure 12: Problems information

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Controls

Show [All ▼]

The show control is used to specify the problem types to show. The available options are:

- All
- Scheme
- WAS
- Other

The Problems information form can be sorted according to:

- Date
- Completed
- Person

The form can show:

- All
- Scheme
- WAS
- Other

Description of columns in the Problems information form:

Scheme
Specific scheme or river reach where a problem is found.

Type
Type of problem, for instance on a scheme or in the program.

Date
Date that the problem occurred.

Description
Description of the problem.

Person
Person or contact who reported the problem.

Finished
Date when the problem was solved.

Ref no
Reference number given for the problem.

Completed
This is to state if the problem was solved. A selection of Yes or No can be made from a drop down list.

CHAPTER 3 WATER REQUEST MODULE

This module is used to administer all the water requested by users. Some reports that can be printed are: a water balance sheet for each user (**Input|Water|Water balances**); a water usage report of all the users (**Output|Water|Water balance report**) and the percentage water used report of the water allocated (**Output|Water|% Quota used**).

3.1 WATER BALANCES

The water balances form keeps a record of water balances for all users. The operator can recalculate a specific record by double clicking on the record or recalculate all records by clicking on the *Calc balances* speed button. A recalculation is necessary when quota allocations are made, a new water year is created or when enrolment changes. The water balances as calculated on this form are used throughout WAS to reflect the water use of all users. All the values on this form are automatically updated by WAS when water is requested or transferred.

Plot	Quota tot (m3)	Quota used (m3)	Balans (m3)	Prev used (m3)	Invoice used (m3)	Transfers
KOFFIE	182000	1025520	-843520	0	1025520	
LB10	617730	543765	73965	0	543765	
LB11	398700	401100	-2400	0	401100	
LB12	412720	358693	54027	0	358693	
LB12A	206437	0	206437	0	0	
LB12B	0	0	0	0	0	
LB13	206360	115800	90560	0	115800	
LB14	370200	366600	3600	0	366600	
LB17	330330	332440	-2110	0	332440	
LB18	176330	147600	28730	0	147600	
LB19	2091166	1279644	811522	0	1279644	
LB2	77000	133200	-56200	0	133200	
LB2/1	3600	0	3600	0	0	
LB22	1187340	1504731	-317391	0	1504731	
LB22/1	0	0	0	0	0	
LB22/3	1800	1800	0	0	1800	
LB22/4	3600	1800	1800	0	1800	

Kalkfontein-besproeiingsraad 1996/1997   27/09/2000

Figure 13: Water balances

Speed buttons

Calc balances

Update previous used

3.1.1 QUOTA / EXTRA / SURPLUS / FLEXI PAGES

User

This is the unique name or reference number identifying a specific user.

Quota tot (m³)

Total quota volume allocated to a specific user. The total is calculated depending on the user type, enrolment, season and quota allocation for a given year for the specific scheme (see **Input|Water|Water quotas**). The quota for the different user types is calculated as follows:

- Irrigation: Enrolment(ha)*Quota(m³/ha)
- Irrigation(Summer):   Summer volume
- Irrigation(Winter):   Winter volume
- Industrial: Free volume + Quota volume

Quota used (m³)

Total quota volume used for every user.

Balance (m³)

Available volume of water for every user. The balance displays the difference between *Quota tot* and *Quota used* volumes.

Prev used (m³)

The cumulative volume of water used for every user up to the previous month end. The difference between the *Quota used* and the *Prev used* volumes is used to calculate the water usage for every user since the last month end. The Prev used volume is automatically updated by WAS but the *Update previous used* speed button can be used to change this value if necessary.

Invoice used (m³)

The difference between the *Quota used* and the *Prev used* volumes.

3.2 WATER QUOTAS

The Quotas/Surplus water page is used to capture the water quota allocations for a specific scheme. This form is also used to indicate the weeks for water surplus conditions. The water quota is normally captured in the first week of a given water year. Additional quota allocations can be captured in any other week. It is important to remember to recalculate all water balances if the quota allocation changes (**Input|Water|Water balances**).

To open the Quotas/Surplus water form select **Input|Water|Water quotas**.

3.2.1 QUOTA PAGE

Week
Week number when quota allocation is made.

Quota (m³/ha)
Water quota allocation. This value is multiplied by the enrolment of every user to calculate the total volume of water every user is allowed to used for the specific water year. The recalculation can be done on the Water balances form (Input|Water|Water balances).

3.2.2 SURPLUS PAGE

Week
Week number when water surplus conditions apply.

Surplus
Defaults to "Yes" when a new record is inserted. Only the weeks where water surplus conditions apply need to be captured.

3.3 WATER REQUESTS

The water request form is used to capture all the water requests on a weekly basis. WAS handles original requests, additional request and cancellations. Once a request type is selected, the corresponding white, blue or red header colours are displayed. The user can enter three different abstraction flow rates next to A, B and C. Only the letters A, B or C can be entered in the corresponding Day and Night boxes. WAS automatically calculates the total volume and hours of water requested and updates the water balance of the specific user. To change the default 12-hourly values below the Day and Night boxes, use Ctrl-S and Ctrl-D keys on the keyboard.

When water is requested for an extension, water is automatically transferred from the master user to the extension. An extension normally has a zero balance. The only time that an extension will have a

positive water balance is after a cancellation. Water transfers are not reversed when water is cancelled but the water balance will be zeroed after the next water request by the specific user.

A list of all the water requests can be displayed by selecting the Grid page on the water request form. A set of water requests can be copied from one week to another week by pressing the duplicate button. The water request form will not accept non-existent users and users that are listed in the stop water page on the user information form.

To open the Water Request form, select **Input|Water|Request**.
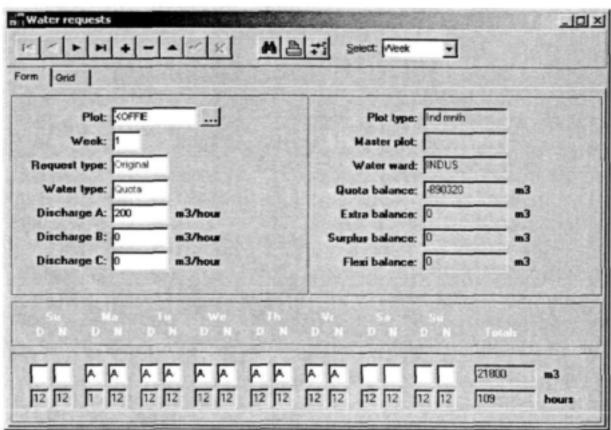
Figure 14: Water requests

Speed Buttons

This button is used to duplicate all the water requests from one week to another.

The select box is used to filter the water request for a user or week. If user is selected all the water requests for a specified user are displayed in a weekly order. If week is selected all the water requests for a specified week is displayed with the different users in alphabetical order.

Descriptions of the pages in the Water Requests form:

3.3.1 FORM PAGE

The form page is used to capture all the water requests on a weekly basis. The form page is specifically designed to make data capturing without using a mouse possible. It is the only form in WAS that uses the

Enter-key for navigation on the form. The following is a list of keys used to capture data on the water request form:

- Insert: Insert a blank record with default week, request type and water type.
- Enter: Move to next edit box.
- Tab: Move to next edit box.
- Down-arrow: Move to next edit box.
- Up-arrow: Move to previous edit box.
- Shift-tab: Move to previous edit box.
- Ctrl-S: Decrement hours.
- Ctrl-D: Increment hours.
- Spacebar: Clear day and night edit boxes.
- F2:   Post data (save).

WAS uses the previous posted water request to determine the default week, request type and water type to be used for the next insert.

User

This is the unique number or reference number identifying a specific user.

Week

This is the week number for which water is requested.

Request type

Using the spacebar you can make a selection;

- Original
- Additional
- Cancel

This can only be done when in Edit or Insert mode.

Water type

Using the spacebar you can make a selection:

- Quota
- Extra
- Surplus
- Flexi

This can only be done when in Edit or Insert mode.

Quota water is the water used under normal conditions and it is the product of the enrolment (ha) and the quota allocation (m^3/ha) or a volume (m^3) for users without any enrolment.

Extra water is water that can be purchased under certain conditions and used over and above the normal quota water. This normally happens when a dam is overflowing.

Surplus water is water that can be used over and above the normal quota water when surplus conditions apply. This normally happens when a dam is overflowing.

Flexi water is used at the end of a water year when users start using water allocated for the following water year. Flexi water is also used at the start of a new water year when unused water of the previous water year is used for a specified period in the current water year. WAS can transfer positive quota water balances as flexi water from one water year to a following water year. WAS can also clear all flexi water balances for the current water year. This can be done on the Water balances form (**Input|Water|Water balances**).

Discharge A, B & C

Three abstractions can be used to capture a water request form. Enter the values for the different abstractions. These values cannot be entered into the capturing boxes at the bottom of the screen. Only the symbols A, B and C are accepted by the system.

User type

When the user number is captured, the information is automatically retrieved from the user information.

Master user

When the user number is captured, the master user for that specific user is automatically retrieved from the user information.

Water ward

The water ward will automatically be retrieved when the user number is captured.

Quota balance

Once the user number is captured, the current Quota water balance for the specific user will be shown. A negative water balance is displayed in red.

Extra balance

Once the user number is captured, the current Extra water balance for the specific user will be shown. A negative water balance is displayed in red.

Surplus balance

Once the user number is captured, the current Surplus water balance for the specific user will be shown. A negative water balance is displayed in red.

Flexi balance

Once the user number is captured, the current Flexi water balance for the specific user will be shown. A negative water balance is displayed in red.

Su D – Su N

The 16 edit boxes from the first Sunday day through to the second Sunday night is used to capture the discharge requested for the corresponding day and night values. The water request form represents a week but some schemes will start on a Sunday and other will end on a Sunday therefore only one Sunday day and one Sunday night box can be used for capturing. WAS displays an error message if both Sunday edit boxes are used.

3.3.2 GRID PAGE

The grid form is used to display the water requests on a spreadsheet format for a specified week or user. The grid is read only and cannot be used to insert or modify any records but it is very useful to find specific records. The current record on the grid page will be the record displayed on the form page.

User

This is the unique number or reference number identifying a specific user.

Week

This specifies the week number between 1 and 53.

Request type

This specifies the water request type:

- Original
- Additional
- Cancel

Water type
This specifies the water type:

- Flexi
- Quota
- Extra
- Surplus

A (m³/h)
This displays the value of abstraction A of the water request.

B (m³/h)
This displays the value of abstraction B of the water request.

C (m³/h)
This displays the value of abstraction C of the water request.

Tot h
This displays the total hours for the specific water request.

Tot Q
This displays the total abstraction for the specific water request.

3.4 METER READINGS

The meter readings form is used to capture all the measured volumes of water. Two meters can be used, meter A and meter B. The difference between the beginning and end meter readings is used to calculate the total volume. If both meters A and B are used, the average volume is calculated. To open the meter readings form select **Input|Water|Meter Volumes** from the main menu.

The top of the form is used to display information on the current record and cannot be edited. A negative water balance is displayed in red. This information is updated as the user scrolls up and down between the records in the spreadsheet. Data can only be captured and edited in the spreadsheet. The meter readings form will not accept non-existent users and invalid week numbers will also be rejected.
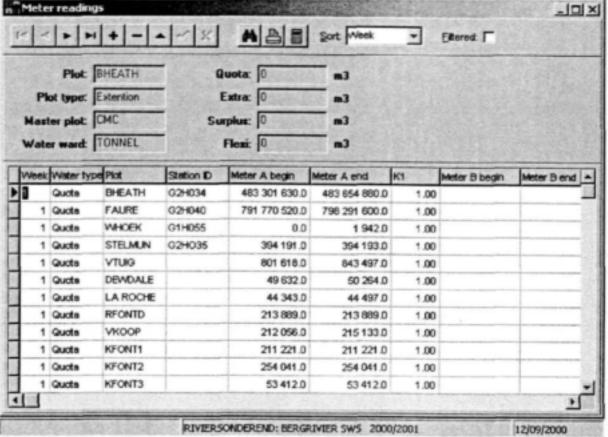
Figure 15: Meter readings

Speed Buttons

Recalculate meter volumes

Sort
The Meter readings form can be sorted by:

- User
- Week
- Order

The sort order has an effect on the filter option that is described in the following paragraph.

Filtered
The filtered box is used to filter the meter readings on the basis of a week or user number depending on the selection in the sort box.

Week
The numbers 1- 53 specifies the number of weeks for the year.

Water Type
A selection can be made from a drop down list:

- Flexi

- Quota
- Extra
- Surplus

Station ID
ID of the measuring station (See **Input|Water|Measuring stations & Discharge tables**).

User
This is the unique name or reference number identifying a specific user.

Meter A begin
Start reading of the meter for the specified week or month. This can be manually inserted and is taken from the end reading of the previous period, unless the meter was faulty.

Meter A end
End reading of the meter for the specified week or month.

K1
Factor that is multiplied by the meter reading for meter A to convert the meter reading to cubic meters automatically.

Meter B begin
Begin reading of the meter for the specified week or month. This can be manually inserted and is taken from the end reading of the previous period, unless the meter was faulty.

Meter B end
End reading of the meter for the specified week or month.

K2
Factor that is multiplied by the meter reading for meter B to convert the meter reading to cubic meters automatically.

Volume (m³)
Volume of water for the specific user measured in cubic meters.

% Diff
Percentage difference between the two sets of meter readings and is calculated by the system.

Note
In this section, additional information for the user's attention can be captured regarding meter readings.

No
The No and Order group work together and it specify the order of the records on screen, and the order in which they are printed. This is set up in the user information section (**Input|User information**). The group number refers to a person.

Order
The Nr and Order group work together and it specifies the order of the records on screen, and the order in which they are printed. This is set-up in the user information section (**Input|User information**). The group order refers to a user, meter, sluice, pump, etc.

3.5 WATER TRANSFERS

The water transfer form is used to capture water transfer volumes between users on a weekly basis. The header displays the relevant 'From User' and 'To User' information that cannot be edited. Any negative water balances are displayed in red.

Water can be transferred automatically between users where an extension user is linked to a master user. This link is created in the user information form (Input|User information). Automatic transfers have a note 'AUTO' displayed in the Note column. There are no limits to the number of extensions that can be linked to a master user. The water transfer form will not accept non-existent users and users that are listed in the stop water page on the user information form. Invalid week numbers will also be rejected.

To open the water transfer table select Output|Water|Transfers.
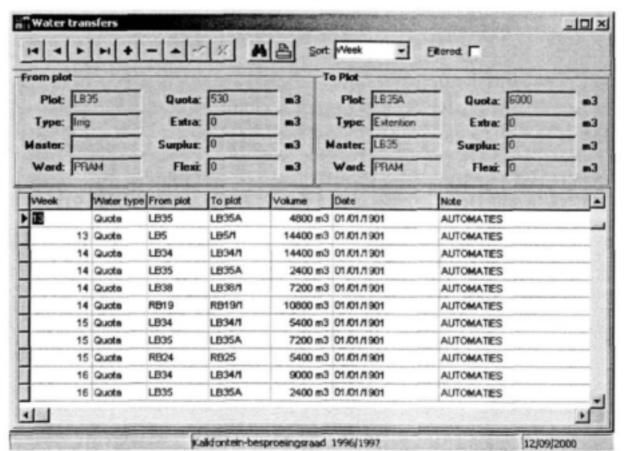
Figure 16: Water transfers

Sort
The water transfers can be sorted by:

- Week
- From user
- To user

Filter
The filter option is used to set a filter on the Week, From User and To User depending on the sort order selected. The current record is used to set the filter.

From user
Number/name of the user from where water must be transferred.

To user
Number/name of the user to where water must be transferred.

Week
The numbers 1- 53 specify the number of weeks for the year.

Water type
The following options can be selected from a drop down list.

- Quota
- Extra
- Flexi
- Surplus

From user
Number/name of the user from where water must be transferred.

To user
Number/name of the user to where water must be transferred.

Volume
Volume of water that is needs to be transferred between the two users.

Date
The date defaults to the current date, but the operator can change it.

Note
Additional information for the operator's attention can be captured here. In the case of an automatic transfer between a master user and an extension the word 'AUTO' will be entered by the program.

3.6 WEATHER STATIONS

Automatic weather station data can be captured or imported into WAS from text files. The weather data is used by WAS during the water release calculations to calculate evaporation and transpiration losses for each reach of the canal or river. It is possible to link a different weather station to every reach but if no weather station is specified default values specified by the user are used.

Weather forecasts are handled by capturing the weather data in advance. WAS will use the forecasted data where necessary, just remember to replace the forecasted data with the real data when it becomes available.

To go to the weather stations form select **Input|Water|Weather** stations from the main menu.
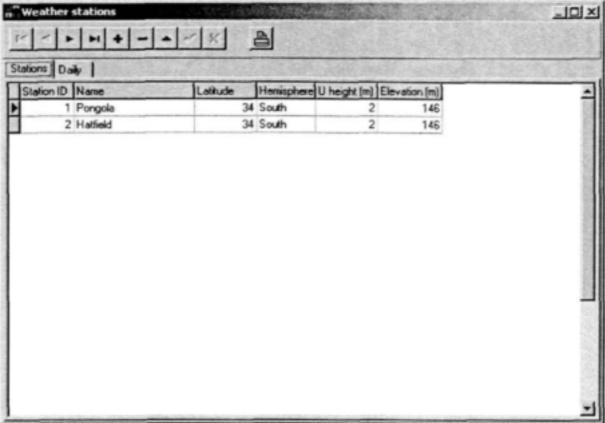
Figure 17: Weather stations (Stations page)

The weather station data is described in the following paragraphs.

Station ID
Weather station ID.

Name
Name of the weather station.

Latitude
Latitude of the weather station.

Hemisphere
Hemisphere where the weather is situated that is selected form a drop down list.

U height (m)
Height of the wind speed measurement.

Elevation
Elevation of the weather station.
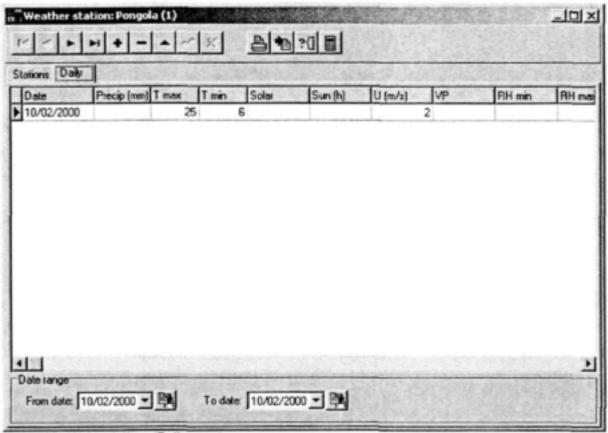
Figure 18: Water stations (Daily page)

Speed buttons

Import data from a text file.

Refresh the data set according to the date range settings.

Recalculate all the ETo values with the FAO Penman-Monteith equation.

Copy the date on the current record to the corresponding *From date* and *To date* edit boxes.

The daily weather data is described in the following paragraphs.

Date
Date of measurement.

Precip (mm)
Daily rainfall in mm.

T max
Maximum daily temperature in °C.

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T min
Minimum daily temperature in °C.

Solar
Solar radiation in MJ/m^2/d.

Sun (h)
Sun hours.

U (m/s)
Average daily wind speed in m/s.

VP
Vapour pressure in kPa

RH min
Minimum daily relative humidity in %.

RH max
Maximum daily relative humidity in %.

T dry
Dry bulb temperature in °C.

T wet
Wet bulb temperature in °C.

Dew point
Dew point.

Est
Indicates if the record is estimated or not.

ETo
Calculated FAO Penman-Monteith grass reference daily evapotranspiration. ETo is calculated according to the FAO procedure, as recommended by Smith, Allen and Pereira (1996). The following equation is adopted:

$$ETo = \frac{0.408 \cdot Delta(Rn - G) + Gamma \cdot 900/(Tavg + 273) \cdot U2 \cdot VPD}{Delta + Gamma(1 + 0.34 \cdot U2)}$$

where

Delta:	Slope of the saturation vapour pressure curve (kPa/°C)
Rn:	Net radiation (MJ/m^2/d)
G:	Soil heat flux (MJ/m^2/d)
Gamma:	Psychrometer constant (kPa/°C)
Tavg:	Daily average air temperature (°C)
U2:	Daily average wind speed measured at 2 m height (m/s)
VPD:	Vapour pressure deficit (kPa)

Essential weather data are: date, rainfall and maximum and minimum temperature. If not measured, solar radiation is calculated from maximum and minimum temperature, elevation, latitude and date. If wind speed is not measured, an average wind speed of 2 m/s is assumed. If not measured, vapour pressure is calculated from measured minimum and maximum relative humidity, and if that is not available, from measured dry and wet bulb temperature. WAS assumes the minimum temperature reaches dew point if no atmospheric vapour measurements are available.

3.7 WATER BALANCE STATEMENTS

The water balance sheet displays a detailed water balance of any given user. The water balance sheet for a single user can be viewed on screen. The water balance sheets for a group, ward or scheme can only be sent to the printer.

The water balance sheet can be opened by selecting **Output|Water|Balance Statements**.

Week	Orig (m3)	Add (m3)	Cancel (m3)	Total (m3)	Balance (m3)	% Used	Quota (m3/ha)	Transfer (m3)	Measured (m3)
1	21800	0	0	24376	157624	13	7700	0	2576
2	24000	0	0	50376	131624	28	0	0	2000
3	24000	0	0	74376	107624	41	0	0	0
4	24000	0	0	98376	83624	54	0	0	0
5	24000	0	0	122376	59624	67	0	0	0
6	24000	0	0	146376	35624	80	0	0	0
7	24000	0	0	170376	11624	94	0	0	0
8	0	0	0	170376	11624	94	0	0	0
9	0	0	0	170376	11624	94	0	0	0
10	24000	0	0	194376	-12376	100	0	0	0
11	24000	0	0	218376	-36376	100	0	0	0
12	24000	0	0	242376	-60376	100	0	0	0
13	24000	0	0	266376	-84376	100	0	0	0
14	24000	0	0	290376	-108376	100	0	0	0
15	24000	0	0	314376	-132376	100	0	0	0
16	24000	0	0	338376	-156376	100	0	0	0
17	24000	0	0	362376	-180376	100	0	0	0
18	24000	0	0	386376	-204376	100	0	0	0
19	24000	0	21600	388776	-206776	100	0	0	0

Kalkfontein-besproeiingsraad 1996/1997   12/09/2000
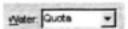
Figure 19: Water balance sheet

Speed buttons and controls

Range: Plot ▼
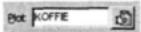
Specifies the range of the water balance sheets that will be generated. Only the water balance sheet for a single user can be viewed on screen. The rest can only be sent to the printer. The options that can be selected from a drop down list are:

- User
- Ward
- Group
- Scheme

Water: Quota ▼

Specifies the water type of the water balance sheets that will be generated. The water type is selected from a drop down list with the following options.

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- Quota
- Extra
- Surplus
- Flexi

Plot [KOFFIE]

The user, ward or group number is entered in this edit box depending on the range setting. The label of the edit box will change depending to the range setting selected. If the edit box is active, the enter key can be used to refresh the report otherwise click on the speed button.

A description of all the columns in the report follows.

Week
A number the specifies the end of a given week.

Orig. (m³)
The original amount of water requested in a specific week, measured in cubic meters.

Add (m³)
The additional amount of water requested in a specific week, measured in cubic meters.

Cancel (m³)
Amount of water cancelled in a specific week, measured in cubic meters.

Total (m³)
Cumulative volume of water requested up to the specific week measured in cubic meters.

Balance (m³)
User water balance for a specific week, measured in cubic meters. The water balance is calculated in the following way:

$$Balance[j] = Balance[j-1] + Orig[j] + Add[j] - Cancel[j] - TranferTo[j] + TransferFrom[j]$$

where

$$Balance[1] = Quota - (Orig[1] + Add[1] - Cancel[1] - TranferTo[1] + TransferFrom[1])$$

% Used
Percentage of water used up to a specific week.

Quota (m³/ha)
Quota of water allocated for irrigators, measured in cubic meters per hectare. Water can be allocated in any given week.

Transfer (m³)
Total volume of water transferred from, and to, the specific user in a specific week. This is measured in cubic meters.

Measured (m³)
Total volume of water measured in a specific week, and it is measured in cubic meters.

3.8 WATER REPORT

The water report displays a summary of all the water requests and meter readings on a daily and weekly basis. The report can be generated for a specific ward, group or the total scheme.

To open the Water Report screen, select **Output|Water|Water Report**.

Figure 20: Water report

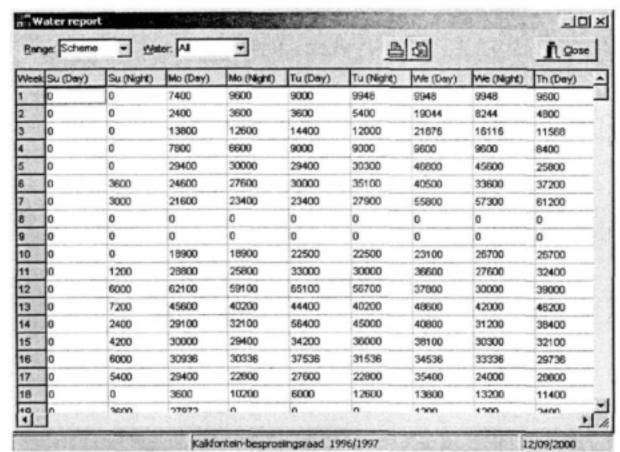**Speed buttons**

Show Report

Defines the range of the water requests that will be summarised for the report. The available options are:

- User
- Ward
- Scheme

Water
Specifies the water type that is used to generate the report. The available options are:

- Quota
- All
- Extra
- Surplus
- Flexi

User
This is the unique number or reference number identifying a specific user.

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Su (Day) – Su (Night)
This report is generated for the period Sunday morning to the following week Sunday night.

Measured
Total volume of measured water in every week.

Total
Total of all the water requested for every week.

3.9 WATER BALANCE REPORT

The water balance report is not to be mistaken with the Water Report. This report is a combination between the user information, the addresses and the water usage information. The water balance report only accounts for water requests, water transfers and meter readings.

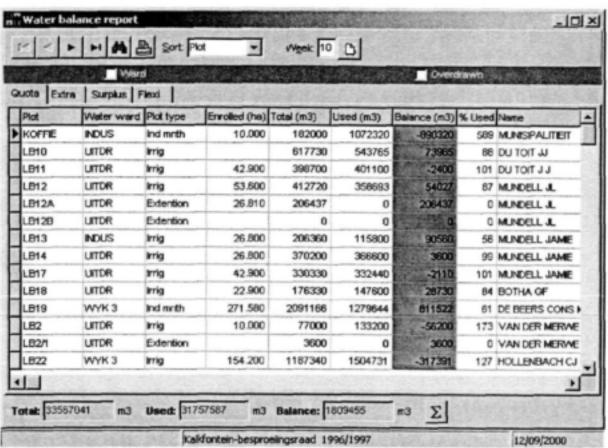To open the water balance report, select **Output|Water|Water balance report**.

Plot	Water ward	Plot type	Enrolled (ha)	Total (m3)	Used (m3)	Balance (m3)	% Used	Name
KOFFIE	INDUS	Ind mnth	10.000	182000	1072320	-890320	589	MUNISIPALITEIT
LB10	UITDR	Irrig		617730	543765	73965	88	DU TOIT JJ
LB11	UITDR	Irrig	42.900	398700	401100	-2400	101	DU TOIT J J
LB12	UITDR	Irrig	53.600	412720	358693	54027	87	MUNDELL JL
LB12A	UITDR	Extention	26.810	206437	0	206437	0	MUNDELL JL
LB12B	UITDR	Extention		0	0	0	0	MUNDELL JL
LB13	INDUS	Irrig	26.800	206360	115800	90560	56	MUNDELL JAMIE
LB14	UITDR	Irrig	26.800	370200	366600	3600	99	MUNDELL JAMIE
LB17	UITDR	Irrig	42.900	330330	332440	-2110	101	MUNDELL JAMIE
LB18	UITDR	Irrig	22.900	176330	147600	28730	84	BOTHA GF
LB19	WYK 3	Ind mnth	271.580	2091166	1279644	811522	61	DE BEERS CONS I
LB2	UITDR	Irrig	10.000	77000	133200	-56200	173	VAN DER MERWE
LB2/1	UITDR	Extention		3600	0	3600	0	VAN DER MERWE
LB22	WYK 3	Irrig	154.200	1187340	1504731	-317391	127	HOLLENBACH CJ

Total: 33567041 m3   Used: 31757587 m3   Balance: 1809455 m3   Σ

Kalkfontein-besproeiingsraad 1996/1997   12/09/2000

Figure 21: Water balance report

Speed buttons and controls

Week 10

Used to refresh the dataset after the week has been changed.

Ward

Used to filter the dataset to the current water ward.

■ Overdrawn

Used to display only records with negative water balances.

The Water Balance report can be sorted according to:

- User
- User type
- Water ward
- Total
- Used
- %Used
- Balance

The Water balance report consists of four pages, including reports on the current water balances. A number of columns appear in each of the different pages:

3.9.1 QUOTA / EXTRA / SURPLUS / FLEXI PAGES

The above-mentioned pages have the same information, except the quota page has an extra column, namely Enrolled (ha). A description of all the columns follows.

User
This is the unique number or reference number identifying a specific user.

Water Ward
Water ward linked to the specific user.

User Type
Specific user type.

Enrolled (ha)
Number of hectares enrolled for every user.

Total (m^3)
Total volume of water allocated to every user.

Used (m^3)
Total volume of water used by every user.
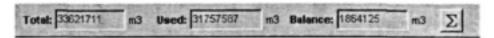
Balance (m^3)
Water balance of every user.

% Used
Percentage water used by every user.

Name
Name linked to every user that is captured as part of the address information.

Totals can be calculated, at the bottom section of this report by clicking on the summation button at the bottom of the screen.

Total: 33621711 m3 Used: 31757587 m3 Balance: 1864125 m3 Σ

3.10 MEASURING STATIONS

The measuring stations form is used to capture measurements or readings based on date and time. The data can be from graphs, loggers, measuring plates or meters. Integrated into this form are discharge tables that are used to convert water levels to discharges and vice versa. This form is also used to capture inflows and outflows for river systems and to generate discharges for stations that are linked to an indicator site. Volumes can easily be calculated between dates and sent to the meter readings if necessary. All readings and discharges can be represented graphically with user-defined ranges.

To open the measuring stations form, select **Input|Water|Measuring stations**.

Figure 22: Measuring stations

Speed Buttons

Meter readings

Generate Q from indicator site.

Sort
The Measuring Structures form can be sorted by:

- Station
- Name

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- User

This screen consists of four pages, namely Stations, Readings, Discharge table and Graph. Herewith, short descriptions of each page:

3.10.1 STATIONS PAGE

Station
Measuring station identification string that is a maximum of 10 characters long.

User
A user that is linked to a measuring station. This link is used to automatically send calculated volumes between a specified date and time range to the meter readings form.

Name
A longer description of the station and can be 40 characters long.

H Units
Vertical units that can be selected from a drop down list.

Q Units
Discharge units that can be selected from a drop down list.

Min h (mm)
Minimum y-axis value on the graph for water levels.

Max h (mm)
Maximum y-axis value on the graph for water levels.

Min Q
Minimum y-axis value on the graph for discharge.

Max Q
Maximum y-axis value on the graph for discharge.

Continuous
The user has a choice between a line and bar graph that can be selected from a drop down list.

Indicator site
The link to an indicator site that is used to generate data for a specific station for a date and time range specified by the user. When this column is active an ellipses button appears that is used to access the flow ratios form.

Flow ID
This is the flow ID that will be used for the specific indicator site.

3.10.2 INDICATOR SITE FLOW RATIOS

The indicator site flow ratios form can be accessed through an ellipses button in the indicator site column on the stations page of the measuring structures form. The flow ratios are linked to an indicator site for which date and time readings for a measuring station are captured.

To access this form select a specific record in the Indicator site column of the measuring structures form and click on the ellipses button that will appear.
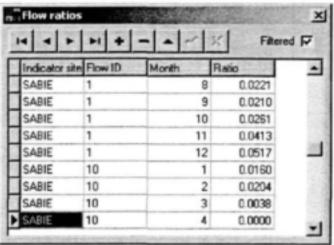
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Figure 23 Indicator site flow ratios form

The filtered box is used to filter only the values of the linked indicator site.

Indicator site
Specific indicator site identification string.

Flow ID
Flow identification number of the specific linked site. This number is used to reference a range of values within the indicator site.

Month
Month linked to the specific indicator site and flow identification number.
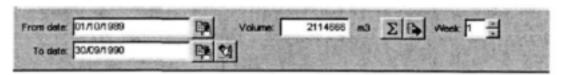
Ratio
Flow ratio that is used to calculate related discharges of linked sites which all have a Flow ID.

3.10.3 READINGS PAGE

The readings page is used to capture water levels and discharges. A date and time reading can be specified to calculate the total volume for the range. To capture the *from date*, highlight the specific date in the data set and click on the speed button next to the from date box. This volume can be automatically sent to the meter readings form if a link is created on the stations page and the user clicks on the export speed button.

A description of all the columns on the readings page follows.

Station
The station identification string that is automatically filled in depending on the current selected station on the stations page.

Date & time
Exact date and time when a reading or measurement took place.

Reading (mm)
The specific reading and the units will depend on the setting on the stations page. If a discharge table is available for this station, the discharge will be looked up and inserted in the discharge column when the

record is posted to the database. If a discharge table is not available, the discharge must be captured manually or left blank.

Q (m³/s)
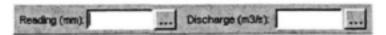The discharge and the units will depend on the setting on the stations page. If a discharge table is available for this station, the corresponding reading will be looked up and inserted in the reading column when the record is posted to the database. If a discharge table is not available, the reading must be captured manually or left blank.

3.10.4 DISCHARGE TABLE PAGE

The discharge table page is used to capture discharge tables for measuring structures with a reading (water level) and discharge relationship. This form can be used to look up a discharge from a known reading and vice versa. To lookup a discharge the user must capture the known reading in the readings edit box as shown in the figure below and click on the ellipses button. The same can be done to look up a reading from a known discharge.

Reading (mm): [   ] [...] Discharge (m3/s): [   ] [...]

Station
The station identification string that is automatically filled in depending on the current selected station on the stations page.

Reading (mm)
Reading taken in mm.

Q (m³/s)
Discharge in volume per unit of time.

3.10.5 GRAPH PAGE

On this page different graphs can be displayed by selecting one of the radio buttons. The available radio buttons are:

- Readings vs Time
- Discharge vs Time
- Discharge Table

Reading vs Time
The reading versus time graph displays water levels on the y-axis and a date and time range on the x-axis. The date and time range is specified at the bottom of the Readings page. The maximum and minimum values for the scaling of the graph are specified on the stations page.
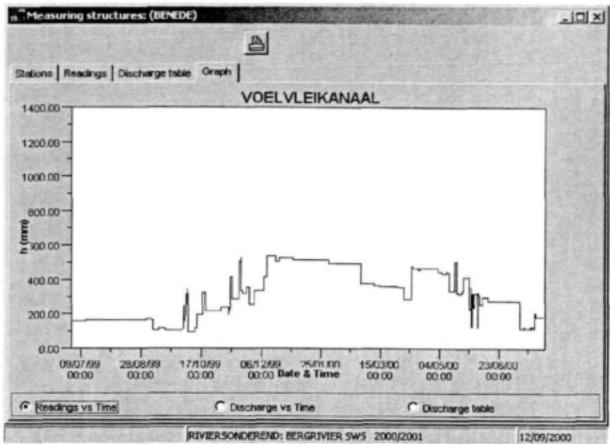
Figure 24: Readings vs Time graph

Discharge vs Time

The discharge versus time graph displays the discharge on the y-axis and a date and time range on the x-axis. The date and time range is specified at the bottom of the Readings page. The maximum and minimum values for the scaling of the graph are specified on the stations page.
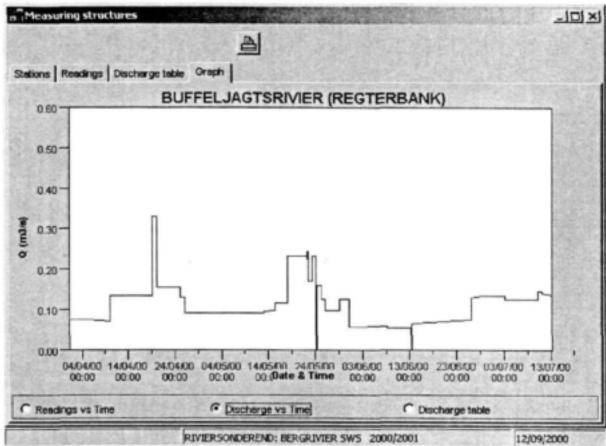
Figure 25: Discharge vs Time graph

Discharge Table

The discharge table graph displays the water level on the y-axis and the discharge on the x-axis. The maximum and minimum values for the scaling of the graph are specified on the stations page.
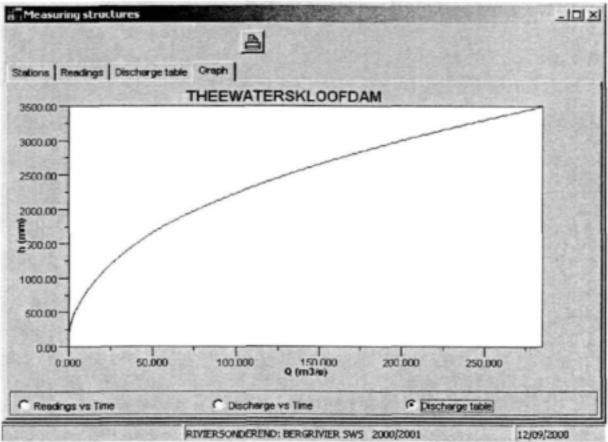
Figure 26: Discharge table graph

3.11 OPERATOR DEFINED WATER REPORTS

The Operator defined water reports provide the operator with the option to generate customised reports. Different schemes can be part of the same report. Water requests, meter readings and date and time based water usage can be included on the same report. Once a report is created, copying the specific report and just modifying it can easily create similar reports. To copy a report, use the copy options at the bottom of the screen.

To open the Operator defined water reports, select **Output|Water|User defined water reports**.
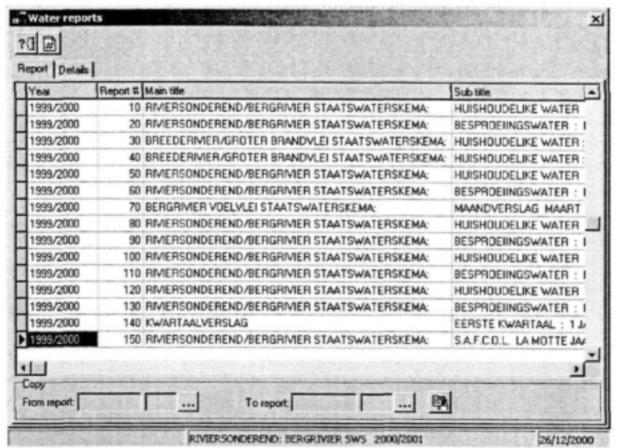
Figure 27: Water reports

Speed Buttons

Refresh Report

Renumber lines

Copy report

The report consists of two pages that are described in detail in the following paragraphs.

3.11.1 REPORT PAGE

Any number of reports can be captured on the report page. Each has its own report number, title and sub-title that will be part of the printed document. Descriptions of all the columns follow.

Report#
Each report has a unique number that defines the order that the reports appear on the screen. To change the position of a specific report, renumber the line. Selecting the renumber icon can renumber the lines.

Main Title
Main title of the report that will appear on the printed document.

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Sub Title

Sub title of the report that will appear on the printed document.

3.11.2 DETAILS PAGE

Line	Ind/Irr	Scheme	Code (+)	Plot (+)	Code (-)	Plot (-)	Description
10		1	Title		Title		SUIDWES-KAAPSE WATERRAAD
20	Ind	1	+Meter	ROOS	Title		Ruensveld-Oos
30	Ind	1	+Meter	RWES	Title		Ruensveld-Wes
40		1	Title		Title		
50		1	Subtotal		Title		SUBTOTAAL WATERRAAD
60		1	Title		Title		
70	Irr	1	+Meter	VBESP	Title		VYEBOOM BESPROEIINGSRAAD (H6H020)
80		1	Title		Title		
90	Irr	1	+Meter	RSELOSL	Title		RIVIERSONDEREND BESPROEIINGSRAAD
100		1	Title		Title		
110		1	Title		Title		THEEWATERSKLOOFDAM BESPROEIERS
120	Irr	1	+Meter	RFONTA	Title		Rustfontein A P
130	Irr	1	+Meter	RFONTD	Title		Rustfontein D
140	Irr	1	+Meter	TSIDEA	Title		Theeside Farm A
150	Irr	1	+Meter	TSIDEB	Title		Theeside Farm B
160	Irr	1	+Meter	TSIDEC	Title		Theeside Farm C
170	Irr	1	+Meter	TSIDED	Title		Theeside Farm D
180	Irr	1	+Meter	TSIDEE	Title		Theeside Farm E

RIVIERSONDEREND: BERGRIVIER SWS 2000/2001   26/12/2000

Figure 28 Operator defined water report: Details page

The layout of the report is customised in the details page. Descriptions of columns follow.

Line
This is the line number on the report. It refers to a number that defines the sequence in which the lines of the report will be printed. Selecting the renumber icon can renumber the lines.

Ind/Irr
Specifies the column in which the resulting volume will be placed. A selection can be made from a drop down list:

- Industrial
- Irrigation

Scheme
A unique number identifies each scheme. If the number is not known, it can be selected from a lookup table as shown below:

Nr	Description
104	Buffelspoort 1
105	Buffelspoort 2
9	DWAF HK
106	Damkom
99	Demo [Debit]
0	Demo [State]
107	HB Poort 56[3] met WNF
108	HB Poort 56[3] sonder WNF
103	Hartbeespoort Nuwe vore
102	Hartbeespoort-besproeiingsraad
2	Kalkfontein-besproeiingsraad
1	Loskop [95/96]
3	Rietrivier-SWS
160	Sabie rivier

Figure 29: Schemes

Code +
This code is used to specify the type of calculations for the specific row. A drop down list provides the user with the following options:

- Title
- + Meter
- + Graph
- - Meter
- - Graph

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- Subtotal
- Total

Descriptions of above-mentioned options:

Title
If the title is selected, no calculations will be done and the description will be used as a title in the report.

+ Meter
Meter volume for the specified weekly range multiplied by a positive sign.

+ Graph
Volume calculated from a graph for a specific date range multiplied by a positive sign.

- Meter
Meter volume for the specific weekly range multiplied by a negative sign.

- Graph
Volume calculated from a graph for a specific date range multiplied by a negative sign.

Sub Total
Total calculated from the previous sub total.

Total
This is calculated as the total of all the data in the respective columns in the report, and will only total all sub totals.

User +
Unique number or reference number identifying a specific user linked to the Code (+) column.

Code –
This code is used to specify the type of calculations. If the Code- option is used, the resulting volume will be subtracted from the resulting volume of the Code+ settings on the same row. A drop down list provides the user with the following options:

- Title
- + Meter
- + Graph
- - Meter
- - Graph
- Subtotal
- Total

Descriptions of mentioned options:

Title
If the title is selected, no calculations will be done and the description will be used as a title in the report.

+ Meter
Meter volume for the specified weekly range multiplied by a positive sign.

+ Graph
Volume calculated from a graph for a specific date range multiplied by a positive sign.

- Meter
Meter volume for the specific weekly range multiplied by a negative sign.

- Graph
Volume calculated from a graph for a specific date range multiplied by a negative sign.

Sub Total
Total calculated from the previous sub total.

Total
This is calculated as the total of all the data in the respective columns in the report, and will only total all sub totals.

User –
Unique number or reference number identifying a specific user linked to the Code (-) column

Description
The description will either be used as a title or a description of the specific water user, depending on the code used. Totals & subtotals have no descriptions or related information.

From Week
This links to the water requested for the corresponding week, if it is a meter.

To Week
This links to the water requested for the corresponding week, if it is a meter.

From date & time
In case of a graph, the correct time and date is very important.

To date & time
In case of a graph, the correct time and date is very important.

% Loss
Percentage of water lost to industrial and irrigation usage. This will be calculated, and put into the industrial and irrigation columns respectively.

Ind (m³)
Calculated industrial water volume, and depends on the line specification.

Ind loss (m³)
Calculated industrial water loss, and depends on the line specification.

Ind tot (m³)
Total industrial water volume and the industrial water loss.

Irr (m³)
Calculated irrigation water volume, and depends on the line specification.

Irr loss (m³)
Calculated irrigation water loss.

Irr tot (m³)
Total of the irrigation water volume column and the irrigation water loss.

Note
This gives the option for notes that will be included in the detail report to specify i.e. faulty meters.

CHAPTER 4 WATER RELEASE MODULE

This module links with the water administration and request modules and can be used to
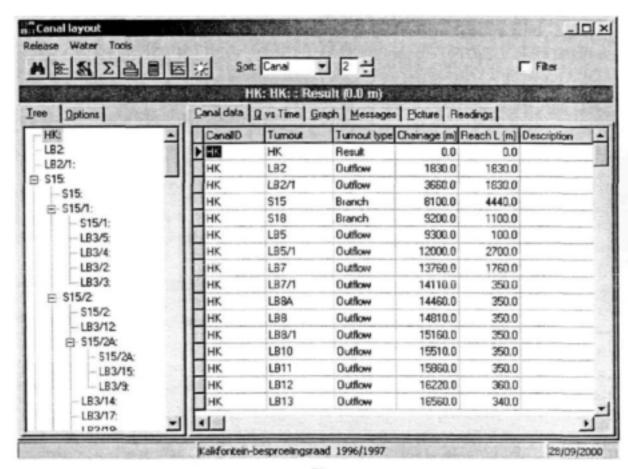
- Minimise distribution losses on canal networks and in river systems.
- Calculate water releases for the main canal and all its branches allowing for lag times and water losses such as seepage and evaporation.
- Determine operational procedures for a dam with varying downstream inflows and outflows in a river allowing for lag times and water losses such as seepage, evaporation and transpiration.

A schematic layout of the total canal network or river system is captured with details such as the cross-sectional properties, position of sluices or pumps, canal/river slope, measuring structures and canal capacities. Every reach can be analysed and calibrated on its own with a built in properties calculator. Global changes to the canal or river data is simplified by means of built in tools.

Discharges are converted to the corresponding measuring plate readings where needed. Calculated water releases, water distribution sheets and water loss analysis reports can be printed. Graphical output of all inflows, outflows, cross-sections and longitudinal profiles can be viewed on the screen or sent to a printer. Water release graphs, calculated with different settings, can be superimposed for comparison purposes.
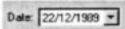
4.1 CANAL OR RIVER LAYOUT

To open the canal or river layout form, select **Input|Canal network** from the main menu or click on the *canal network* speed button on the main screen.

CanalID	Turnout	Turnout type	Chainage [m]	Reach L [m]	Description
HK	HK	Result	0.0	0.0	
HK	LB2	Outflow	1830.0	1830.0	
HK	LB2/1	Outflow	3660.0	1830.0	
HK	S15	Branch	8100.0	4440.0	
HK	S18	Branch	9200.0	1100.0	
HK	LB5	Outflow	9300.0	100.0	
HK	LB5/1	Outflow	12000.0	2700.0	
HK	LB7	Outflow	13760.0	1760.0	
HK	LB7/1	Outflow	14110.0	350.0	
HK	LB8A	Outflow	14460.0	350.0	
HK	LB8	Outflow	14810.0	350.0	
HK	LB8/1	Outflow	15160.0	350.0	
HK	LB10	Outflow	15510.0	350.0	
HK	LB11	Outflow	15860.0	350.0	
HK	LB12	Outflow	16220.0	360.0	
HK	LB13	Outflow	16560.0	340.0	

Figure 30: Canal or river layout

Speed buttons and controls

The set week control is only visible when working with weekly-based water requests. This is normally the case when managing water distribution on canal networks. It is used to set the default week that is used for water release calculations. The week number can be changed by entering the number directly into the edit box or by clicking on the up and down arrows. The default week is also used to display water requests and releases when clicking on the tree.

The set date control is only visible when working with date and time based water requests. This is normally the case when doing water management on rivers and inflows and outflows occur. It is used to set the starting date of a 17-day window that is used for water release calculations.

The set filter control is used to set a filter on the current record using the canal or river ID.

Draws a schematic layout of the canal or river using the current record as the starting point. The form opens with the previous canal or river layout.

Opens the change canal or river data form. This form is used to make global changes to the canal or river data. The user has the option to include branches or not. See paragraph 4.2 for details.

Opens the calculate release form. This form is used to calculate water releases for a canal network or river system.

Opens the properties calculator form. The data of the current record is duplicated on the properties calculator form that is used to analyse the current reach in detail. The user can use the properties calculator as a calibration tool for any reach. See paragraph 4.4 for a detail description.

Opens the measuring stations form. This form is used to capture data and time related data that is used for in- and outflows on date and time based water management systems like rivers. It is also used to capture data for discharge tables that can be linked to measuring structures. The discharge tables are used to automatically convert discharges to measuring plate readings that are printed on water release reports or distribution sheets. See paragraph 3.10 for a detail description.

Opens the weather stations form. This form is used to capture weather station data that is used by WAS during the water release calculations to calculate evaporation and transpiration losses for every reach of the canal or river. See paragraph 3.6 for a detail description.

The Canal Layout form can be sorted according to:

- Canal (Includes rivers)
- Turnout
- Structure

Descriptions of pages and columns:

4.1.1 TREE PAGE

The Tree page displays a tree view of the total canal or river network with all its branches, inflows and outflows. The user can browse through the canal or river network and jump to a specific point by selecting it with the mouse. Branches can be expanded or collapsed by double clicking or by clicking the minus or plus signs respectively.

Selecting the draw tree button at the top of the screen to redraw the tree. The start of the tree will depend on the current selected record on the canal or river data page.

4.1.2 OPTIONS PAGE

The Options-page displays a list of radio buttons that, if selected, displays the corresponding information on the canal or river tree view. The tree must be redrawn before the new options will take effect. The different options are:

- None
- Open/Close Time
- Chainage (m)
- Reach Length (m)
- Structure
- Max Discharge (m^3/h)
- Canal or River Slope
- Seepage (l/s per 1000m^2)
- Bottom Width (m)
- Manning-n: Manning roughness coefficient of the canal (not available for rivers)
- Calibration Coefficient
- Setting Interval
- Maximum Velocity (m/s)
- Lag time at maximum discharge

4.1.3 CANAL OR RIVER DATA PAGE

This page, displays the fixed data of the canal or river network. A description of every column follows.

Canal ID
Identification string of the canal or river. The Canal ID string can be a maximum of 10 characters long.

Turnout
Branch or an abstraction identification string. The Turnout string can be a maximum of 10 characters long.

Turnout type
This column specifies whether the turnout is a branching canal, an outflow, inflow or a result. A branch is a secondary canal and WAS can handle branching canals that is a few levels deep (branches on branches). In the case of canal networks, outflows are captured as water requests (**Input|Water|Requests**) or meter readings (**Input|Water|Meter volumes**). Canal networks normally have no inflows. In the case of river systems, outflows and inflows are captured on the measuring stations form (**Input|Water|Measuring stations**). A Result turnout type can be specified at any other

60

point that is not the source or a branch. The turnout type is selected from a drop down list with the following options:

- None
- Branch
- Outflow
- Inflow
- Result

The *outflow* turnout type is a generic identifier for all types of outflows like sluices, pumps, meters, etc. The *inflow* turnout type is a generic identifier for all types of inflows like diffused inflows, pumps, river branch, etc.

Chainage (m)
This is the distance from the start of the canal or river to the specific point.

Reach L (m)
This is the distance from the start to the end of a specific reach. The reach length is not a user input value but it is calculated by WAS from the different chainages. The reach lengths must be recalculated every time after changes were made to any chainage value. To recalculate, select **Tools|Calc reach length**.

Description
A description of the specific point in the canal or river can be given in this column with a maximum of 40 characters long.

Structure
Type measuring structure at the specific point in the canal or river, if any. These structures are used to measure discharge. The structure is select from a drop down list and sizes must be entered for non-standard sizes if necessary. The available structures are:

- None:
- Pressure V-Notch: The corresponding measuring plate readings are calculated with the standard V-notch equation.
- Parshall 1ft – 12ft: Twelve Standard Parshall flume sizes are listed. If the size of the Parshall flume is not on the the list, the size can be entered manually in the Size-column.
- Crump Weir: The corresponding measuring plate readings are looked up in a specified discharge table. The name of the discharge table is specified in the DT-column. A discharge table can be created on the measuring stations form (select the measuring stations button at the top of screen or from the main screen select **Input|Water|Measuring stations**).
- Rectangle 0C – 2C: The corresponding measuring plate readings are calculated with the standard rectangular-weir equation.
- Meter:

Size (mm)
This column is used to specify the size of a non standard Parshall flume. If a measuring structure with a standard size is selected in the structure column, this column can be left blank.

DT (Discharge table)
This column refers to the discharge table that is linked to the measuring structure specified in the structure column. A discharge table is a conversion table used to convert measuring plate readings to discharges and vice versa. The discharge table can be selected from a look up table by clicking on the ellipses button. A discharge table can be created on the measuring stations form (select the measuring stations button at the top of screen or from the main screen select **Input|Water|Measuring stations**).

Q Cap (m³/h)
Maximum discharge capacity of the canal or river. The units can either be m³/hour or m³/s depending on the request type selected in the Irrigation schemes form (**Input|Irrigation schemes**).

Seep
Seepage loss factor specified in l/s per 1000 m² wetted area. The seepage factor can be different for every reach but is normally taken as a constant for a specific canal, branch or river. The seepage factor needs to be calibrated with measured inflows and outflows.

Time
Fixed opening and closing time for the outflow for the specific reach. The user has the choice to specify the opening and closing times on the canal data form or on the water request form. If the times are specified on the water request form, it can be different from week to week. If it is specified on the canal data form, it is assumed to stay constant from week to week. The user can change this option on the Irrigation schemes form (**Input|Irrigation schemes**). The time parameter is not used when working with date and time related inflows and outflows like river systems.

Cv
Coefficient used to calibrate the lag time for every reach. The average velocity in every reach is multiplied by the Cv-coefficient to calibrate the lag time for every reach. The Cv-coefficient is applied to the range of flows in a reach.

Set (h)
Time setting interval in hours that WAS uses to calculate release settings at the source and all branches. If no setting is specified, WAS will use a default setting of 5 minutes to do all calculations. The setting can be different for the source and every branch.

Prn grp
This number is used to group releases together for batch printing. To batch print; select the **Print release group** option under the main menu.

Section
Under this column, a selection can be made from the following options:

- Rectangle
- Trapezoid
- Parabola
- Pipe
- Rect/Para
- User def (used for river reaches)

Section file
The section file is used to specify a customised section shape that is not included in the standard selections.

bo (m)
Bottom width of the canal. This is not used for user defined sections like river reaches.

Top b (m)
Top width of the canal. This is not used for user defined sections like river reaches.

h Max (m)
Maximum height of the canal or river.

Weir h (m)
Height of the weir across the canal or river at the end of the specific reach.

Weir b (m)
Width of the weir across the canal or river at the end of the specific reach.

Manning-n
Manning roughness coefficient of the reach. The Manning equation is used to calculate the normal flow depth in every reach. The normal flow depth is then used with the reach length to calculate the wetted area and the water surface area. The wetted area is used to calculate the seepage and the water surface area is used to calculate the evaporation in every reach.

In the case of a river reach the Manning-n is a function of the water depth and is read as part of the cross-sectional properties in a properties file for every reach.

The Manning equation is defined as follows:

$$Q = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

where

Q:	Discharge	
A:	Cross-sectional area	
S:	Bottom slope	
n:	Manning roughness coefficient	

Canal Slope
Longitudinal slope of the reach. WAS can calculate the slope for every reach from a known bottom level (*right click*|**Calc slope from Yb**).

Y bottom (m)
Bottom level of the reach above a datum line. WAS can calculate the bottom level for every reach from a known slope (*right click*|**Calc Yb from slope**).

Storage (m³)
Storage volume of the reach.

Fill Q (m³/h)
Discharge rate that is required to fill the reach after a dry period. This discharge rate is used to calculate the time required to fill the reach.

Fill %
Percentage of the reach that requires filling. It is required to determine the capacity of water that is required to fill the reach when it is not completely dry.

MAR Q (m³/h)
Maximum abstraction right in cubic meters per hour – The MAR Q is calculated with the following equation.

$$MARQ = Enrolment * \frac{325}{MAR}$$

MAR (h/week)
Maximum abstraction right in hours per week. The MAR is calculated with the following equation.

$$MAR = Enrolment * \frac{325}{MARQ}$$

Riparian (m)
Riparian width that is the total width of the vegetation across a canal or river reach. The riparian width minus the water surface width is used to calculate the transpiration losses. Every reach can be linked to

a different weather station that is used to calculate evapotranspiration factors. If no weather station is linked, a default evapotranspiration factor is used.

4.1.4 Q VS TIME PAGE

The Q vs Time-page displays the calculated water release in text format, if it is the main or any branching canal. The day of week, time of day and discharge are displayed and if the specific reach has a measuring structure, the calculated mm reading is displayed for the particular discharge. The last column displays the cumulative volume for the particular week. This volume is used by WAS to calculate the global loss for the particular week.

4.1.5 GRAPH PAGE

The graph page displays a graphical view of the calculated release. The cumulative volume for a particular week is also displayed on the graph. It is possible to repeat the calculation with different settings and to draw the second graph on top of the first graph. In this way, comparisons between releases calculated with different settings, can easily be made. If the selection on the tree view is an abstraction point, then the corresponding water request is displayed if any. The graph can be printed by selecting the Print speed button on the toolbar at the top of the screen. To view the release/request graph for different canals or turnouts, select it on the tree view page.

4.1.6 MESSAGES PAGE

The messages page displays any message noted during a release calculation. The messages include the name of the canal or river, the calculation start and stop time, the calculation settings that were checked and if the canal or river was overflowing or not. A canal or river will overflow when the calculated depth is greater than the specified maximum depth of a given reach. The messages should be checked after each calculation.

4.1.7 PICTURE PAGE

The picture page displays a picture of the canal, river or abstraction point of the specific reach if it is available. A normal colour photo can be taken and then scanned and imported into WAS.

4.1.8 READINGS PAGE

Station
Station or measuring point in the scheme.

Date & time
Exact date and time when the reading took place.

Reading (mm)
Particular reading that took place in mm.

Q (m^3/s)
Discharge in volume per unit of time.

4.2 CHANGE DATA

This form is designed to simplify the process of making global changes to the canal or river data. To open the change data form, use the change data speed button on the toolbar or select **Tools|Change data** from the menu. The user has the option to include branches or not and it will save a lot of time making global changes to the data if used correctly. A specific check box must first be selected before the corresponding value can be entered.

Figure 31: Change data

The change data form has two pages that are described in the following paragraphs.

4.2.1 LOSSES PAGE

This page refers to parameters relevant to water losses. The check boxes must be checked to enable editing in the corresponding edit boxes. Any number of parameters can be changed at once. The different parameters are described below.

Seepage
Seepage factor (l/s per 1000 m^2) for the particular reach. The seepage is the loss of water through the wetted area of the canal or river.

Storage volume
Total storage volume (m^3) for the particular reach. This is water that needs to be released before any water distribution to the users can take place.

Fill up discharge
Operator specified discharge (m^3/hour or m^3/s) that will be used to fill the storage volume of every reach.

Fill up %
This describes the storage level of a specific reach. An empty reach will be 0% full and a totally filled reach will be 100% full. This value is used by WAS to calculate the water volume that must be released to fill a specific reach to maintain the required flows.

Clear time setting: [Set(h)]
This option is used to clear the time settings for the specified river or canal network. Time settings are used to specify the opening or closing intervals at points where the release is calculated in a canal or river network.

4.2.2 PARAMETERS PAGE

Section

The section property is used to specify the cross section of the canal/river. The different sections can be selected from a drop down list and are:

- Rectangle
- Trapezoid
- Parabola
- Pipe
- Rect/Para
- User def (used for rivers)

Discharge (Q Cap)

Maximum discharge or capacity of the canal or river. In the case of canals the maximum designed discharge is taken. The maximum discharge value for rivers is not that important and any reasonable value can be taken.

h Max

Maximum canal or river height (or depth). In the case of a prismatic canal it is measured from the bottom of the canal to the top of the canal lining. In the case of a river it is measured from the bottom of the river to the top of the riverbank. The maximum height is used to determine when the canal or river is overflowing. The value for rivers is not important and any reasonable value can be taken. What is important is that cross-sectional properties for rivers must be available for all possible flow depths.

Top width

Top width of the canal measured in meters. This parameter is only relevant for rectangular, trapezoidal and rect/para cross-section types.

Bottom width

Bottom width of the reach measured in meters. This parameter is only relevant for rectangular, trapezoidal and rect/para cross-section types.

Canal slope (So)

This parameter specifies the longitudinal slope of the canal or river reach.

Calibration const (Cv)

This is a constant that is multiplied with the average water velocity in a reach. This is used when calculating lag times. The problem however exists that the real velocity and the calculated velocity is not the same. The calibration coefficient is therefore used to calibrate the lag time for every reach.

Weir h

Height of the weir across the canal or river reach measured in meters.

Weir width

Width of the weir across the canal or river reach measured in meters.

Manning-n

Manning roughness coefficient of the reach for all prismatic sections. The Manning-n for user-defined sections varies as a function of flow depth and is read from a file.

4.3 CALCULATE RELEASE

WAS can calculate water releases on a weekly or on a date and time basis. Water distribution on canal networks is normally done on a weekly basis and river system calculations are done on a date and time basis. To open the calculate release form, either select the *calculate release* speed button on the toolbar or select **Release|Calc...** from the menu.
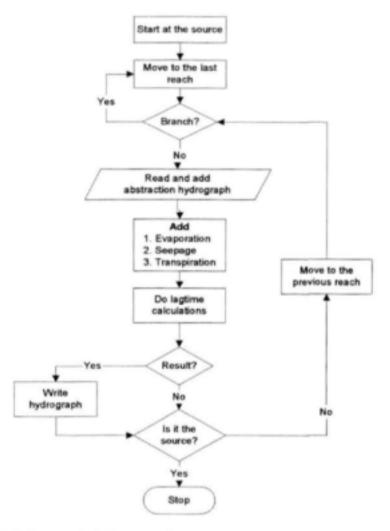
Figure 32: Release calculation procedure

The release calculation procedure starts at the source and moves down to the end of the last reach. From there it will move back towards the source processing every reach by adding the abstraction and losses and calculate the lag time for the reach. If it encounters a branch the solution is temporarily saved. The procedure is repeated for the branch, the saved solution is added and the procedure continues its path back to the source.

The solution handles branches on branches up to 6 levels deep. The operator can also specify any number of arbitrary points on the canal or river where the solution must be saved for later viewing. The number of reaches that WAS can handle is only limited to the size of the hard drive.

4.3.1 CALCULATION OF LAG TIMES

The lag time in a reach is calculated with the following equation:

$$Lagtime = \frac{Reach\ lengh}{Average\ velocity}$$

4.3.2 CALCULATION SEEPAGE LOSSES

The seepage loss in a reach is calculated using:

$$Seepage = Seepage\,rate \times Reach\,length \times Wetted\,perimeter$$

The seepage rate is specified in l/s per 1000m^2 wetted area.

4.3.3 CALCULATION OF EVAPORATION LOSSES

The evaporation loss in a reach is calculated using:

$$Evaporation = Evaportion\,rate \times Reach\,length \times Surface\,width$$

The evaporation rate is specified in mm/day.

4.3.4 CALCULATION OF TRANSPIRATION LOSSES

The transpiration loss in a reach is calculated using:

$$Transpiration = Transpiration\,rate \times Reach\,length \times (Riparian\,width - Water\,surface\,width)$$

The transpiration rate is specified in mm/day.

Weather forecasts are handled by capturing the weather data in advance. WAS will use the forecasted data where necessary, just remember to replace the forecasted data with the real data when it becomes available. To go to the weather stations form select **Input|Water|Weather** stations from the main menu.

4.3.5 DIFFUSED INFLOWS

Diffused inflows can be handled as number of point inflows on very short reaches although it can be very time consuming to capture the data if too many reaches are used. The calculation time is a function of the number of reaches on the canal or river network, the processing speed of the computer and the access time of the hard drive.

4.4 CALCULATION SETTINGS

The first figure shows the form for weekly calculations and the second figure shows the form for date and time based calculations.
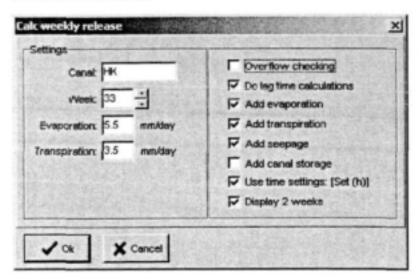
Figure 33: Calculate weekly release

Figure 34: Calculate date & time release

Canal
Canal or river identification string.

Week
Specifies the week number between 1 and 53. The week number is only visible for weekly calculations as can be seen in the previous two figures.

Evaporation
Loss of water through the surface of the water. This is measured in millimetres per day (mm/day).

Transpiration
Loss of water through foliage in the riparian zone. This is measured in millimetres per day (mm/day).

Start date
Start date of the 17-day date and time related calculations. The start date is only visible for date and time related calculations as can be seen in the previous two figures.

Overflow checking
The discharge in each reach will be checked against the capacity discharge of the specific reach. If the discharge exceeds the canal capacity, a message is written in the messages page.

Do lag time calculations
The lag time will be calculated for each reach by making use of the mean velocity and the length of the specific reach. The lag times will vary depending on the discharge in the canal.

Add evaporation
The evaporation loss will be calculated for each reach considering the free water surface.

Add transpiration
The transpiration loss will be calculated for each reach.

Add seepage
The seepage loss will be calculated for each reach considering the wetted area.

Add canal storage
The canal storage will be added to the calculated release. This option is normally used if the canal is empty and it needs to be filled.

Use time settings
WAS can calculate time settings as small as five minute intervals. This is too small for any practical purposes and the time setting is used to enforce a practical time setting. The time setting can only be used for the river or main canal and branches, it cannot be used for turnouts into farms.

Display 2 weeks
This specifies to use a 2-week window for water release calculations when using weekly-based water requests. This option is only visible when using weekly-based water requests.

4.5 PROPERTIES CALCULATOR

To open the properties calculator form, click on the speed button on the top of the canal layout page.
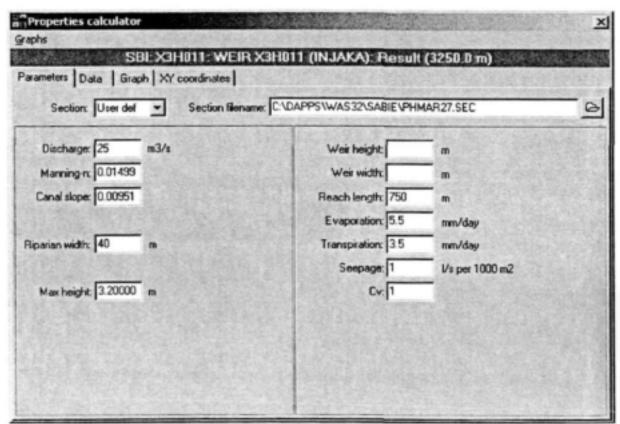

Figure 35: Properties calculator

4.5.1 PARAMETERS PAGE

Section
The following cross-section types can be selected from a drop down list:

- **Rectangle**
  If selected, the top width-capturing box falls away.
- **Trapezoid**

- **Parabola**
  If selected, the bottom width-capturing box falls away and the side slope-capturing box changes to top width.
- **Pipe**
  If selected, the bottom width-capturing box as well as the side slope-capturing box disappears and a new box – Diameter – is added.
- **Rect/Para**
  If selected, the side slope-capturing box is replaced with the top width-capturing box.
- **User def**
  If selected, the XY Coordinates page and the section filename-edit box appear. The section filename specifies the filename and location of the user defined cross-sectional properties. The user defined cross-section type is normally used for rivers.

Discharge
Release of water measured in cubic meters per hour (m^3/hour).

Manning-n
Manning roughness coefficient of the canal or river reach. For user defined cross-sections like rivers the Manning-n value is a function of the flow depth and is read from a cross-section properties file. The Manning-n value is assumed constant for prismatic cross-sections.

Canal slope
Longitudinal slope of the canal or river reach.

Riparian width
Riparian width of the river that is used for transpiration calculations. The riparian width is normally not used for lined canals.

Max height
Maximum height of the canal or river reach.

Weir height
Weir height across the canal or river reach.

Weir width
Weir width across the canal or river reach.

Reach length
Length of the canal or river reach measured in meters.

Evaporation
Loss of water in the canal or river reach through the surface of the water measured in mm/day.

Transpiration
Loss of water in the canal or river reach through transpiration over the riparian width measured in mm/day.

Seepage
Loss of water through the wetted area of the canal or river reach measured in l/s per 1000 m^2.

Cv
Lag time calibration constant of the reach. To calibrate the lag time in a reach, the average velocity is multiplied by the Cv-constant. The Cv-constant is assumed constant over the total range of discharges for a given reach.

4.5.2 DATA PAGE

The data page displays all the steady state calculations on the reach that can be used for calibration purposes for every reach. The specified maximum discharge is divided by ten and the normal flow depth is calculated for each discharge using the Manning-equation. The other parameters are calculated from the flow depth and reach length.

Q (m3/s)	h (m)	Area (m2)	b (m)	P (m)	v (m/s)	v*Cv (m/s)	Lag (min)	Vol (m3)	Evap (m3/h)	Trans (m3/h)	Seep
0	0.227	0.498	3.730	3.816	0.50	0.50	33.2	498	2	8	0
3	0.611	2.679	7.810	8.102	0.93	0.93	17.9	2679	3	7	0
5	0.803	4.390	9.451	9.844	1.14	1.14	14.6	4390	4	6	0
8	0.941	5.732	9.945	10.431	1.31	1.31	12.7	5732	4	6	0
10	1.063	6.988	10.547	11.115	1.43	1.43	11.6	6988	4	6	0
13	1.167	8.103	10.848	11.512	1.54	1.54	10.8	8103	5	6	0
15	1.260	9.105	10.975	11.735	1.65	1.65	10.1	9105	5	6	0
18	1.346	10.059	11.094	11.946	1.74	1.74	9.6	10059	5	6	0
20	1.428	10.970	11.208	12.145	1.82	1.82	9.1	10970	5	6	0
23	1.506	11.846	11.315	12.335	1.90	1.90	8.8	11846	5	6	0
25	1.580	12.696	11.412	12.513	1.97	1.97	8.5	12696	5	6	0

Figure 36: Properties calculator: Data page

The different columns are described below.

Q (m³/h)
Discharge used for calculations. The canal or river capacity is taken and divided by 10 to create a number of rows to analyse the specific reach.

h (m)
Normal flow depth of the canal or river calculated with the Manning equation.

Area (m²)
Calculated cross-sectional area of the reach at every discharge.

b (m)
Calculated water surface width of the reach at every discharge.

P (m)
Calculated wetted perimeter of the reach at every discharge.

v (m/s)
Calculated average velocity of the reach at every discharge.

v'Cv (m/s)
Average velocity multiplied by the calibration coefficient.

Lag (min)
Lag time over the reach at every discharge.

Vol. (m³)
Capacity of the reach at every discharge.

Evap. (m³/h)
Evaporation loss over the reach at every discharge.

Trans (m³/h)
Transpiration loss over the reach at every discharge.

Seep (m³/h)
Seepage loss over the reach at every discharge.

Fr
Dimensionless Froude Number calculated at every discharge to determine if the flow is sub- or supercritical. If this number is greater than one, the flow is supercritical (fast), if it is less than one; the flow is subcritical (slow).

4.5.3 GRAPH PAGE

A number of graphs are available that can be viewed on screen or sent to a printer. An example of a river cross-section is displayed in the following graph. The available graphs can be selected from a drop down menu with the following options:

- Water depth
- Area
- Surface width
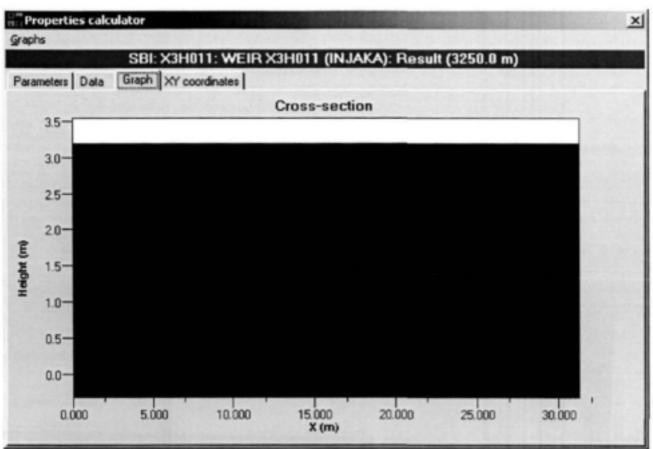- Wetted parameter
- Velocity
- Lag time
- Cross-section

Figure 37: River cross-section

4.5.4 XY COORDINATES PAGE

This page is used to display XY-coordinates of user-defined cross-sections. The XY-coordinates are used to draw the cross-section. This page is only visible when a user-defined cross-section is selected

4.6 DISTRIBUTION SHEET

The distribution sheet form is used to generate reports for water bailiffs that are used for water distribution on canal networks. Distribution sheets can be printed per water ward and in a user specified sort order. To open the Distribution sheet, select **Output|Water|Distribution sheet**:
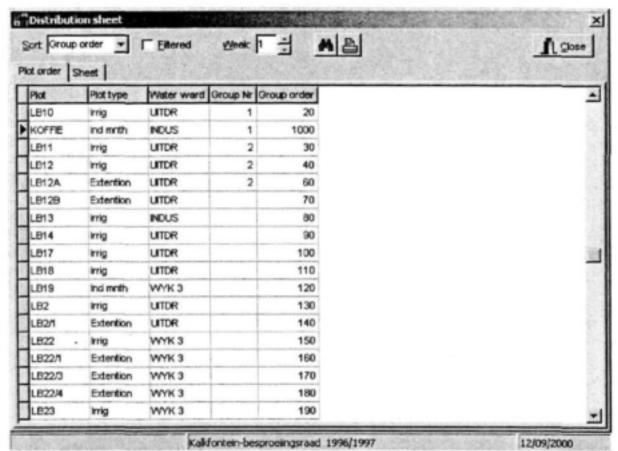
Figure 38: Distribution sheet

The Distribution sheet can be sorted according to:

- User
- Water ward
- Group order

4.6.1 USER ORDER PAGE

User
This is the unique number or reference number identifying a specific user.

User type
Specific user type.

Water ward
Water ward of every user.

Group no
Group no linked to every user. The group no and group order is used in combination to specify the printing order of the distribution sheet.

Group order
Group order within the specified group no. The group no and group order is used in combination to specify the printing order of the distribution sheet.

4.6.2 SHEET PAGE

User

This is the unique number or reference number identifying a specific user.

Structure

Structure measuring the water delivery at the specific point. If the discharge can be converted to a measuring plate reading by means of an equation or discharge table the program will do so and print the corresponding measuring plate readings as part of the report.

Hours

Total hours of water requested for the specified week.

Type

Water request type abbreviated as follows:

- O: Original
- A: Additional
- K: Cancellation

Su (Day) – Su (Night)

This report is generated for the period Sunday morning to the following week Sunday night.

Vol. (m³)

Total volume of water requested for the specified week.

Time

Opening and closing time of the specific sluice or starting and stopping time of the specific abstraction.

CHAPTER 5 STATE ACCOUNTING MODULE

This module links with the water request module and administers all the water accounts on an irrigation scheme or water management office. The user can choose between two accounting systems. The one is the current Department of Water Affairs accounting system and the other one is a full debit system that prints monthly accounts on pre-printed stationery, reconciliation reports, age analysis reports and audit trail reports.

5.1 STATE ACCOUNTS

The State Accounts are based on a system used by government owned irrigation schemes, which use two invoices per year for irrigators and monthly invoices for industrial user accounts. This system is not auditable because financial information can be change without an audit trail. Outstanding balances cannot be transferred from one year to the other and it is therefore impossible to print a single report on the financial status of a single user. The interest calculation is very complicated and can only be calculated when a payment is made by a user.

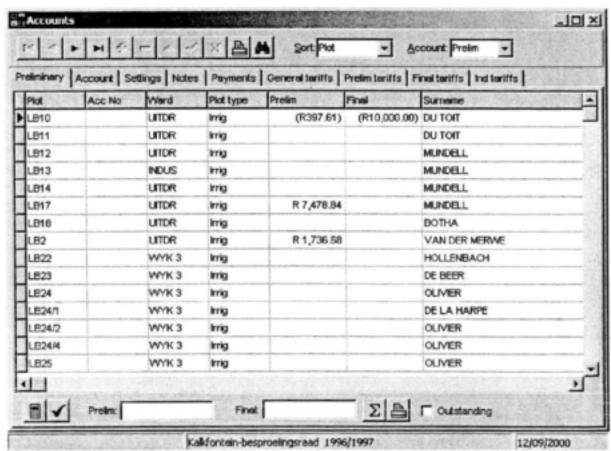To open the State Accounts, select **Input|Accounts** from the main menu:

Plot	Acc No	Ward	Plot type	Prelim	Final	Surname
LB10		UITDR	Irrig	(R397.61)	(R10,000.00)	DU TOIT
LB11		UITDR	Irrig			DU TOIT
LB12		UITDR	Irrig			MUNDELL
LB13		INDUS	Irrig			MUNDELL
LB14		UITDR	Irrig			MUNDELL
LB17		UITDR	Irrig	R 7,478.84		MUNDELL
LB18		UITDR	Irrig			BOTHA
LB2		UITDR	Irrig	R 1,736.58		VAN DER MERWE
LB22		WYK 3	Irrig			HOLLENBACH
LB23		WYK 3	Irrig			DE BEER
LB24		WYK 3	Irrig			OLIVIER
LB24/1		WYK 3	Irrig			DE LA HARPE
LB24/2		WYK 3	Irrig			OLIVIER
LB24/4		WYK 3	Irrig			OLIVIER
LB25		WYK 3	Irrig			OLIVIER

Figure 39: State accounts

Speed buttons and controls

The account drop down list box is used to select the account type.

- Prelim

- Final
- Ind Mnth

Calculate all accounts

Initialise accounts

The Accounts screen can be sorted according to:

- User
- Name
- Water ward
- Account nr

5.1.1 PRELIMINARY / FINAL / MONTHLY PAGE

The title of the first page depends on the selection in the account drop down list box. Only the irrigation users are displayed if the account type is set to Prelim or Final. Only the monthly accounts are displayed if the account type is set to Ind Mnth.

User
This is a unique number or reference number identifying a specific user.

Acc no
Account number of the specific user.

Ward
The irrigation scheme is divided into different water wards. Each ward has a specific name or code by which it is recognised. The code for the water ward, where the user is situated, will automatically be retrieved when the user number is captured.

User type
By capturing the user number, this information will automatically be retrieved from the user information form.

Prelim
The preliminary column displays the invoice total of the fist invoice of two for the current water year for irrigation users. This column is only visible if the account type is set to *Prelim* or *Final*.

Final
The final column displays the invoice total of the second invoice of two for the current water year for irrigation users. This column is only visible if the account type is set to *Prelim* or *Final*.

Monthly
The monthly column displays the invoice total of industrial monthly accounts. This column is only visible if the account type is set to *Ind Mnth*.

Surname
Surname of the user.

Name
Initials or name of the user.

5.1.2 ACCOUNT PAGE

In this page, the user can view the actual invoice of a specific user.

5.1.3 SETTINGS PAGE

This page is used to specify settings that have an effect on the printing of invoices.

Printer Font
The user can set up the following:

- Font
- Size
- Style

Titles
These capturing boxes allow the user to capture the different titles of the scheme. These titles will appear at the top of the invoice. There are four capturing boxes:

- Main
- Prelim Account
- Final Account
- Month Account

The operator can select which title should be printed on which account.

Account note
In the notes page, a note can be typed. This note can then be tagged to a specific invoice or it could be a general note sent out with all the invoices. If the note should be sent out to a specific user, make sure to capture the correct user number in the provided box. Radio buttons that can be selected:

- None
- General
- User
- Both

Address search order
This specifies the address that will appear on the invoice. Two options are available:

- Postal then owner
- Owner then postal

Note ID
In the notes page, the user has the option of typing a note with a unique ID. This note ID can be selected and will then be printed on the invoice.

Month
The specific month can be selected from a drop down list.

Print top margin
The settings of the printer can be changed in this box to where you want the printer to start printing the top margin.

Print left margin
The settings of the printer can be changed in this box to where you want the printer to start printing the left margin.

Print zero balances
In this section the user can decide if zero balances must be printed or not.

Print title
In this section the user can decide if the title must be printed or not.

5.1.4 NOTES PAGE

This is where notes can be inserted that appear on invoices and statements.

Note ID
A number or name allocated to a specific note. These notes will later be tagged to an account and are printed on the invoice. The user has the choice between:

- Afrikaans
- English

5.1.5 PAYMENTS PAGE

This page refers to payments received.

User
This is a unique number or reference number identifying a specific user.

Type
Two types of payments are used in the State Accounting system, and can be selected from a drop down list:
- Preliminary
- Final

Date
Date when payment was received.

Receipt nr
Number of the receipt when payment was received.

Amount
Amount that was paid.

Note
Any information concerning the account and payments can be placed here. This information is for the user's use only and is not sent out with the invoice.

5.1.6 GENERAL TARRIFFS PAGE

Year
A selection of a specific year can be made from a drop down list.

Days grace
Number of days extra for payment that the scheme allows the user.

Min amount
Minimum amount payable.

Min mnth payable
Minimum amount per month that is payable.

5.1.7 PRELIM TARRIFFS

Year
A selection of a specific year can be made from a drop down list.

Issued
Date on which the prelim tariffs were issued.

Date 30
Date payable after 30 days of issue.

VAT (%)
VAT rate.

Interest (%)
Interest rate.

Canal full quota (R/ha)
The full quota water tariff that is payable for water delivered through a canal.

% Payable
Percentage that must be paid.

WRF (R/ha)
Water Research Fund (WRF) rate.

WRF Interest (%)
Water Research Fund interest rate.

WRF VAT (%)
Water Research Fund VAT rate.

19mm (R)
The tariff for a 19mm diameter household or livestock pipe installed in a canal.

25mm (R)
The tariff for a 25mm diameter household or livestock pipe installed in a canal.

32mm (R)
The tariff for a 32mm diameter household or livestock pipe installed in a canal.

38mm (R)
The tariff for a 38mm diameter household or livestock pipe installed in a canal.

River full quota (R/ha)
The full quota water tariff that is payable for water used from a river.

5.1.8 FINAL TARRIFFS

The final account rates and tariffs are captured on this page and consist of the following.

Year
A selection of a specific year can be made from a drop down list.

Issued
Date on which the final tariffs were issued.

Date 30
Date payable after 30 days.

VAT (%)
VAT rate.

Interest (%)
Interest rate.

Canal min (R/ha)
Minimum canal tariff.

River min (R/ha)
Minimum river tariff.

Canal used (c/m^3)
Canal water usage tariff.

River used (c/m^3)
River water usage tariff.

Extra 1 (c/m^3)
Extra water used tariff applied up to 10 000 m^3.

Extra 2 (c/m^3)
Extra water used tariff applied from 10 000 to 20 000 m^3.

Extra 3 (c/m^3)
Extra water used tariff applied from 20 000 to 30 000 m^3

Extra 4 (c/m^3)
Extra water used tariff applied from 30 000 to 40 000 m^3

5.1.9 INDUSTRIAL TARRIFFS

User
This is the unique number or reference number identifying a specific user.

Free vol (m^3)
This is the amount of free water allocated to a specific user.

Quota vol (m^3)
This is the quota of water allocated to a specific user.

Total vol (m^3)
This is the total volume of water, free water and quota water, allocated to a specific user.

Tariff ID
Tariff ID linked to the specific user.

CHAPTER 6 DEBIT ACCOUNTING MODULE

This is a full debit system that prints monthly accounts on pre-printed stationery. This includes reconciliation reports, age analysis reports and audit trail reports.

6.1 ACCOUNT REQUESTS

The Account Requests form is used to answer queries an all accounts. To open the Account Requests form, go to **Output|Accounts|Account Requests**:

Plot	Surname	Initials	90-120	60-90	30-60	0-30	Total
1	BERGRET FARMS PTY LTD		0	0	0	-367.85	(R367.
10	LATEGAN	P.	0	0	0	242.99	R 24:
100	ROOS	P.S.	12928.57	1349.43	1367.74	1141.2	R 16,78
1000	ELS	J.C.	3351.72	484.97	491.55	454.91	R 4,78:
1001	LOUW	D.P.	0.01	662.01	662.01	589.81	R 1,91:
1002	B.J. STANDER	MNR	4066.96	708.32	717.93	657.77	R 6,19
1003	OOSTHUIZEN	P.J	0	0	0	515.58	R 51:
1004	OOTSHUIZEN	P.J.	0	0	0	559	R 55!
1005	DU PLESSIS	J.C	0	0	0	189.95	R 18!
1006	LABUSCHAGNE	K.	0	0	681.31	607.85	R 1,28:
1007	DU PLESSIS	J.C.	0	0	0.01	374.48	R 37-
1008	DU PLESSIS	J C	0	0	0	481.31	R 46
1009	PAULEY	H.L.	0.03	958.99	958.99	854.4	R 2,77:
101	ROOS	P.S.	13604.6	1454.23	1473.96	1335.92	R 17,86
1010	DU PLESSIS	J.C	0	0	0	841.21	R 84
1011	WENHOLDT	M.H.	0	0	309.28	280.51	R 58!
1012	BASSON BOERDERY	J.S.	903.3	903.3	915.72	828.61	R 3,59

Hartbeespoort-besproeiingsraad 1999/2000   12/09/2000

Figure 40: Accounts requests

The Account requests form can be sorted according to:

- User
- Surname

Descriptions of pages in this form:

6.1.1 USER PAGE

The user page is where all the information relating to specific user is captured.

User
This is a unique number or reference number identifying a specific user, in this case, an account number.

Surname
Surname of the user owner or tenant.

Initials
Initials of the user owner or tenant.

90 – 120
Number of days that the account is outstanding. In this column, the account is 90 – 120 days and more.

60 – 90
Number of days that the account is outstanding. In this column, the account is 60 – 90 days.

30 – 60
Number of days that the account is outstanding. In this column, the account is 30 – 60 days.

0 – 30
Number of days that the account is outstanding. In this column, the account is 0 – 30 days.

Total
Total amount outstanding.

6.1.2 CURRENT PAGE

This page displays the current transactions for a specific account. All current transactions are processed during the month end procedure and are printed on the invoice of the specific account. All transactions are archived at the end of the month end procedure.

Type
Transaction type.

Nr
Transaction number.

User
This is a unique number or reference number identifying a specific user. In this case, it is used as an account number.

Date
Date when a transaction took place.

Account
Type of transaction that took place.

Amount
Amount of the transaction.

6.1.3 ARCHIVE PAGE

This page displays all archived transactions of a specific account. This information is normally used to resolve any queries.

Type
Account type.

Nr
Transaction number.

User
A unique number or reference number identifying a specific user, in this case, an account number.

Date
Date when the transaction took place.

Account
Type of transaction that took place.

Amount
Amount of the transaction.

6.1.4 INVOICE PAGE

The invoice page displays the invoices of all accounts created during the previous month end procedure. All invoices are updated during a month end procedure and only the current invoices can be reprinted.

6.2 SOURCE DOCUMENTS

To open the Source documents form, select **Output|Accounts|Source documents**. The source documents form is used to report on all source documents and it is designed to generate reports with a range of settings that can be specified by the user. It is possible to query the database for any current transaction as well as archived transactions. The user can set a date range, make use of a filter or specify the document type to minimise the number of transactions that will be displayed on screen. This is especially useful when working in the archive because the number of transactions increases after every month end. All transactions created since the last month end are current, which is then archived as part of the month end procedure.

From and to date
When the ellipses button is selected a pop-up calendar appears. Only the transactions created for a specified date range will be displayed.

Filtered
This option is context sensitive and will filter the column that the cursor is standing on. The filter option is only available on the Details page.

Use archive
If the use archive box is checked only the archived transactions for the specified date range and document type will be displayed.

Doc type
The document type option is used to specify the document type to be displayed within the date range. The following options are available from a drop down list:

- *All*
- Hand invoice
- Hand receipt
- Hand journal
- Comp invoice
- Comp receipt
- Comp journal

Find doc
This button is used to find a document by typing the document number into the pop-up find box.

Note
The note box at the bottom of the screen displays the note that is linked to the current transaction, if any.

Total amount
Total amount of all transactions.
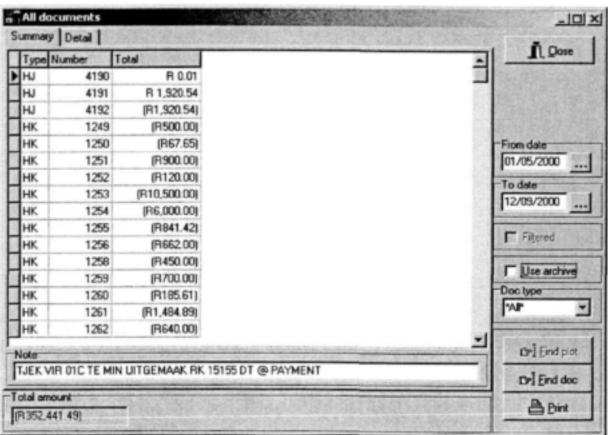
Print
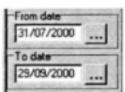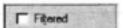Used to print the current report.

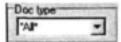

Figure 41: Source documents

Controls

The *from* and *to* dates are used to specify a date range to select only a subset of data from the database.

The *filtered* check box is only available on the details page and is used to filter the current subset of data. The filter is context sensitive and uses the current value in the active column to set the filter.

The *use archive* check box is used to switch between the current and archived records. All current records are archived after every month end procedure.

The *document type* drop down list box is used to specify the document type/s that is selected from the database. Available options are:

- Hand invoice
- Hand receipt
- Hand journal
- Comp invoice
- Comp receipt
- Comp journal

The following describes the different columns on the Summary and Detail pages.

6.2.1 SUMMARY PAGE

This page displays the totals of the different transaction types that occurred with a grand total at the bottom of the screen. The transactions that are displayed depend on the date range and document type setting.

Type
Transaction type.

Number
Transaction number.

Total
Total of each transaction type.

6.2.2 DETAIL PAGE

This page displays a detailed report of all the different transaction types that occurred. The transactions that are displayed depend on the date range, filter setting and document type setting.

Type
Transaction type.

Nr
Transaction number.

User
This is a unique number or reference number identifying a specific user.

Date
Date when the transaction was created.

Account
Description of transaction.

Amount
Total of each transaction type.

6.3 AUDIT TRAIL

To open the Audit Trail form, select **Output|Accounts|Audit trial** from the main menu:
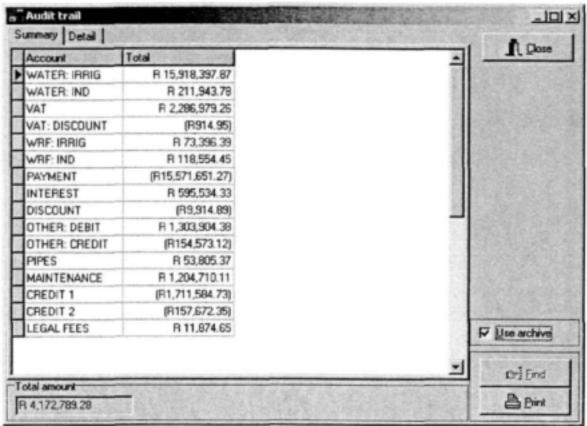
Figure 42: Audit trail

Descriptions of pages:

6.3.1 SUMMARY PAGE

The summary page displays the list of transactions and totals.

Account
Type of transaction that took place.

Total
Total of the transaction that took place.

Use Archive
This will change the list of transactions displayed between current and archived transactions.

Total amount
Total amount of all transactions.

Find
This feature provides the user with the option to find a document by typing the document number into the pop-up find box.

Print
This is to print the summary of the audit trail.

6.3.2 DETAIL PAGE

This page displays a detailed report of all the different transaction types that occurred.

Type
Transaction type.

Nr
Transaction number.

User
This is the unique number or reference number identifying a specific user, in this case an account number.

Date
Date when the transaction took place.

Account
Type of transaction that took place.

Amount
Amount of the transaction.

Use Archive
This will change the list of transactions displayed between current and archived transactions.

Find
This feature provides the operator with the option to find a document by typing the document number into the pop-up find box.

Print
This is to print the summary of the audit trail.

Total amount
Total amount of all transactions.

Note
The note box at the bottom of the screen displays the note that is linked to the current transaction, if any.

6.4 ACCOUNT BALANCES

To open the Account Balances, select **Output|Accounts|Reports|Age analysis** from the main menu:
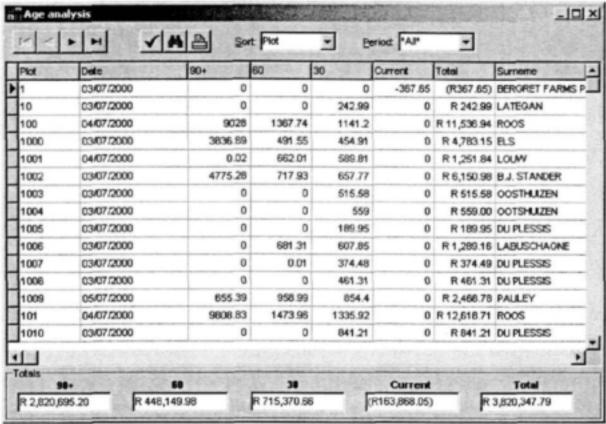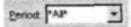
Figure 43: Age analysis

Speed buttons and controls

Verify account balance records

The period list box is used to set the aging period that is used to limit the output of the age analysis to a specific period. The options available are:

- *All*
- Current
- 30 Days +
- 60 Days +
- 90 Days +
- Credit

The Age analysis can be sorted according to:

- User
- Surname
- Current
- Ward

90

User
This is the unique number or reference number identifying a specific user. In this case an account number.

Date
Date when the age analysis was last updated.

90+
Total amount of all accounts that is 90 days and more outstanding.

60
Total amount of all accounts that is 60 days and more outstanding.

30
Total amount of all accounts that is 30 days and more outstanding.

Current
Current amount outstanding of all accounts.

Total
Total amount outstanding of all accounts.

Surname
Surname of the user.

Initials
Initials of the user.

Line 1 to Line 3
Address lines.

City
Name of the city on the address of the user.

Code
Postal code.

Tel No
Telephone number of the user.

Ward
Water ward of the user.

6.5 INDUSTRIAL LEVIES

To open the Industrial Levies screen, select **Output|Accounts|Report|List of industrial levies** from the main menu.
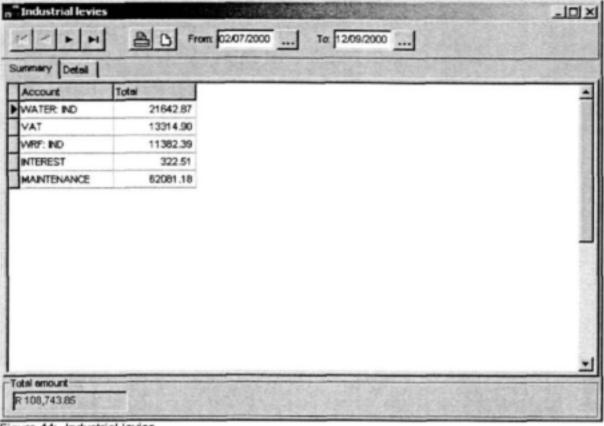
Figure 44: Industrial levies

Speed buttons

The Refresh Report button is used to refresh the report if the date range has changed.

6.5.1 SUMMARY PAGE

The summary page displays the summary of the industrial levies (*Ind Mnth* users) in the following columns:

Account
Type of transaction that took place.

Total
Total amount of the transaction, and is displayed at the bottom of the screen.

6.5.2 DETAIL PAGE

The detail page displays the detail of the industrial levies in the following columns:

User
This is the unique name or reference number identifying a specific user, in this case an account number.

Date
The date when the transaction took place.

Acc No
The account number of a specific user.

Units
Depending on the account type the units column will display the volume of water used if the account type is industrial water usage or nothing if the account type is VAT.

Tariff
The tariff of the corresponding account type.

Amount
The amount of the transaction, and the total amount are displayed at the bottom of the screen.

6.6 MONTH END PROCEDURE

To do Month End, select **Output|Accounts|Month end|Do month end** from the main menu. Several steps are involved in the month end procedure and are described in the following paragraphs.

Step 1:
The Month End procedure consists of a series of forms that prompt the operator for certain input. The first form shows three check boxes that must be checked before the operator can proceed to the next form:
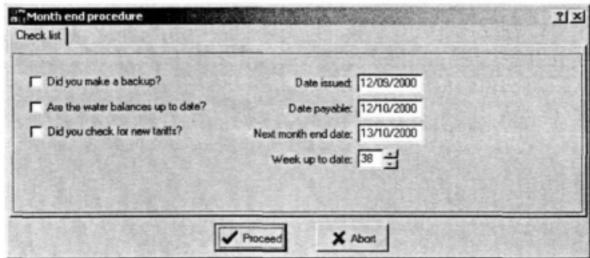

Figure 45: Month end procedure: Checklist

Check List:

- Did you make a back up?
- Are the water balances up to date?
- Did you check for new tariffs?

Four other edit boxes prompt the operator for:

Date issued
Date when the invoices will be issued.

Date payable
Date when the invoices must be paid.

Next month end date
Date of the next month end – must be 28 days or more after the previous month end date.

Week up to date
Week number that the water requests are up to date. This week number will also be used to display the meter readings for the specific week on the invoices if any.

Move on to the next form by selecting the **PROCEED** button.
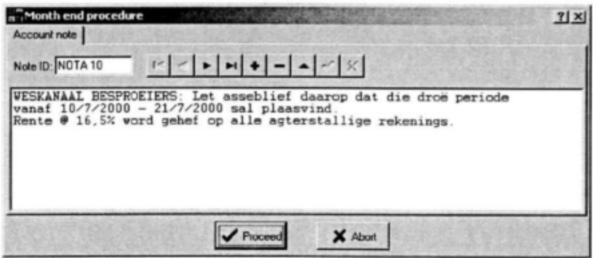
Step 2:
The Account Note page will open:

Figure 46: Month end procedure: Account note

Any notes that need to be attached to an invoice can be captured here. Select the **PROCEED** button if you want to continue with the month end procedure. If you aren't sure about going ahead with the procedure, select the **ABORT** button. When the abort button is selected, an error message, stating that roll back will start, will be generated by the system. When the **OK** button is selected, automatic roll back will commence. The user will then be back in the main screen of the program.

Step 3:
If the user wishes to proceed with the month end procedure, the **DATES & TARIFFS** screen will open:

Figure 47: Month end procedure: Dates & tariffs

If any of the tariffs have changed, the user now has the opportunity to change it. The Dates & Tariffs screen is a dialogue box with three pages.

6.6.1 SET NO PAGE

The Set No page displays all the Tariff sets for the current scheme. A tariff set consists of all the different tariffs and dates needed to do a month end procedure. A tariff set is assigned to a specific account on the user info form. The default tariff set is zero and does not have to be assigned. Only tariff sets greater than zero must be assigned to a specific account.

Set nr
Different tariff sets that can be linked to individual accounts. A tariff set is assigned to a specific account on the user information form (**Input|User information**). The default tariff set is zero and does not have to be assigned. Only tariff sets other than zero must be assigned to a specific account.

Description
Description of the specific tariff set.

6.6.2 TARIFFS PAGE

In the Tariffs page, the user can capture or edit the tariffs. The Tariff column in this page has a fixed number of entries that is automatically created when a new tariff set is inserted.

To Change a tariff
Select the Insert/Upd button at the bottom of the screen. A pop-up dialogue box will appear. The title of this dialogue box will differ, depending on the date or tariff that is selected. Change the current data and select OK with the mouse pointer. If the delete button is selected a confirmation prompt will appear.

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The user is able to delete any historical values of a tariff set, but is prevented from deleting any active values of a tariff set.

Selecting the history button can see a list of historical values of a specific tariff. To switch back to the current values of a tariff set, select the current button.

Descriptions:

Set nr
Tariff set number.

Tariff
Description of the specific tariff.

Date
Date when the tariff was last changed.

Value
The Tariff column has a fixed number of entries that is automatically created when a new tariff set is inserted:

Selecting the Insert/Upd button at the bottom of the screen can change any tariff. A pop-up dialogue box will appear. The title of this dialogue box will differ, depending on the date or tariff that is selected. Change the current data and select OK with the mouse pointer.

When the Delete button is selected, a confirmation prompt appears. The operator is able to delete any historical values of a tariff set but is prevented from deleting any active values of a tariff set.

Selecting the history button can see a list of historical values of a specific tariff. To switch back to the current values of a tariff set, select the current button.

6.6.3 CONTROL PARAMETERS PAGE

Different transactions done for a specific month can be viewed in the Control Parameters page of the Dates & Tariffs form.

If all the tariffs are correct, Select OK. A pop-up dialogue box asking 'Tariffs OK', 'Proceed Month End?' will appear. Select the YES button to proceed. The **PROGRESS PAGE** is displayed. Seven actions with check boxes are displayed:

- ❑ Check and Print Tariffs
- ❑ Do calculations
- ❑ Print Reconciliation
- ❑ Print Age analysis
- ❑ Print Statements
- ❑ Do ageing
- ❑ Archive transactions

These buttons are automatically checked by the system. After completion a pop-up dialogue box telling the user that month end procedure is completed will appear. Select OK. The user will go back to the main screen of the program.

Descriptions:

Name
Parameter ID only for internal use.

Description
A more descriptive name for the specific parameter.

Value
Specific parameter value.

In all three pages the **Delete, Insert/Upd, History, Current, Print** and **OK** buttons can be found. When the user is in the Set No Page, the History and Current buttons will not be activated and when the Control Parameters page is selected only the Print and OK buttons are activated.

6.7 AGE ANALYSIS

To print *Month End Age Analysis*, select **Output|Accounts|Month end|Print age analysis** from the main menu.

Plot	Surname	Initials	90-120	60-90	30-60	0-30	Total
1	BERGRET FARMS PTY LTD		0	0	0	-367.65	(R367.65)
10	LATEGAN	P.	0	0	0	242.99	R 242.99
100	ROOS	P.S.	12928.57	1349.43	1367.74	1141.2	R 16,786.94
1000	ELS	J.C.	3351.72	484.97	491.55	454.91	R 4,783.15
1001	LOUW	D.P.	0.01	662.01	662.01	589.81	R 1,913.84
1002	B.J. STANDER	MNR	4066.96	708.32	717.93	657.77	R 6,150.98
1003	OOSTHUIZEN	P.J	0	0	0	515.58	R 515.58
1004	OOTSHUIZEN	P.J.	0	0	0	559	R 559.00
1005	DU PLESSIS	J.C	0	0	0	189.95	R 189.95
1006	LABUSCHAGNE	K.	0	0	681.31	607.85	R 1,289.16
1007	DU PLESSIS	J.C.	0	0	0.01	374.48	R 374.49
1008	DU PLESSIS	J C	0	0	0	461.31	R 461.31
1009	PAULEY	H.L.	0.03	958.99	958.99	854.4	R 2,772.41
101	ROOS	P.S.	13604.6	1454.23	1473.96	1335.92	R 17,868.71
1010	DU PLESSIS	J.C	0	0	0	841.21	R 841.21

Totals

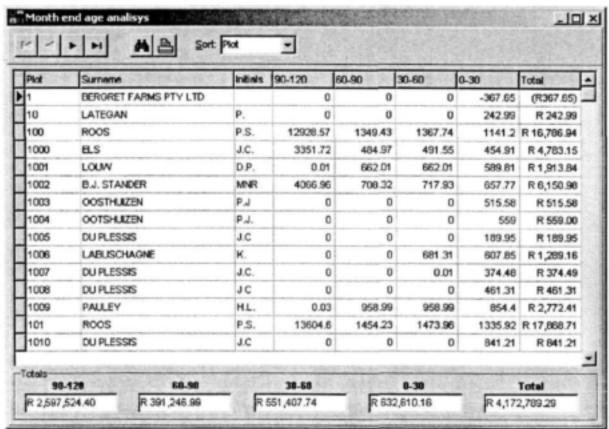| 90-120	60-90	30-60	0-30	Total
R 2,597,524.40	R 391,246.99	R 551,407.74	R 632,610.16	R 4,172,789.29

Figure 48: Month end age analysis

Description of columns:

User
This is the unique number or a reference number identifying a specific user, in this case an account number.

Surname
Surname of the user.

Initials
Initials of the user.

90 –120
Amount and the number of days that all the accounts are outstanding.

60 – 90
Amount and the number of days that all the accounts are outstanding.

30 – 60
Amount and the number of days that all the accounts are outstanding.

0 – 30
Amount and the number of days that all the accounts are outstanding.

Total
Total amount outstanding on all the accounts.

6.8 INVOICES

To print Invoices, select **Output|Accounts|Month end|Print statements** from the main menu:

Plot	Name	Address	Amount	Flag
300	FRAYNE P	POSBUS 2643	18375.28	
739	BEZUIDENHOUT W.J.	POSBUS 2822	1242.55	
152	OELOFSE K.	POSBUS 452	3833.05	
326	FULLIMPUT	POSBUS 67	3852.90	
110	ENGELBRECHT E.M.	POSBUS 794	2656.16	
1143	MEYER D.A.	POSBUS 1	559.00	
1144	MEYER D.A.	POSBUS 1	559.00	
1239	PRETORIUS SMAE	POSBUS 10	1499.01	
D68	SMIT M.J.R	POSBUS 1002	150.98	
D44	CARRARO G.	POSBUS 1004	157.40	
X65	DE LANGE LANDGOED	POSBUS 1004	1616.12	
409	MONTGOMERY H.S.	POSBUS 1025	4019.69	
585	DU PLESSIS J.H.	POSBUS 103	3830.19	
586	DU PLESSIS J.H.	POSBUS 103	3830.19	
596	DU PLESSIS W.A.J.	POSBUS 104	4584.02	
597	DU PLESSIS W.A.J.	POSBUS 104	4899.30	

Nr of invoices: 1689   Total amount: R 4,172,788.50   Nr not printed: 0

Figure 49: Invoices

Speed buttons

Find sub-string

Invoices can be sorted according to:

- User
- Name
- Address

Description of pages:

6.8.1 USER PAGE

The user information page.

User
This is a unique number or reference number identifying a specific user, in this case it is used as an account number.

Name
Name of the user.

Address
Address of the user.

Flag
Printed state of the invoice. If checked, the document is marked for printing.

6.9 RECONCILIATION

To view the **Reconciliation** information, select **Output|Accounts|Reconciliation** from the main menu:
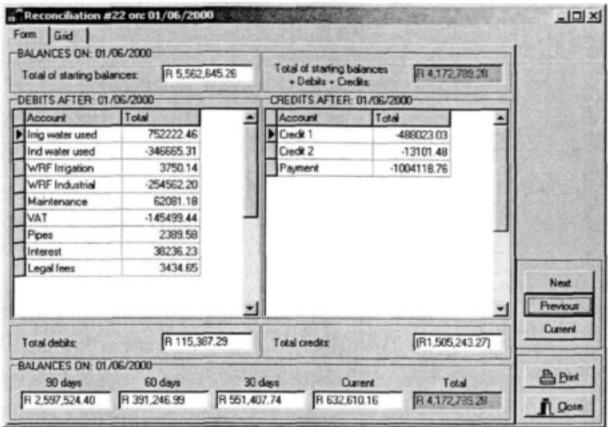
Figure 50: Reconciliation

The Reconciliation screen is used to view the status of the outstanding accounts registered with the scheme. Description of display boxes at the bottom of the screen:

Total debits
Total debits for a specific period.

Total credits
Total credits for a specific period.

90 days
Account balances outstanding for a period of 90 days and more.

60 days
Balances outstanding for a period of 60 days and more.

30 days
Balances outstanding for a period of 30 days and more.

Current
Total of all current balances.

Total
Total of all account balances. A value in brackets indicates a credit balance.

Description of pages in the Reconciliation form:

6.9.1 FORM PAGE

Total of starting balances
Total balance that the new month will start with.

Total of starting balances + Debits + Credits
This refers to the total balance the new month will start with including debits and credits.

Account
Account number of a specific user.

Total
Total of the debits and credits of a specific account.

6.9.2 GRID PAGE

The Grid page displays all the account information in more detail.

Number
Reconciliation number.

Account
Description of the specific account.

Total
Total of the specific account.

6.10 SOURCE DOCUMENTS

To open the Source Documents screen, select **Input|Accounts|Source documents** from the main menu:
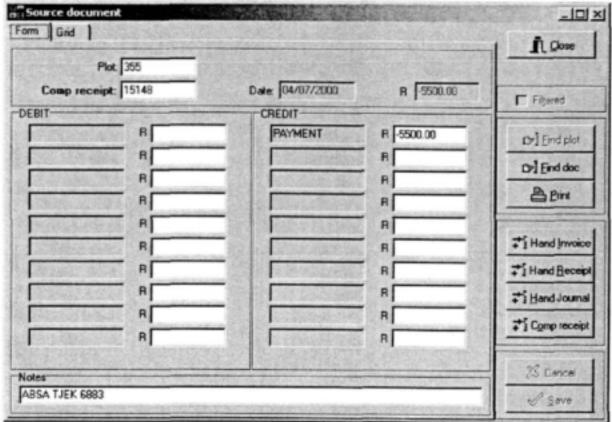
Figure 51: Source document

The Source Document form consists of two pages:

6.10.1 FORM PAGE

To enter data, select the following buttons:

- Hand Invoice
- Hand Receipt
- Hand Journal
- Comp receipt

When one of these buttons is selected, a clean form for data capturing will appear:

The user number and Hand journal number can be entered manually. Please note that the title of this capturing box will change according to your selection. The data for the Date and R capturing boxes is generated by the system.

Information to be captured:

- Debit
- Credit

Accounts
Description
▶ AMORTAGE
BOARD: LEVY
CAPITAL: LEVY 1
CAPITAL: LEVY 2
CMC: IND
CREDIT 1
CREDIT 2
DISCOUNT
DLU LEVY
EXTRA
INTEREST
LEGAL FEES
MAINTENANCE
OTHER: CREDIT
OTHER: DEBIT
PAYMENT
PENALTY
PIPES
SERVICE LEVY
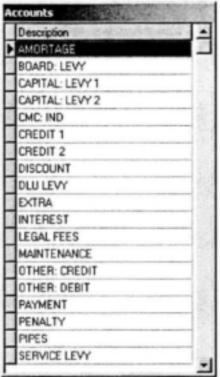
Figure 52: Accounts lookup

If an error was made, select the cancel button at the bottom right hand corner. If this error is saved by mistake, the only way of correcting this is to do a Hand Journal.

Find document
This option provides the user with the opportunity to search for a document by providing the system with the document number. The data of that specific document will be displayed.
Options:

- A Hand invoice
- B Hand journal
- C Hand receipt
- D Comp invoice
- E Comp journal
- F Comp receipt

When one of the above options is selected, a pop-up input box asking for the document number will appear. Type in the number and select OK with the mouse pointer. The data will be displayed in the Source Document form.

Hand receipt or Comp receipt
When selecting these buttons, a receipt box will appear.
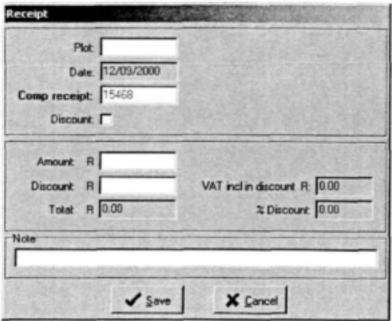
Figure 53: Receipt

The User and Receipt number boxes can be entered manually. If discount is given, select the radio button. The values in the *Total, VAT Incl. in discount* and *% Discount* boxes are calculated by WAS and cannot be captured by the user.

6.10.2 GRID PAGE

The grid page sorts all the invoices, receipts, journals and data:

Type
Data will be sorted according to the type of entry, for example, Hand Journal (HJ), Hand Receipt (HK), Comp Receipt (RK).

Nr
Number of the receipt, invoice or journal.

User
This is a unique number or reference number identifying a specific user, in this case, it is used as an account number.

Date
Date when the information was captured.

Account
Type of transaction that took place.

Amount
Amount of the transaction that took place.

6.11 ACCOUNT NOTES

To open the Account Notes, select **Input|Accounts|Account notes** from the main menu:

Figure 54: Account/User notes

This form consists of a navigation toolbar, a find option and a close option. Use the toolbar to open a new capturing box or to edit existing notes.

Note ID
This is a unique number for a specific ID. The note can be typed in the adjacent box.

6.12 HANDING OVER

The handing over of accounts module is used to administer the legal action to be taken towards an account holder who is more than 90 days outstanding on an account.

The module automatically adds all outstanding accounts to a list and charges a legal levy (admin fee) to each account. It also reports on the total amount of money paid and total amount still outstanding. To open the Handing over form, select **Input|Accounts|Handing over** from the main menu.
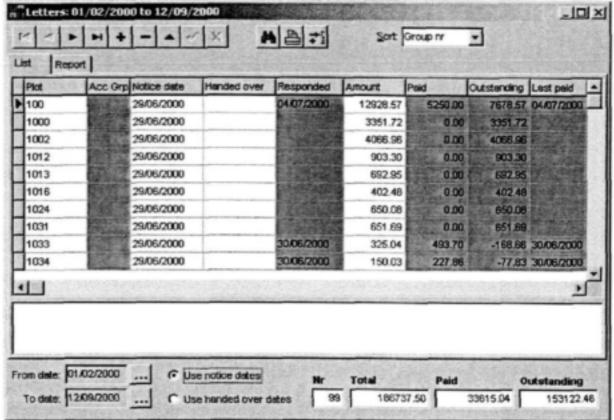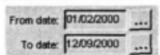
Figure 55: Handing over

Speed buttons and controls

This button is used to add accounts (users) to the handing over list that are more than R 50.00 outstanding on balances 90 days and older. If an account is added to the list a legal levy is automatically charged against the account. An account will not be added twice. The legal levy tariff can be edited on the dates and tariffs form (**Input|Accounts|Dates & tariffs**).

The from and to date boxes are used to specify the date range for the subset of data to be displayed on screen.

Select the radio button to apply the date range to notice dates.

Select the radio button to apply the date range to handed over dates.

6.12.1 LIST PAGE

This page is used to capture all the accounts that will be handed over for legal action.

User

This is a unique number or reference number identifying a specific user in this case, it is used as an account number.

Acc group

This is a group number assigned to an account to group the different accounts of the same person.

Notice date

Date when the notice was sent out. This date will default to the current date.

Handed over

Date when the account was handed over. This date can be selected from a pop-up calendar, or can be inserted manually.

Responded

Date when the last payment was received. This date will automatically be retrieved from the source document.

Amount

Outstanding amount that the user was handed over for.

Paid

Amount that was paid up to date.

Outstanding

Outstanding amount after payment was received.

Last paid

Date when the last payment was received.

Last amount

Last amount that was paid.

Arranged

If the account holder made any arrangements with the scheme, either Yes or No can be selected from a drop down menu. Details can be added in the notes box.

6.12.2 REPORT PAGE

This is a detailed report of the handed over account.

User

This is a unique number or reference number identifying a specific user. In this case it is used as an account number.

Arranged

Arrangements made for payment.

Sluice

The sluice number is included in the report to act as a reference for a physical address, where the handed over letter can be delivered.

Acc Group

Is a group number assigned to an account to group the different accounts of the same person.

Notice date

Date when the notice was sent out.

Handed over
Date when the account was handed over for legal action.

Amount
Outstanding amount.

Paid
Amount paid up to date.

Last date
Last date of payment.

Last paid
Last amount that was paid.

Surname
Surname of the account holder.

Initials
Initials of the account holder.

Line 1 – 3
This is where extra address details can be inserted.

Code
Postal code.

Tel
Telephone number of the user.

90+
Amount outstanding for 90 days and more.

60
Amount outstanding for 60 days.

30
Amount outstanding for 30 days.

Current
Current amount outstanding.

6.13 WATER SALES

The Water Sales screen is used to capture all water sales. To open the Water Sales form select **Input|Accounts|Water Sales** from main menu:

Figure 56: Water sales

The Water sales form can be sorted according to:

- Receipt no
- User
- date

Descriptions of columns:

User
This is a unique number or reference number identifying a specific user.

Water type
Type of water that was purchased, i.e. extra water.

Date
Date when the sale took place, and will default to the current date.

Volume (m³)
Volume in cubic meters purchased.

Receipt Nr
Receipt number of the transaction.

Amount
Amount of the sale.

VAT
Amount of VAT payable.

Total
Total amount of the sale, and will be calculated automatically.

CHAPTER 7 DATABASE MANAGEMENT

7.1 BACK UP

A back up is very important, and if possible, a back up should be done every day. WAS compresses the database using pkzip or any other similar program that is specified by the operator. To do a back up, select **Scheme|Back up** from the main menu:
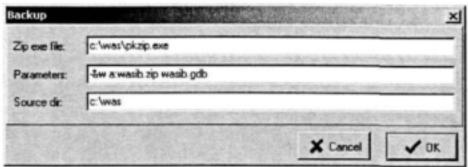
Figure 57: Back up

Zip exe file
The name and path of the executable file used to create the backup.

Parameters
Parameters that need to be specified for the backup such as backup filename and files to backup. Refer to the documentation on the backup program that is used for any further details.

Source dir
Default path for the files to backup.

7.2 RESTORE

WAS restores a backup using pkunzip or any other similar program that is specified by the user. To restore data, select **Scheme|Restore** from the main menu:
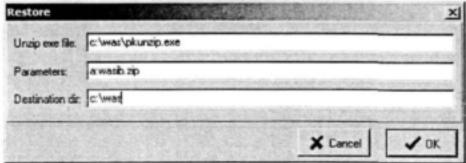
Figure 58: Restore

Unzip exe file
The name and path of the executable file used to create the backup.

Parameters
Parameters that need to be specified for the restore such as the path and filename to restore. Refer to the documentation on the restore program that is used for any further details.

111

Destination dir
Default path for the files to restore.

7.3 EMPTY DATABASE

To empty the database, select **Scheme|Empty database** from the main menu. Please note that a password is required for protection.

7.4 CLEAR ACCOUNTS

To clear all accounts, select **Scheme|Clear accounts** from the main menu. Please note that a password is required for protection.

CHAPTER 8 CALCULATING DAM OPERATING PROCEDURES

WAS has the capability to calculate operational procedures for a dam to meet certain downstream irrigation demands, in stream flow requirements (IFR), diffused inflows and any other inflows or outflows that can be quantified. The program takes any losses such as evaporation, transpiration and seepage into account. The calculation of the evaporation and transpiration losses can be reach specific by linking a different weather station to every reach. The lag times are calculated using the average velocity in every reach. The average velocity in every reach is calculated using the Manning equation. The program handles any user-defined cross-sections such as river sections. There is no limit to the number of reaches that the program can handle.

The following paragraphs describe the daily data needs, the operational steps and some questions and answers on the subject.

8.1 OPERATOR DAILY DATA NEEDS

Some of the daily data that an operator needs can be captured in advance. This is data such as the irrigation demands that will be based on irrigation schedules supplied by irrigators. An operator will need the following data on a daily basis:

- Indicator site data.
- IFR values for the specific site. This can be generated by WAS using the indicator site data.
- Diffused inflows downstream of the dam.
- River inflows downstream of the dam.
- Irrigation demands.
- Industrial and household demands.
- Weather station data for the calculation of evaporation and transpiration. The minimum data required to do the calculation is minimum and maximum temperatures. If a weather station is not linked to a reach, the operator can specify default values.
- Indicator site data such as the date, time and discharge values.

8.2 OPERATIONAL STEPS

The basic steps to calculate operational procedures for a dam are the capturing of weather data, irrigation demands, update indicator site flows, industrial and household demands, river inflows, generating IFR data from indicator site values and to calculate and print the dam settings. The following flow diagram displays the operational steps that need to be done to calculate dam settings.
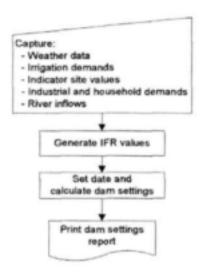
```
┌─────────────────────────────┐
│ Capture:                    │
│  - Weather data             │
│  - Irrigation demands       │
│  - Indicator site values    │
│  - Industrial and household demands │
│  - River inflows            │
└─────────────────────────────┘
              │
              ▼
     ┌──────────────────┐
     │ Generate IFR values │
     └──────────────────┘
              │
              ▼
     ┌──────────────────┐
     │    Set date and    │
     │ calculate dam settings │
     └──────────────────┘
              │
              ▼
     ┌──────────────────┐
     │  Print dam settings │
     │       report       │
     └──────────────────┘
```

Figure 59: Operational steps

8.3 QUESTIONS AND ANSWERS

8.3.1 HOW DO I CAPTURE THE WEATHER DATA?
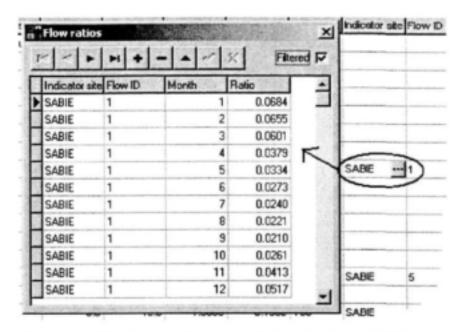
Automatic weather station data can be captured or imported into WAS from text files. The weather data is used by WAS during the water release calculations to calculate evaporation and transpiration losses for each reach of the canal or river. It is possible to link a different weather station to every reach but if no weather station is specified default values specified by the user are used. To go to the weather stations form select **Input|Water|Weather stations** from the main menu. See paragraph 3.6 for a detailed description on weather station data.

8.3.2 HOW DO I HANDLE WEATHER FORECASTS?

Weather forecasts are handled by capturing the weather data in advance. WAS will use the forecasted data where necessary, just remember to replace the forecasted data with the real data when it becomes available.

8.3.3 HOW DO I CAPTURE THE INDICATOR SITE VALUES?
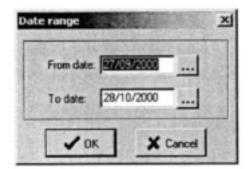
The indicator site flow ratios form can be accessed through an ellipses button in the indicator site column on the stations page of the measuring structures form. To access the measuring structures form select **Input|Water|Measuring stations** from the main menu. Once on the measuring stations form select a specific record in the indicator site column and click on the ellipses button that will appear. If the field in the indicator site column is empty, you must first specify the name of the indicator site you would like to link. The indicator site and flow id must have a value.

The normal editing keys can then be used to insert, update and delete records.

8.3.4 HOW DO I GENERATE IFR DATA FROM INDICATOR SITE VALUES?

Go to the measuring stations form by selecting **Input|Water|Measuring stations** from the main menu and then click on the generate Q from indicator site speed button. The following date range form will appear.

WAS will then run through all the measuring stations and generate data for all sites that are linked to indicator sites. Data will only be generated for the specified from and to date range.

8.3.5 HOW DO I HANDLE DIFFUSED INFLOWS?

Diffuse inflows are handled as a point inflow within a reach. The diffuse inflows can be distributed over an unlimited number of reaches that can be anything from 100mm to hundreds of kilometres in length. A single measuring station describing a specific diffuse inflow pattern can be linked to an unlimited number of reaches.

8.3.6 HOW DO I CAPTURE IRRIGATION DEMANDS AND RIVER INFLOWS AND OUTFLOWS?

Any inflows and outflows in a river system are captured on the measuring stations form using the normal editing keys to insert, update and delete records. Go to the measuring stations form by selecting **Input|Water|Measuring stations** from the main menu.

8.3.7 HOW DO I CALCULATE THE DAM SETTINGS?

Dam settings are calculated using the following Calc date & time release form. This form can be accessed using the specific speed button on the canal network form (Input|Canal network). The user needs to specify certain settings that are described in detail in paragraph 4.3.
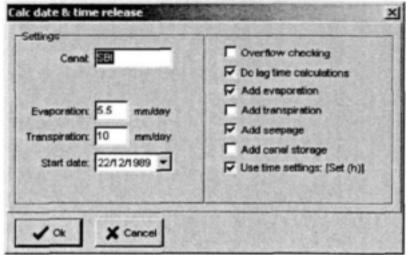
Figure 60 Calc date & time release form.

8.3.8 HOW DO I PRINT THE DAM SETTINGS?

Once the dam settings have been calculated (see paragraph 8.3.6), the user can print the settings by:

- Click on the Q vs Time page.
- Click on the item on the tree view that you want to display. The corresponding release settings will be displayed on the Q vs Time page.
- Click on the print speed button to print the settings.

8.3.9 HOW DO I CALIBRATE THE LAG TIMES?

The Cv-coefficient on the *canal network form* is used to calibrate the lag time for every reach. The average velocity in every reach is multiplied by the Cv-coefficient to calibrate the lag time for every reach. This means that a bigger Cv-coefficient will result in a shorter lag time for the reach. The properties calculator can be used to analyse any reach. See paragraph 4.4 for more details.

All the Cv-coefficients can be changed at once by using the *change data form* on the *canal network form*. To open the canal network form select **Input|Canal network** from the main menu. To open the *change data form*, use the *change data* speed button on the toolbar or select **Tools|Change data** from the menu. See paragraph 4.6 for more details.

APPENDIX D

GIS

User's Manual

GIS

User's Manual

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1   Introduction

This program allows you to display and edit mapping information. The electronic map consists of several layers, each of which contains features such as lines and/or points. The geographic information system (GIS) is designed to link to the WAS, RiskMan and SWB databases and display relevant information on a map. The GIS program is also developed as an editing tool to create and edit maps to be used with the different databases.

The GIS can mainly be used by irrigation schemes as a management tool to display relevant information from the WAS, RiskMan and SWB databases on their irrigation scheme map. The main benefit from using a geographic information system is the fact that data can be displayed spatially on a map. This gives the user a much better understanding of the data and a tool to analyze the data in different ways. As a management tool it is much easier to do planning on a map and to communicate information to subordinates.
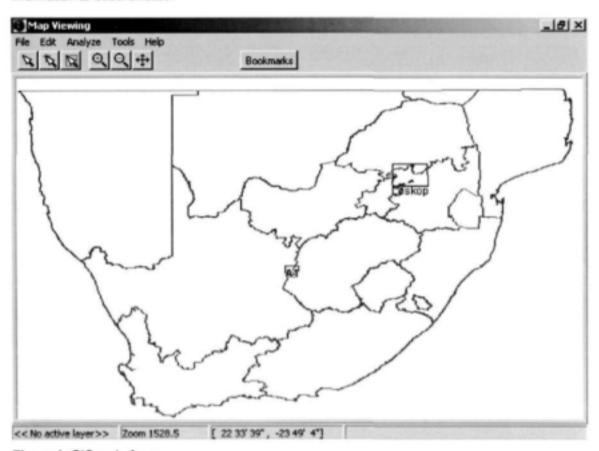
Figure 1 GIS main form

The GIS program is written in Delphi 5 (Inprise Corp.) and uses MapInfo MapX ActiveX (OCX) control for the mapping technology. The program has the capability to link to Paradox and Interbase databases and display relevant information on a map. The GIS provides standard tools including:

- Navigation tools (Zoom-in, Zoom-out, Pan, Centre) that let the user change the scale and placement of the map.
- A labelling tool that lets the user click a map feature to label it.
- A set of selection tools that give the user various ways to select map features.
- A thematic mapping tool that is used to analyze point and range data.
- A map layer tool that is used to create different layers to display specific information. The user can show or hide layers depending on the detail that needs to be seen.
- An editing tool to create lines, join lines and split lines.
- Bookmark tool that is used to save and retrieve different views of a map.

1

The actual data for a single layer is stored in a file (with extension .tab). To display a combination of layers, a geoset file (.gst extension) is used. The geoset file specifies which layers should be displayed and how they should be displayed, i.e. what color to use, what line type, etc.

2   Status display

The status bar at the bottom of the main window displays the following information:

- First panel: Currently active layer. This is the layer where items can be edited, deleted and added.
- Second panel: Displays the current zoom level. The zoom level is the distance represented on the screen from the left side of the visible part of the map to the right side of the screen.
- Third panel: Displays the current coordinates in degrees, minutes and seconds

3   Map Layers

A map layer is used to represent items of a similar type, i.e. to represent all the farms a farm layer is used, and to represent the rivers a river layer is used. It is possible to create any number of layers, each one for a specific type of item. In the standard data supplied the following layers are defined:

- Farm layer (consisting of region items)

- River layer (consisting of region items)

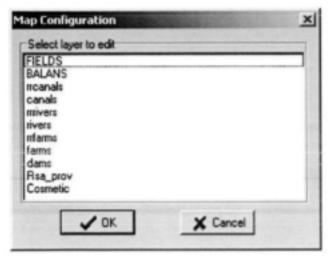- Canals (consisting of line items)

- Dams (consisting of region items)

Map Configuration

Select layer to edit

```
FIELDS
BALANS
rrcanals
canals
rrrivers
rivers
rrfarms
farms
dams
Rsa_prov
Cosmetic
```

✔ OK   ✗ Cancel

Figure 2 Map layer selection

3.1   Create a new layer

To create a new layer, select "Edit, New layer" from the main menu and enter the following:

- The name of the layer (this is a short name to describe the type of items to be saved in the layer); and

2

- The actual file name, which will be used to save the map data.

3.2 Change the way a layer is displayed

To change the way a layer is displayed, select "Edit, Configure Layers" from the menu. Select the layer, click on "Display" and then under "Override style" select the way items are to be displayed.

Note: When changing layers, never change the "DrawLayer" and "EditLayer" layers. These are temporary layers used internally in the software and should not be changed by the end user.

4 Keyboard shortcuts

When using the map, the following keys can be used:

Del Deletes currently selected item. Remember, deleting an item permanently deletes it from the layer data file. Keep backup copies of data!

F6 Start editing a line or region features. After selecting a feature, pressing F6 breaks up that feature into the individual points it is made up of. These points can then be moved, deleted and new points can be added.

F7 Merge two line features: When two line features are selected, pressing F7 will connect the two endpoints to form one continuous line feature.

F8 Split single line into two lines: When busy editing a line feature and with a single point on the line feature selected, pressing F8 will split the original line into two separate line features.

Ins Insert new point into line or region feature: When busy editing a line or region feature, pressing the Insert key will insert a new point into the line or feature just prior to the currently selected point.

F5 Go to specific coordinates: When pressing F5 you can enter the actual coordinate values to position the cursor. These values are entered in degree, minute and second values. If busy dragging a single point (either standalone or as part of a region or a line) F5 will change the coordinates of that point to the entered value.

F2 Rename feature: With a feature selected, pressing F2 allows the user to enter a new name for the feature.

5 Navigation

When viewing information on the map it is necessary to zoom in and out, and to pan the map left, right up and down. Items can also be selected to delete them or view information about them.

In order to access these functions, the correct mapping tool must be selected. The following map tools are included:

- Zoom in   When this tools is selected, clicking anywhere on the map zooms into that point. It is also possible to click, and while keeping the mouse buttons down, select a rectangle. The selected rectangle will, when the mouse button is released, be selected to fill the whole viewing area.
- Zoom out   When this tools is selected, clicking anywhere on the map zooms out from that point.

- Pan   When this is selected, click any point on the map and while keeping the mouse button down, move it in any direction. This will move the center point of the map in the direction the mouse is moved.
- Select   With the selection tool it is possible to select individual items or groups of items. Clicking on an item will select it. If the "Ctrl" button is pressed while clicking, multiple items can be selected at the same time. Note: Only items from the currently active layer can be selected. The currently active layer is displayed at the bottom of the screen. To change it, select "Edit, Set active layer" from the menu.

6   RiskMan, WAS and SWB GIS integration

The GIS program has the ability query the RiskMan, WAS and SWB databases and display the relevant information on a map. Two types of data can be displayed, the first type is point data and the second type is range data. The range type displays data for different ranges in user specified colors. The following two figures display parts of the Loskop and Orange-Riet GIS map respectively.
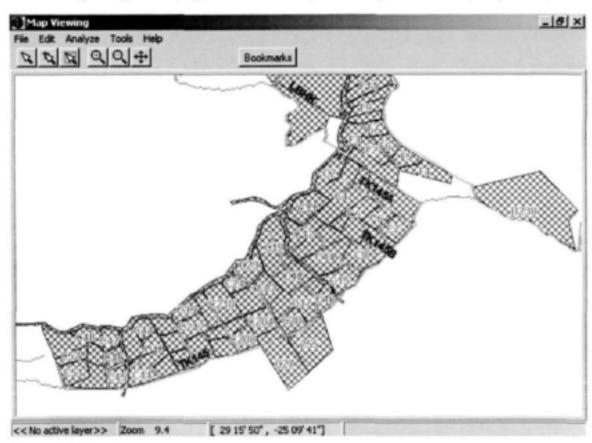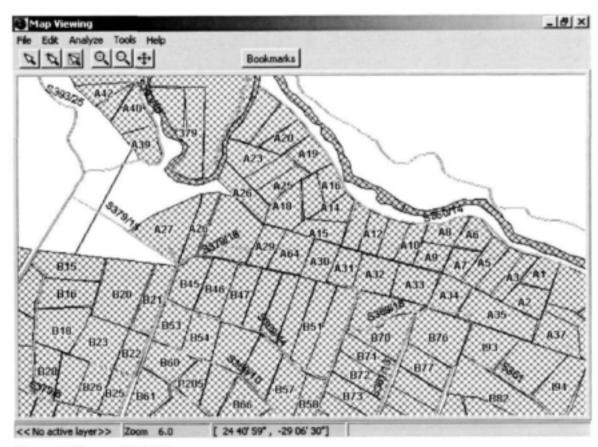

Figure 3 Loskop GIS map

Figure 4 Orange-Riet GIS map

6.1 Display database information

The following figures display examples of data that can be viewed from the different databases. By selecting a farm on an active farm layer, the details of the owner can be displayed. By selecting a canal on an active canal layer, the canal details can be displayed. By setting up a specific theme, thematic information can be displayed such as the number of different crops on an irrigation scheme and where they are planted.
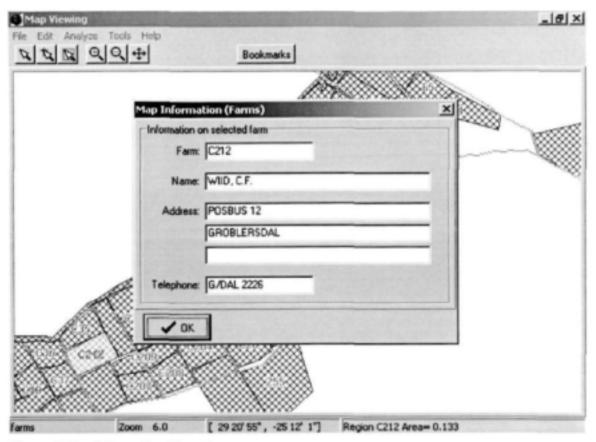
Figure 5 Map information (Farms)
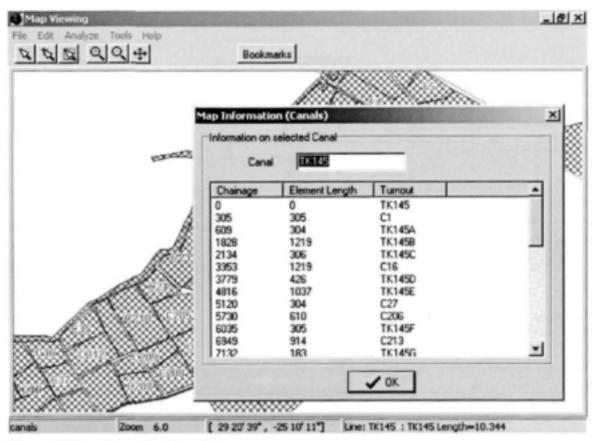
Figure 6 Map information (Canals)
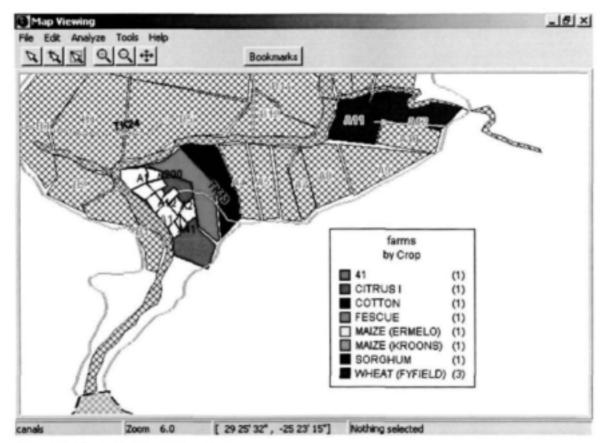
Figure 7 Thematic information display

7 Find feature

The GIS program has features to find specific information on a map. The following forms display how to:

- Find a specific feature. Select **Edit|Find** from the main menu or press the F3 key.

- Find a group of features within specified ranges. Select **Edit|Advanced find** from the main menu.

- Go to specified coordinates. Select **Edit|Goto coordinates** or press the F5 key.

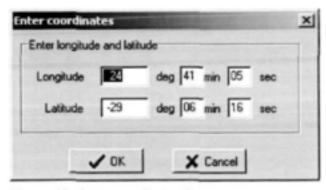**Figure 8** Find feature form

Figure 9 Find group of items

Figure 10 Go to coordinates form

Other related WRC reports available:

Facilitating irrigation scheduling by means of the soil water balance model

JC Annandale, N Benadé, NZ Jovanovic, JM Steyn & N Du Sautoy

The interest in scheduling irrigations with crop growth computer models is rapidly increasing, particularly since personal computers have become accessible to crop producers. Most of the existing models, however, either are crop-specific or do not simulate daily crop water use. Some models are relatively simple to use for planning purposes, but do not allow real-time scheduling. Other models accurately describe the complexity of natural processes. This makes them suitable for research purposes, but they are generally not applicable in practice due to the large amount of input data required and lack of a user-friendly interface.

The soil water balance (SWB) model is a mechanistic, real-time, generic crop, soil water balance, irrigation scheduling model. SWB gives a detailed description of the soil-plant-atmosphere continuum, making use of weather, soil and crop management data. It thus largely overcomes the problems of other models for irrigation scheduling as indicated above. However, since SWB is a generic crop growth model, parameters specific for each crop have to be determined

Calibration and validation of SWB with independent data sets of relevance for irrigation scheduling were required in order to establish the reliability of the model in representing the real-world system.

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