TECHNOLOGY TRANSFER OF THE SOIL WATER BALANCE (SWB) MODEL AS A USER-FRIENDLY IRRIGATION SCHEDULING TOOL

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EXECUTIVE SUMMARY

Technology Transfer of the Soil Water Balance model (SWB) as a User-Friendly Irrigation Scheduling Tool

Most commercial farmers recognize that effective irrigation scheduling is a prerequisite to save irrigation water and to improve water-use efficiency. However, only a small percentage of irrigation farmers currently use scientific irrigation scheduling aids. One important reason for this may be the lack of quick, simple and reliable irrigation scheduling techniques. This aspect has been addressed to a large extent by the development of the Soil Water Balance model, SWB. Although this model follows a scientifically sound mechanistic approach, a user-friendly interface makes it accessible to any person with basic computer literacy.

During the past decade, several research projects have been carried out to develop crop specific model parameters for a wide range of commercial crops. These have been included in the data base of SWB. Validation studies have indicated that the model generally performs very well under a wide range of conditions. However, since its release in the late 1990's, SWB had, for example, only been used by a small number of people, although its release had received quite wide publicity. Feedback from users indicated several shortcomings that needed to be addressed. It also became evident that although several potential users had shown interest in SWB, most struggled to get the model up and running in spite of our perception that SWB was a user-friendly tool. This probably resulted in the limited use of SWB by commercial irrigators. In addition, previously disadvantaged farmers and their advisors mostly do not have access to automatic weather station data and computer facilities to enable them to enable them to benefit from this technology.

It therefore became clear that in order to make SWB more usable and accessible to all potential users, some actions needed to be taken. This firstly involved some changes to the computer software, and secondly the training of potential users on a

national scale to enable them to use the model independently. The following objectives were therefore set for the project:

To further develop, where necessary, the SWB model as a user-friendly irrigation-scheduling tool in order to facilitate the technology transfer to irrigators.
To transfer developed technology to potential users by establishing the SWB model as a user-friendly irrigation-scheduling tool through training sessions.

At the onset of this project, a one-day workshop was held in Pretoria to identify SWB shortcomings and the changes needed to improve the model and its user-friendliness. Most of the current SWB users and prominent potential future users (consultants and individual farmers) were invited to the workshop. After the recommended modifications to SWB were identified, the necessary changes were made and material compiled for the different training courses.

The approach followed to transfer the developed technology (SWB model) to potential users, was to present training sessions to three target groups:

- **Commercial irrigation farmers** were to be trained on the use of SWB as a user-friendly tool for irrigation scheduling of their crops.
- **Irrigation consultants** received more detailed training that would enable them to advise farmers on the irrigation scheduling of their crops.
- **Tertiary level students** were trained in the basic principles of the soil water balance and its management through the use of the SWB model. For this purpose, a multi-media, self-paced teaching package is being developed.

The same course outline was used for all three course levels, although the emphasis was different for the student, consultant and farmer. The course material covered a theoretical description of the soil-plant-atmosphere continuum, followed by an introduction to the SWB model. Practical demonstrations and exercise sessions formed an integral part of all three courses.

The duration of farmer training courses ranged from one to one and a half days. The course covered the principles of the soil water balance, but no detail model theory was addressed. Attendees were then taught how to use the user-friendly interface, whereafter the course was rounded off with practical exercises.

The courses for consultants were of the same format as the farmer courses, but with more emphasis on background theory, the assumptions made in the model and problem solving. The duration of this course ranged from two to three days.

The project team was of the opinion that it would be impossible to provide satisfactory backup support to individual farmers countrywide. Farmer courses were therefore planned and scheduled in conjunction with SWB consultants active in specific irrigation areas. It was hoped that the consultants could act as the link between the research team and farmers. The research team was therefore dependent on consultants to request farmer courses.

The third course is designed as a semester course for senior tertiary level learners (students). This is made up of a self-paced multi-media learning package, and includes the use of SWB to train students in irrigation water management.

The interest in consultant courses was better than anticipated, but few of the attendees continued to use SWB as a scheduling tool after completing the course. Various reasons were given for this, but the most important was probably the fact that most of the attendees were not irrigation advisors *per se*. Follow-up conversations with some of these representatives revealed that they were mainly interested in expanding or refreshing their knowledge on plant water relations to serve their clients better. Most did not plan to assist farmers with real-time scheduling and were therefore not interested in arranging farmer courses. Some of the irrigation consultants who attended the training did not switch to the SWB model as scheduling tool, but continued using their own models or tools to advise farmers on irrigation management. This could probably be attributed to the fact that they were familiar with their own systems and did not see enough benefit in changing to another system. Often, they also have invested substantial amounts of time and capital into developing their own systems and would therefore not like to abandon them. Furthermore, some consultants felt that SWB was still too complex and required too many input parameters for use as a real-time scheduling tool. Feedback on course content and presentations was generally very positive and most attendees rated it highly.

Fewer farmer courses were presented than initially planned, undoubtedly as a direct result of the approach followed for the initiation of farmer courses. Since consultants were to act as the link between the research team and on the ground irrigators, the research team depended on consultants to request courses for their clients. As only a few of the attending consultants were involved in irrigation scheduling, the number of farmer courses presented was limited. It also became evident that in some instances, irrigation scheduling consultants did not want their clients (farmers) to attend formal SWB training, as this could possibly make them independent users of SWB, which would influence the consultant's business negatively.

Very valuable lessons were also learned with regard to the planning and presentation of training courses to consultants and farmers. Attendees should be consulted in setting dates that are acceptable to all of them. The timing of courses is very important, and they should not coincide with critical periods, like planting and harvesting, within a particular production region. Although most attendees indicated that the duration of such courses were adequate, it became evident that many people had difficulties in taking several days out of their schedules to attend courses. The length of courses should therefore also be carefully considered in consultation with the persons involved.

As planned, a tertiary level course was developed on understanding the detailed principles of the soil-plant-atmosphere continuum in order to efficiently manage irrigation. The course content is to be condensed into a self-paced multimedia-training package, which should be especially useful to previously disadvantaged students who might lack the background knowledge in this subject. The multimedia package on CD is to be called “Irrigation Management” and will contain graphics, animations, photos and video clips to support the text. Development of the multimedia package, which is done in conjunction with the Department of Telematic Learning and Education at the University of Pretoria, is proving to be a lengthy and very time-consuming process. After collation of information on the different topics covered, the information then has to be condensed into a format to be used on individual multimedia screens. Most of the photos, animations and video clips have to be generated by professional photographers and graphic designers, to ensure high quality. These professionals are only able to work part-time on the project, and due to their limited agricultural background, several iterations are often necessary to ensure that the slides and graphic designs comply with requirements. All these factors slow progress, and as a result, the multimedia package will take much longer to develop than initially anticipated.

On completion, the multimedia package will be made available to all local tertiary education institutions, including previously disadvantaged institutions such as the Universities of Fort Hare and Limpopo. The opportunity also exists to market the CD internationally. The printed version of the course will be published as a separate WRC report, and will therefore be available free of charge to local students and interested irrigation managers.

Irrigation calendars were also developed as an alternative to real-time irrigation scheduling with SWB. The SWB model was modified to enable the generation of site-specific recommendations of seasonal irrigation requirements, which can be printed out and supplied to the farmer. The calendars can be used in conjunction with wetting front detectors and rain gauges to adjust recommended irrigations for actual field conditions. Irrigation calendars should be especially useful to farmers without computers and access to real-time weather data. The approach was evaluated for previously disadvantaged barley farmers in the Taung Irrigation Scheme and preliminary results are promising. Commercial farmers could, however, also benefit from this simpler management option, which is not promoted as a replacement for real-time scheduling, but as a site specific simplified application of the SWB model. Once these farmers have mastered basic irrigation scheduling principles, they could progress to real-time use of SWB for still better irrigation management.

Apart from the formal courses presented, the project team undertook several other technology transfer actions, including exhibitions and demonstrations at farmer days and congresses, as well as visits by and to individuals who have shown interest in SWB. There were also many research related spin offs for the SWB model. Examples of these are the improvements made to the model functionality and interface, as well as the contacts made for new sources of contract research. These people now know about the existence of SWB, and may become future users. Several private companies have, for example, indicated their interest in funding research projects to determine crop parameters for cultivars and crops not currently included in the SWB database, such as for wheat, barley, tobacco, maize and potatoes. A web site was also created to support current and prospective SWB users. The SWB program and updated versions of it can be downloaded from the site (**http://www.nbsystems.co.za/swb**).

It can be concluded that the first objective of this project, namely to further develop the SWB model as a user-friendly irrigation scheduling tool has been achieved to a great extent, as most of the concerns raised by users and course attendees have been attended too. However, some feedback suggests that certain aspects, such as required model inputs, could be simplified still further. This aspect will receive attention during further model development.

The second objective, which focused on the transfer of developed technology to potential users by establishing the SWB model as a user-friendly irrigation scheduling tool through training sessions, has only partly been met. Although training sessions were presented and many people were exposed to SWB, it can unfortunately not be claimed that SWB has now been accepted as a scheduling aid on a broad basis. It could be concluded from this that the use of SWB for real-time irrigation scheduling may only be a realistic option for leading farmers and consultants rendering a scheduling service to irrigators. It is, however, believed that the training sessions were a useful capacity building experience for most attendees, which should result in a positive impact on the country's water management in the long term.

A backup service to individual users could be provided by the establishment of call centres manned by trained staff in key areas. Such call centres could, for example, be established and manned by Water User Associations or Irrigation Boards, or they could be run by consultants as business ventures. Centres like these could handle all SWB related enquiries and problems of users. They could also generate irrigation calendars for farmers who cannot be serviced by SWB consultants.

Since the completion of this project, the WRC has initiated a follow-up project to focus on the technology transfer and integrated implementation of water management models in irrigated agriculture. The aim of this project is the integrated implementation of several models (SWB, SAPWAT, RiskMan, WAS and ACRU) for decision-support. The target groups who could potentially benefit from this include staff of Catchment Management Agencies, Water User Associations, agricultural advisors and leading farmers on irrigation schemes. As part of this project, a special effort will be made to further enhance the user-friendliness of these models in an effort to further adoption. Several aspects of SWB could also be attended to. Model set up and input data acquisition can be simplified by the inclusion of data bases with default soil and long term weather data. For real-time schedulers, an effort should be made to facilitate real time weather data retrieval. An SMS or e-mail service could, for example, be instituted to send out recommendations to the user.

The project team has not been discouraged by the poor adoption of SWB at the conclusion of this project; to the contrary, we are enthusiastic to meet the challenge, as we are convinced that we have an accurate and useful tool that can make a real difference to the efficiency of field scale irrigation management.

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"Technology Transfer and Development Actions to Promote and Facilitate the use of SWB as an Irrigation Scheduling Tool"

The Steering Committee responsible for this project consisted of the following persons:

Dr GR Backeberg	Water Research Commission (Chairman)
Dr SS Mkhize	Water Research Commission
Mr PJ Maritz	Department of Agriculture
Mr R Kushke	Agricultural Research Council (ISCW)
Mr FPJ van der Merwe	Department of Water Affairs and Forestry
Mr OA van der Westhuysen	University of Pretoria
Prof PS Hammes	University of Pretoria
Mr JF Taljaard	Committee secretary

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CHAPTER 1

INTRODUCTION

Effective irrigation scheduling is recognized by most commercial farmers as an important method to save irrigation water and to improve the yield and quality of their product. However, only a small percentage of irrigation farmers currently use any irrigation scheduling aids, other than their experience, to decide when and how much to irrigate their crops. A survey conducted by Stevens et al (2005) amongst 332 irrigation schemes showed that only 18% of farmers were applying objective scheduling practices, while the majority of irrigators relied on the use of intuition or subjective irrigation scheduling. There could be many reasons for this, including the fact that the majority of farmers do not expect a net benefit from applying irrigation scheduling technology (Annandale et al., 1996). Another important reason may be the lack of quick, simple and reliable irrigation scheduling techniques (Steyn et al., 1998). This aspect has been addressed to a large extent by the development of the SWB model (Annandale et al., 1999).

SWB is a mechanistic, generic crop irrigation-scheduling model. It gives a detailed description of the soil-plant-atmosphere system, making use of weather, crop and soil data bases (Jovanovic, *et.al.*, 2000a). Although the model follows a scientifically based mechanistic approach, a user-friendly interface (Figure 1.1) makes it accessible to any person with basic computer literacy.

SWB is a real-time, soil water balance model that performs calculations of the water balance and crop growth on a daily time step to output irrigation requirements. The model includes a crop parameter database that contains a wide range of crops commonly cultivated in South Africa. It should be noted that SWB is a generic crop model and therefore differs in approach to the species specific crop growth models such as CERES Maize (Jones & Kiniry, 1986) and CaneGro (Innman-Bamber, 1991). For this reason, SWB is suitable for the prediction of crop water use for a wide array of crops, but was not really designed for other purposes, such as highly accurate yield predictions.

During the past decade, several research projects have been carried out to develop crop specific growth model parameters for a wide range of commercial crops (Olivier & Annandale, 1998; Jovanovic, *et.al.*, 1999; Jovanovic & Annandale, 2000; Jovanovic, *et.al.*, 2000b). These have been included in the SWB model data base. Validation studies have indicated that, although some modifications were necessary, the model generally performed very well under a wide range of conditions. However, since the release of SWB in the late 1990s, SWB had, for example, only been used by only a small number of people, although its release had received quite wide publicity. Feedback from users indicated several shortcomings in the first version of SWB that needed to be addressed. These included aspects such as user inputs and outputs, data management, specific applications, etc.

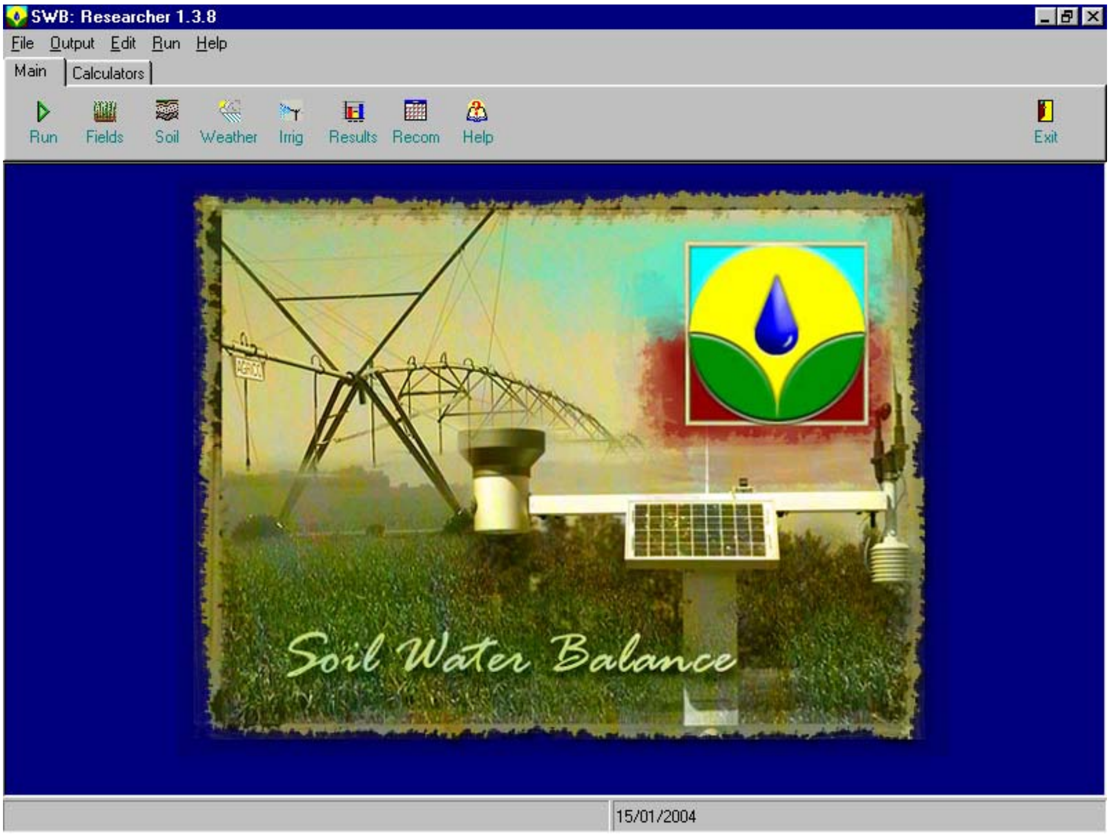

Figure 1.1: SWB model opening screen showing user-friendly interface

It also became evident that although several potential users had shown interest in using it, most struggled to get the model up and running in spite of our perception that SWB was a user-friendly tool. This probably resulted in the limited use of SWB by commercial irrigators. In addition, previously disadvantaged farmers and their advisors usually do not have access to automatic weather station data and computer facilities to benefit from this technology.

One of the most pressing obstacles facing South Africa is the lack of commercial farmers in the historically disadvantaged rural communities. A serious attempt to rectify this imbalance is being implemented through various initiatives. The objective of these initiatives is to support existing subsistence farmers and other interested groups to progress to viable commercial farmers through training and access to land, water, markets and financial support. This objective cannot be achieved without capable extension personnel having a sound understanding of crop production principles. Important here is a thorough understanding of soil-plant-atmosphere interactions and how these influence plant water requirements and therefore irrigation management and scheduling. This is of particular importance for the dry northern region of South Africa. A major objective of this project was to train students who could develop into a core of knowledgeable extension personnel that can, in turn, relate their knowledge to emerging farmers.

From the above-mentioned it is clear, that in order to make SWB usable and accessible to all potential users, some actions needed to be taken. This firstly included changes to the computer software and secondly the training of potential users on a national scale to enable them to use the model independently. A technology transfer project was therefore initiated with the following objectives in mind:

Project objectives

- To further develop, where necessary, the SWB model as a user-friendly irrigation-scheduling tool in order to facilitate the technology transfer to irrigators.

- To transfer developed technology to potential users by establishing the SWB model as a user-friendly irrigation-scheduling tool through training sessions.

CHAPTER 2

DESCRIPTION OF THE SWB MODEL AND MODEL IMPROVEMENTS MADE

Soil Water Balance (SWB) is a user-friendly irrigation-scheduling tool. It is based on the improved generic crop version of the soil water balance model described by Campbell and Diaz (1988). Annandale et al (1999) give a complete description of the SWB model. The main features of the SWB model are briefly discussed in this Chapter.

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 weather, soil and crop databases. The mechanistic and therefore universally valid approach used by SWB to estimate crop water use, has several advantages over the more empirical methods often used. Using thermal time to describe crop development eliminates the need to use different crop factors for different planting dates and regions. Evaporation and transpiration are split in SWB, which solves the problem of taking irrigation frequency into account. Deficit irrigation strategies, where water use can be supply limited, can also be more accurately described.

Extensive use is made of graphics, with the soil water balance graph 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 is also given.

SWB uses databases to store crop parameters, weather, field, water and soil data, 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. SWB calculates crop growth and soil water balance components using three units, namely weather, soil and crop.

Weather Unit

The Weather Unit of SWB calculates the Penman-Monteith grass reference daily evapotranspiration (ETo) 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. 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 gives rise to 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 (Annandale et al., 2000). If actual transpiration is less than potential transpiration, the crop has undergone stress and leaf area expansion will be reduced if the crop is still in the vegetative phase of growth. In other words, there is feedback between the crop and the soil in SWB.

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, and canopy interception and surface runoff calculated after rain or overhead irrigation.

Crop Unit

In the Crop Unit, SWB calculates crop dry matter accumulation in direct proportion to transpiration corrected for vapour pressure deficit. It also calculates radiation-limited growth and uses the lesser 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, should the input growth parameters for a specific crop not be available. This model can then also be used to calculate the soil water balance, but one loses the advantage of mechanistic feedback between the crop and soil, as canopy growth is assumed to depend only on calendar time.

At the end of a simulation run, various output graphs, including the soil water balance graph, are displayed (Figure 2.1). SWB also recommends the daily irrigation requirements. Depending on the current deficit, the model will recommend an irrigation date and quantity, based on the irrigation frequency and timing options selected in the field input form.

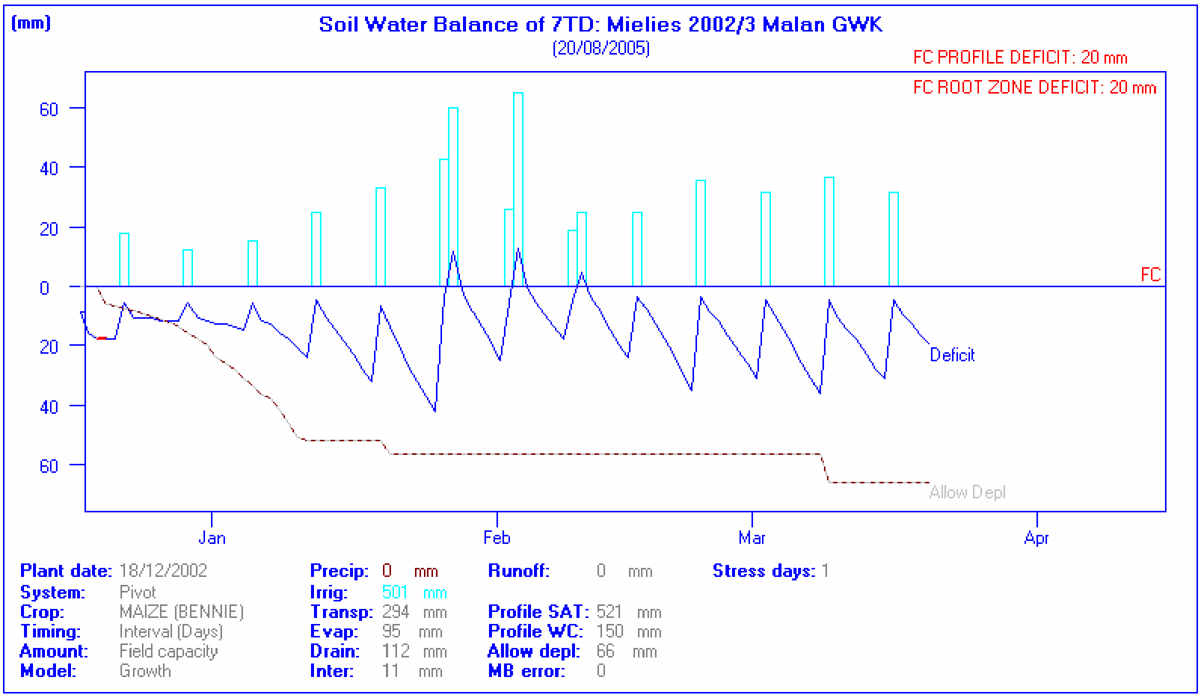

Figure 2.1: Example of the SWB output graph, containing daily precipitation, irrigation and profile deficit.

Model Improvements

At the onset of this project, a one-day workshop was held in Pretoria to identify the current shortcomings of SWB at that stage and to recommend changes that needed to be made to improve the model and its user-friendliness. The SWB research team, as well as most of the users of SWB at that stage (consultants and individual farmers) attended this workshop. Prominent potential future users were also invited to the workshop. After the recommended modifications to SWB were identified, the first six months of the project were spent on making necessary changes.

The important major changes suggested and implemented by the project team are briefly discussed here. A detailed list of all model changes made as part of this project is given in Appendix A.

From a programming perspective, the model code was cleaned up to facilitate easier following of the code by future users and developers. Several changes were also made to the model interface. Three levels of operation or modes, namely the **Irrigation**, **Consultant** and **Researcher** modes, were introduced. These can be selected in the main menu and ensure that only information applicable to a certain level of user is accessible.

The **Field** Form is used for capturing input data with regard to crop type and management. Several changes were introduced to improve simulations and ease of use. Some of the inputs and options now available include the following settings: irrigation system efficiency; the lower boundary condition (free drainage or no drainage) and, selecting the type of crop model and soil water balance model. If sprinkle, pivot or flood is selected, SWB will run the one-dimensional cascading or finite difference model, depending on which soil water balance model is used. If micro or drip irrigation is selected, SWB will run the two-dimensional cascading or finite difference model, depending on the choice of soil water balance model. The fraction of roots in the wetted volume of soil can be entered for both the two-dimensional cascading and finite difference models. This should improve accuracy in the simulation of root water uptake and describe the effects of the inter-row crop area on rainfall use efficiency.

Depending on circumstances, the type of crop model can be changed. Three types of crop models can be selected from the Field form. The **Crop growth** model is based on the calculation of dry matter partitioning to plant organs and leaf area. If crop growth model parameters are not available for a specific crop, the **FAO** model, based on the FAO Kcb basal crop coefficients, may be selected. The **Tree** model is based on the calculation of intercepted radiation from canopy size and leaf area density. For the Tree model the shape of the tree can now be selected as either being ellipsoidal, or an ellipse of which the base of the canopy has been cut off horizontally. The Tree model is only available in Research mode.

The **Soil** Form contains information regarding the soil physical and water holding characteristics of each layer of the soil profile. The most important improvements introduced to this form are the function to import soil characteristics from another field and a tool to create uniform soils. A function to limit root depth to the maximum soil depth was also introduced.

The **Weather** database contains weather stations with daily weather data for each station. Improvements were made to the import and export functions. This facilitates the handling of more data formats and further external data management (e.g. in spread sheets). Weather data in the SWB database can now also be viewed graphically.

Model output screens were modified to improve clarity and user-friendliness. The most important of these changes is the addition of a new output screen that summarizes simulation results on a single page. The screen displays the **SWB graph**, **Water Content graph** and the **Recommendations** for a specific field. **Notes** from the consultant to the farmer can also be added. This screen can be printed, or a consultant has the option to fax the page directly to his client from within SWB, with only a modem being required.

An exciting addition to SWB was the facility to create site-specific **Irrigation Calendars**. These calendars can be printed, and provide farmers with site-specific recommendations on the irrigation requirements of their crops over a season. This facility, which should be especially useful to farmers without computers, is described in detail in Chapter 5.

A web site was created to support current and prospective SWB users. The SWB program and updated versions of it can also be downloaded from the site. Currently the site is hosted under the NB Systems home page:
http://www.nbsystems.co.za/swb

CHAPTER 3

APPROACH TO TECHNOLOGY EXCHANGE

The approach followed to transfer the developed technology (SWB model) to potential users, was to present training sessions to three target groups:

- **Commercial irrigation farmers** were to be trained on the use of SWB as a user-friendly tool for irrigation scheduling of their crops.
- **Irrigation consultants** received more detailed training that would enable them to advise farmers on the irrigation scheduling of their crops.
- **Tertiary level students** were trained in the basic principles of the soil water balance and its management through the use of the SWB model. For this purpose, a multi-media, self-paced teaching package is being developed.

The first six months of the project were spent on making the necessary model changes and compiling the training courses. The same course outline was used for the three course levels, although the emphasis was different for the student, consultant and farmer. The course material consisted of theoretical background of the soil-plant-atmosphere continuum, followed by an introduction to the SWB model. Practical demonstrations and exercise sessions formed an integral part of all three courses.

The training approach was to first present a quite detailed course to irrigation advisors and consultants in specific production regions or provinces. These were then followed by a more basic course aimed at the training of farmers in the use of SWB. The farmers' training courses in certain irrigation areas were scheduled in conjunction with consultants who had already been trained. The consultant acted as the link between the research team and the end user or irrigator. As a result of this approach, the research team was dependent on consultants requesting farmer courses for their clients.

The duration of farmer training courses ranged from one to one and a half days. The course covered the principles of the soil water balance, but no detail of the model theory was addressed. Attendees were then taught how to navigate the user-friendly interface, whereafter the course was rounded off with practical exercises. The final content of each course was finalized with the consultant involved in that area.

The courses for consultants were of the same format as the farmer courses, but with more emphasis on background theory, the assumptions made in the model and problem solving. The duration of this course ranged from two to three days.

The third is a semester course designed for senior undergraduate level learners. This includes a self-paced learning software package, which uses SWB as the tool to train learners in irrigation water management. Due to the self-pacing nature of such a course, it should be especially useful to previously disadvantaged learners who might not have the necessary background knowledge in this subject.

The undergraduate learners are specifically trained in the principles employed in SWB so that they will have a sound understanding of how the system works, it's limitations and strengths, and where it can be correctly applied. After completing the course, these learners should have the required insight and technical knowledge to advise prospective consultants and irrigation farmers in this regard. They should also be in a position to suggest valid model modifications or actions required to promote sound water use in developing agriculture.

The learning package might in future also be used to train graduate learners in irrigation water management at other tertiary institutions offering agricultural training.

CONSULTANT COURSES PRESENTED

Three consultants' training sessions were presented during the course of the project. These courses were presented in Pretoria, Elsenburg (near Stellenbosch) and Bethlehem. A total of 72 people, consisting of researchers, extension officers, consultants and field officers in the private and public sector attended these courses. Figure 3.1 show some attendees doing hands-on SWB exercises during the Elsenburg course. The names of attendees for the three courses are attached as Appendix B.

Figure 3.1 Elsenburg course attendees doing hands-on SWB exercises

The programme for one of the courses is given in Appendix C as an example. Participants were presented with a file containing all of the theory that was covered in the courses for later reference. After completing the course, attendees had to complete an evaluation form (Appendix D). The course evaluation results and feedback on the different courses are summarised in Appendix E. These comments were used to improve the courses that followed. Course attendees were presented with certificates declaring their successful completion of the course (Appendix F).

Course attendees were generally very positive about the course contents and gave valuable feedback for future courses. After attending the consultant courses, many consultants indicated that they would not need help other than e-mail and telephone support (see Appendix E).

Most participants seemed to find the model user-friendly and easy to use after receiving the training. However, some users have indicated that there are too many initial set-up parameters and that the model was still too complex for use by farmers.

Follow-up monitoring, however, revealed that after attending the consultant courses, the number of new SWB users in this community did not increase dramatically. Various reasons were given for this, but the most important was probably the fact that many of the attendees were not irrigation advisors *per se,* but worked for the seed and chemical industries. In follow-up conversations with some of these representatives it became clear that they were mainly interested in expanding or refreshing their knowledge on plant water relations, which could give them a competitive advantage above their competitors. However, some of the consultants who attended the training were indeed irrigation consultants, but did not switch to SWB as scheduling tool. Instead, they continued using their own models or tools to advise farmers on irrigation management. We concluded that this could probably be attributed to the fact that they were familiar with their own systems and did not see enough benefit in changing to another system. Usually, they have also invested substantial amounts of time and capital into developing their own systems and would therefore not like to abandon them.

There were also examples of new users who did indeed start using SWB, but were disappointed with the results, as they used it for purposes it was not designed for. In one instance, a consultant tried to use SWB for yield prediction purposes. The results were not always accurate enough, as can be expected, since yield prediction is not the major focus of a generic irrigation-scheduling model like SWB. The person consequently decided to discontinue using SWB.

Fortunately, there were also a number of consultants who started and continued using SWB to advise farmers on irrigation management. These individuals were in constant contact with the development team, requesting improvements to SWB to improve its usefulness to them.

Course attendees can therefore be categorised according to their level of benefit from the training sessions. The first category includes those who are not irrigation consultants, but took part in the training to improve or refresh their own knowledge on irrigation principles. The second category includes those who tried to use the SWB model for other purposes than irrigation scheduling. Thirdly, there was a group who learnt from the theory but continued using their own model, for various reasons. Lastly, there was a group who decided to switch to the SWB model and were using it to promote their business.

Further consultant courses were planned for Ceres (Western Cape) and Pretoria. These did, however, not take place due to limited interest, but may in future still be presented on an *ad hoc* basis if the need arises. It also became clear that the timing of courses is very important, and they should not coincide with critical periods, like planting and harvesting, within a particular production region.

FARMER COURSES PRESENTED

Farmer training courses were presented at two localities in Mpumalanga, namely Groblersdal (Loskop Irrigation Scheme) and Malelane.

The consultants who work in these areas, and who had previously attended the consultants' courses, were involved with the course arrangements and presentations. Other experienced and respected extension officers in the area were also involved in motivating farmers on the economic importance of irrigation scheduling.

A total of 29 farmers, farm managers and extension officers attended the courses (Name lists attached as Appendix G). The duration of the course programme ranged from one to one and a half days, depending on the previous exposure of participants to SWB. An example of the course programme is given in Appendix H. Farmer response to the training was generally positive, although some perceived the model as being too difficult to use on a routine basis, with too many initial set up parameters.

It was impossible for the project team to provide backup support to individual farmers all over the country. For this reason, farmer training courses were planned and scheduled in conjunction with SWB consultants active in specific irrigation areas. The consultant was supposed to act as link between the research team and the end user or farmer. The project team was therefore dependent on consultants to request farmer courses for their clients. Contrary to initial expectations, the response of consultants requesting farmer courses for their areas was unfortunately rather poor. As only a few of the attending consultants were involved in irrigation scheduling, the number of farmer courses requested and presented was limited. This resulted in a lack of backup support to farmers, which probably contributed to our observation that some of the farmers who attended the training sessions did not continue to use SWB.

More farmer training courses were requested and planned for Wonderfontein (Mpumalanga Highveld), Tafelkop (Mpumalanga), Ceres and Taung (North West Province). However, none of these realized for various reasons, including the following: changes in work situation of the consultant in an area; lack of farmer interest and the fact that most consultants involved were representatives of chemical and seed companies, and were not as such, irrigation consultants. They were thus not interested in providing a day-to-day backup service to farmers and were therefore not interested in facilitating training for them. It also became evident that in some instances, irrigation scheduling consultants did not want their clients (farmers) to attend formal SWB training, as this could possibly make them independent users of SWB, which would influence the consultants business negatively.

Botha *et al* (2000) and Stevens *et al* (2005) previously conducted research in South Africa on the implementation of irrigation scheduling methods (including models). Their studies revealed that the reasons for irrigation farmers not applying scientific irrigation scheduling methods, even after being exposed to them, revolve around issues of time, costs, ease-of-use, irrigation system design, field layout and availability of computers. Consequently, they concluded that commercial irrigation farmers tend to rely mainly on the support from the local co-operative, private consultants and industry experts, rather than using the models themselves. Against the background issues of limited backup support and ease-of use, we may also conclude that in our case, the use of SWB for real-time irrigation scheduling might only be a realistic option for leading farmers and consultants rendering a scheduling service to irrigators. It must also be accepted that SWB is not the best tool for all situations. In the case of very high frequency drip irrigation, for example, real-time weather data is required to ensure accurate model simulations. It cannot be expected from farmers to enter weather data hourly, because of practical limitations. Also, where dedicated crop models are available (e.g. in the sugar industry), these tools will hopefully give better estimations of crop growth and yield, compared to a generic model such as SWB.

It is expected that more commercial farmers might in future be interested in the simpler calendar scheduling approach proposed for resource-poor farmers (see Chapter 5). Further farmer training sessions could then be presented, should the need arise.

CONCLUSIONS AND LESSONS LEARNT FROM TRAINING APPROACH

From the discussion above, it can be concluded that the training courses presented to consultants and farmers did unfortunately not result in a substantial increase in SWB users. We therefore have to assume, that currently, the use of SWB for real-time irrigation scheduling, may only be limited to leading farmers and irrigation consultants. However, we do believe that the training was a very good capacity building experience for attendees, which should eventually result in a positive impact on the country's water management in the longer term.

Very valuable lessons were also learned with regard to the planning and presentation of training courses to consultants and farmers. Some of the practical considerations that should be taken into account include the following: attendees should be consulted in setting dates that are acceptable to all of them. The timing of courses is very important, and they should not coincide with times of peak agricultural activities within a certain production region. Although most attendees indicated that the duration of such courses were adequate, it became evident that many people have difficulties in taking several days out of their schedules to attend courses. The length of courses should therefore also be carefully considered in consultation with the persons involved. Furthermore, the project team believes that researchers and model developers are not necessarily skilled to convey the developed technology to farmers. It is therefore, strongly believed that to ensure the success of future technology transfer projects, properly trained extension workers should be involved.

The approach of using formal courses, as opposed to hands-on working sessions with individual irrigators, should probably also be investigated in future. Stevens *et al*. (2005) have concluded from their work that farmers tend to prefer a hands-on approach with more support over time, rather than formal training courses, which might explain the limited interest of farmers to attend our courses.

Furthermore, the general receptivity of farmers to decision support systems (DSS), such as computer models, should also be considered. The acceptance of on-farm DSS by farmers has been the topic of many studies. According to Hayman (2004), the history of DSS-use for routine decision making on farms in Australia has been disappointing. Mc Cown (2002), noted that few of the documented failures were due to the technical soundness of models, and most failures were due to the challenge of implementation. One problem cited with the acceptance of models is that they focus too narrowly on specific input aspects, while the management of a farm is a far more complex business (Malcolm, 1994). Therefore, farmers rather prefer to be vaguely right (by following their intuition or experience) than precisely wrong, which is possible when using a model. Thus, to solve the whole problem roughly is better than solving part of the problem extremely well. Scientists tend to believe their part of the decision puzzle is the most important. According to Hayman (2004), decision making in farming can be divided into three convenient categories: operational decision making (e.g. spraying, planting or harvesting decisions), tactical decisions (which crop, what area and level of inputs) and strategic decisions (pastures or crop enterprise mix, purchasing extra land). Up to now decision support systems, such as SWB, have focussed on tactical decisions that are characterised by responding to the current state of the system (e.g. irrigation requirement). For many agricultural inputs, yield response is relatively insensitive around the optimum level (Hayman 2004). Therefore, farmers may gain less from being precisely right with detailed simulation models than being approximately right with coarse rules of thumb, especially when you factor in the risk of being precisely wrong with detailed modelling. Moreover, the cost of irrigation water has in the past been relatively low, compared to other inputs, such as fuel and fertilizer. Farmers, therefore, would tend to rather apply slightly more water as insurance, rather than facing the risk of trying to apply the exact amount and getting it completely wrong. Opposed to tactical decisions, the financial implications of an incorrect strategic decision can be far more deleterious, and therefore dominate decisions on the farm.

Apart from the formal training sessions presented during the course of this technology transfer project, there were many research related spin-offs for the SWB model. Examples of this are the improvements made to the model functionality and interface, as well as the contacts made for new sources of contract research. Furthermore, many lectures, exhibitions and informal talks were presented at congresses, information and farmer days, which gave us the opportunity to expose a wide group of people to SWB. These individuals are now aware of the existence of SWB, and might become future users. The project team and other colleagues received some positive personal communications in this regard. Several private companies have, for example, indicated their interest in funding research projects to determine crop parameters for cultivars or crops not currently included in the SWB database, such as for wheat, barley, tobacco, maize and potatoes.

Private companies, such as fertilizer and seed companies, may in future play an important role in the promotion of SWB. Most companies are facing tough times economically, and competition for market share is fierce. Value adding to their products is one way of being ahead of the competition, and SWB can be a value adding service that some companies might be willing to invest in.

We believe that training of different groups (such as water user associations, company representatives and individual farmers) will remain an important vehicle for the promotion of SWB, although the approach to training may differ in future. Further attention should also be given to model improvements to make the user interface even more friendly and easier to use. One option could be to completely separate the different model modes (Researcher, Consultant and Irrigator) and to include default look-up options (e.g. soil properties) to ease model setup. The irrigation calendar option could play a valuable role in bridging the gap between those farmers who do not schedule at all and those who use real-time scheduling. Stevens *et al* (2005) has indicated that farmers tend to change from simpler to more sophisticated scheduling practices as they advance through a learning process in irrigation scheduling.

CHAPTER 4

TERTIARY LEVEL COURSE

The detailed semester course was developed for teaching senior undergraduate students at the University of Pretoria in the dynamics of the Soil-Plant-Atmosphere-Continuum (SPAC) with the aid of the SWB model. This course consists of two components: Students firstly receive formal lectures on the principles governing the SPAC and theory of the SWB model. They are specifically trained in the principles employed by SWB, to ensure a sound understanding of how the system works, and to know its limitations and strengths, and where it can be correctly applied. Furthermore, the course material is also condensed into a self-paced multimedia-training package, which students can follow in their own time. Because of the self-paced nature of such a course, it should be especially useful to previously disadvantaged students who may not have the necessary background knowledge in this subject. Since the learning package will allow the user to select the level of detail he or she wants to see, it should also be useful to consultants and farmers.

After completing the course, the students should have the required insight and technical knowledge to advise prospective consultants and irrigation farmers in this regard. They will also be in a position to suggest valid modifications or actions required to promote sound water use in developing agriculture.

The multimedia package on CD, called “Irrigation Management” (see Figure 4.1), is being developed in conjunction with the Department of Telematic Learning and Education at the University of Pretoria. It will consist of nine chapters containing graphics, animations, photos and video clips to support the text (see Appendix I for the Table of Contents). Where applicable, there are also direct links to the web sites of organisations and institutions concerned with irrigation water management.

Development of the multimedia package has been a lengthy and very time-consuming process. The first step entailed the collation of information on the different topics covered in the course. The information will then be compiled into a hard copy that supplements the multimedia CD.

Figure 4.1: Opening screen of "Irrigation Management" multimedia software for tertiary level teaching of SPAC principles and irrigation management

All information was then condensed into a format that could be used on individual screens. Photos, animations and video clips are used to help explain the various concepts discussed in the text (see Figures 4.2 and 4.3 for examples). For this, some existing photos and video clips can be used, but in most instances new photographs must be taken by professional photographers. For the video clips, a professional narrator is used to describe the filmed procedures. All sketches, figures and animations are also created by professional art designers, to fit the general "look and feel" of the multimedia package. Due to the limited agricultural background of the designers, several iterations are often necessary to ensure that the graphic designs comply with our requirements.

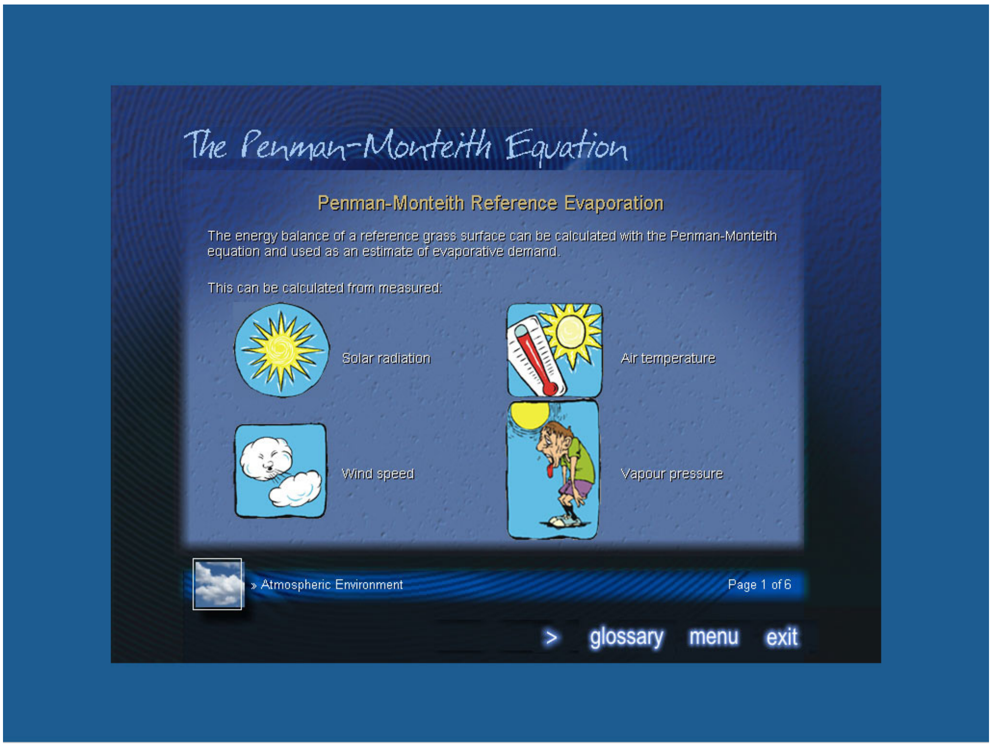

Figure 4.2: Example of a text page with "cartoons" in the "Irrigation Management" multimedia software

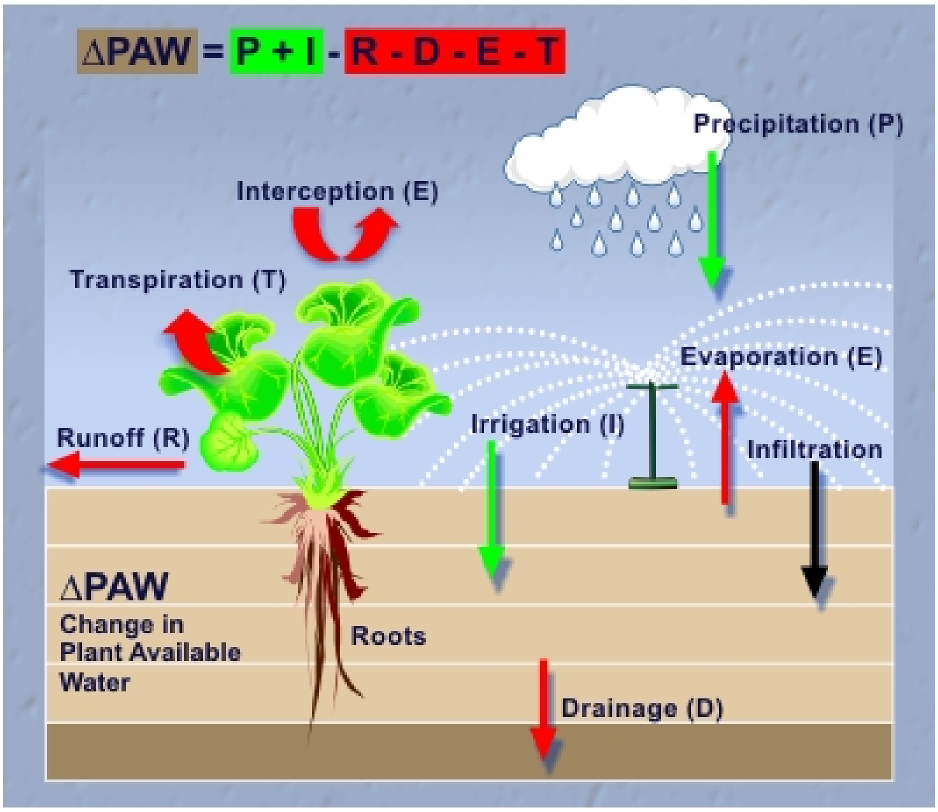

Figure 4.3: Example of the graphics designed for the "Irrigation Management" multimedia software

The multimedia-learning package might in future also be used to train graduate students in irrigation water management at other tertiary institutions. Some tertiary institutions (e.g. the Universities of the Free State and Stellenbosch) have shown interest in the multimedia-learning package. The learning package will in future also be made available to previously disadvantaged tertiary institutions, such as the Universities of Fort Hare and Limpopo, who have already indicated definite interest in the package. The opportunity therefore exists to market the CD nationally and even internationally in future.

The compiled course material was used to present the Irrigation Management course to undergraduate UP learners. Learners were also given the opportunity to evaluate completed parts of the multimedia package after having hands-on experience with a preliminary version of it. After testing the program, students gave their opinion on ease of use, likes, dislikes and recommendations for changes to the software. The feedback was generally positive and students seemed to like most aspects, such as:

- Good graphics and layout
- Language used is easy to understand
- Software is user-friendly
- Can work at own pace and can go back at any time

The results of the evaluation are given in Appendix J. Where possible, most of the student feedback was incorporated into the package.

The “Irrigation Management” multimedia software and manual will be published and distributed as a separate package from this WRC report. The package will be jointly published by the WRC and the University of Pretoria and will be obtainable from the Department of Plant Production and Soil Science of this University.

CHAPTER 5

IRRIGATION CALENDARS TARGETED AT RESOURCE-POOR FARMERS

An exciting recent addition to SWB is a facility to create site-specific, calendar type, irrigation scheduling recommendations. This facility provides a site-specific printout of seasonal irrigation requirements, which can be used in conjunction with wetting front detectors and a rain gauge to schedule irrigations. The use of wetting front detectors and irrigation calendars are combined, since it is believed that SWB performs well at estimating crop water use, while detectors are good at showing the efficacy of irrigation practise. Wetting front detectors therefore give feedback on the previous irrigation event. Typically, a consultant will do the initial model set-up, run the simulations for specific soil, climate, cropping and management conditions, and then provide the farmer with a printed copy of the seasonal recommendations. This should be especially useful to resource-poor farmers without computers, but commercial farmers have also shown great interest in this simpler option.

The approach to be followed to generate and use irrigation calendars is summarized in Appendix K. The calendar approach was tested in a controlled study conducted on the Hatfield Experimental Farm and early results look very promising. A project was consequently initiated in association with Southern Associated Maltsters (SAM), a division of South African Breweries (SAB), to refine and evaluate irrigation calendars in practice. SAB is involved in a community project to promote the commercial production of barley under centre pivot irrigation in the Taung area (North West Province). As these farmers do not have access to computers, the SWB model is used to generate calendar-type recommendations that can be printed out. These were then be used together with wetting front detectors (WFDs) to manage irrigations. Table 5.1 gives an example of an Irrigation Calendar generated for maize.

During 2003, field data was collected to calibrate the SWB model for barley and to expose Taung farmers to WFDs. The following modifications to the model were necessary to enable irrigation calendar generation:

- Function to generate an “average” year from long-term weather data
- Function to generate the calendar
- Printout of the generated calendar

The project reached implementation phase during 2004, when a course was presented to the Taung farmers involved in the project. Farmers were trained in the basic principles of plant water use, as well as in the use of WFDs and irrigation calendars. Irrigation calendars were then implemented on a small scale to evaluate their success. Irrigation management and WFDs were also introduced to a wider group of Taung farmers on a farmers’ day (Figure 5.1), who showed keen interest in testing out the device, once it is implemented on a wider scale.

Table 5.1: Example of Irrigation Calendar in which three irrigations have been applied

Irrigation calendar

Farmer: PJ Mojela
Field: A300 | **Crop: Maize**
Soil type: Sandy loam | **Plant Date: 26/10/2003**
Irrigation System: Sprinkle | **Wetting Front Detectors: Shallow: 4**
Management Option: Field capacity | **Deep: 4**
Irrigation Frequency Option: Days | **Response Factor: 20%**

Date	Day	* Irrigation Requirement (IR), depending on number of Shallow and Deep Wetting Front Detector (WFD) responses			Rain since previous irrigation (mm)	Recom-mended Irrigation amount = IR - Rain
		0-2 Shallow and 0-2 Deep	3-4 Shallow and 0-2 Deep	3-4 Shallow and 3-4 Deep		
		Irrigation Requirement (IR, mm)				
01/11/03	Mon	30	25	20		25
06/11/03	Sat	36	30	24		30
11/11/03	Thu	24	20	16	11	13
16/11/03	Tue	38	32	26		
21/11/03	Sun	34	28	22		
26/11/03	Fri	42	35	28		
etc						

* **Notes**

- Just before irrigation, check wetting front detector response (to the previous irrigation) and use to correct the irrigation requirement – select the correct column.
- Encircle the applicable irrigation requirement, based on WFD response.
- If 0-2 shallow and 3-4 deep WFDs have responded, check your shallow WFDs for problems.
- Record rain and empty gauge just before irrigation
- Deduct rainfall from irrigation requirement to obtain the **Irrigation Amount**
- If **IR – rain < 0**, then skip the irrigation, i.e. irrigation amount = 0

Figure 5.1: The Wetting Front Detector and Irrigation Calendars were demonstrated to resource-poor farmers on a framers' day at Taung

Irrigation calendars were initially introduced as a method to serve resource-poor farmers without access to computers. However, this simpler yet scientifically sound approach could potentially be used as an entry point to service commercial farmers who are interested in scheduling but are not ready to implement real-time SWB scheduling. Irrigation calendars are not promoted as a replacement for real-time scheduling, but as a site specific simplified application of the SWB model. Once these farmers have mastered the basic irrigation scheduling principles, they could progress to real-time users of SWB for even better irrigation management.

CHAPTER 6

RECOMMENDATIONS AND CONCLUSIONS

The objectives of this project were to improve the SWB model and to establish it as a user-friendly irrigation-scheduling tool through technology transfer actions. Training sessions at different levels were used as approach to the technology transfer actions. Consequently courses were compiled for farmers, consultants and tertiary level students.

The interest in consultant courses was better than anticipated, but only a limited number of consultants continued to use SWB as scheduling tool after attending the courses. Various reasons could be given for this, but the most important was probably the fact that most of the attendees were not irrigation consultants *per se*. Follow-up conversations with these consultants / representatives, revealed that they were only interested in expanding or refreshing their knowledge on plant water relations to serve their clients better. They did not plan to assist their clients with real-time scheduling and were therefore not interested in arranging SWB farmer courses. Some of the irrigation consultants who attended the training did not switch to the SWB model as scheduling tool, but continued using their own models or tools to advise farmers on irrigation management. The reason for this is probably the fact that they are familiar with their own systems and did not see enough benefit in changing to another. Usually, they have also invested substantial amounts of capital and time in developing their own systems and would therefore not like to abandon them. Furthermore, some consultants felt that SWB was still too complex and required too many input parameters for use as a real-time scheduling tool. Feedback on courses was generally good and most attendees rated the course content and presentations highly.

Course attendees could be categorised according to their level of benefit from the training sessions. The first category includes those who were not irrigation consultants, but took part in the training to improve or refresh their own knowledge on irrigation principles. The second category includes those who tried to use the

SWB model for other purposes than irrigation scheduling, and consequently stopped using it because of disappointing results. Thirdly, there was a group who learnt from the theory but continued using their own model, for various reasons. Fortunately, there was also a group who decided to adopt the SWB model and use it to promote their businesses.

Fewer farmer courses were presented than initially planned. This probably resulted as a direct outflow of the approach followed for the initiation of farmer courses. As the project team felt that it was impossible to provide satisfactory backup support to individual farmers country wide, farmer courses were planned and scheduled in conjunction with SWB consultants active in those irrigation areas. The consultant acted as the link between the research team and the end user or irrigator, and the research team was therefore dependent on consultants requesting farmer courses. As only a few of the attending consultants were involved in irrigation scheduling, the number of farmer courses presented was limited.

Valuable lessons were learned with regard to the planning and presentation of training courses to consultants and farmers. Some of the practical considerations that need to be taken into account include the following: attendees should be consulted in setting dates that are acceptable to all of them. The timing of courses is very important, and they should not coincide with times of peak agricultural activities within a certain production region. Although most attendees indicated that the duration of such courses were appropriate, it became evident that many people have difficulties taking several days out of their schedules to attend courses. The length of courses should therefore also be carefully considered in consultation with the persons involved.

A tertiary level course was developed on the detailed principles of the soil-plant-atmosphere continuum. The content of this course is also to be condensed into a self-paced multimedia-training package. The self-pacing nature of the course should make it especially useful to previously disadvantaged students who might lack the background knowledge in this subject. The multimedia package on CD is called

“Irrigation Management” and contains graphics, animations, photos and video clips to support the text.

The development of the multimedia package, which is done in conjunction with the Department of Telematic Learning and Education Innovation (TLEI) at the University of Pretoria, is proving to be a lengthy and very time-consuming process. After collation of information on the different topics covered in the course, this information then has to be condensed into a format that could be used on individual multimedia screens. Most of the photos, animations and video clips have to be generated by professional photographers and graphic designers, to ensure high quality. A professional narrator is also used to describe the filmed procedures for the video clips. These professionals are only able to work part-time on the project, and since most of them do not have an agricultural background, several iterations are often necessary to ensure that the slides and graphic designs comply with requirements. All these factors eventually result in the multimedia package taking much longer to complete than initially anticipated.

The multimedia-learning package will in future also be made available to previously disadvantaged tertiary institutions, such as the University of Fort Hare and the University of Limpopo. The opportunity also exists to market the CD nationally and internationally in future. The “Irrigation Management” multimedia software and manual will be published and distributed as a separate package to this WRC report. The package will be jointly published by the WRC and the University of Pretoria and will be obtainable from the Department of Plant Production and Soil Science of this University.

The development of site-specific calendar type irrigation scheduling recommendations, which can be used as an alternative to real-time scheduling, is an exciting recent addition to SWB. This facility provides a site-specific printout of seasonal irrigation requirements, which can be used in conjunction with wetting front detectors and a rain gauge to schedule irrigations. Irrigation calendars should be especially useful to farmers without computers and access to real-time weather data. This approach was evaluated in the field at the Taung Irrigation Scheme and preliminary results were promising. Commercial farmers could also benefit from this simpler management option, which is not promoted as a replacement for real-time scheduling, but as a site specific simplified application of the SWB model. Once these farmers have mastered the basic irrigation scheduling principles, they could be introduced to real-time irrigation management using SWB.

Apart from the formal courses presented, several other technology transfer actions were undertaken by the project team during the report period. These include exhibitions and demonstrations at farmer days and congresses, as well as visits by and to individuals who have shown interest in SWB (see Appendix L).

It can be concluded that the first objective of this project, namely to further develop the SWB model as a user-friendly irrigation-scheduling tool has been achieved to a great extent, as most of the concerns raised by users and course attendees have been attended too. Several model adaptations were made in an effort to simplify the model interface and to make it more user-friendly. However, the feedback from some course attendees suggested that certain aspects, such as the model inputs required, could be still further simplified. This aspect should receive attention during future model development.

The second objective was to transfer developed technology to potential users by establishing the SWB model as a user-friendly irrigation-scheduling tool through training sessions. This objective has only partly been met, since although training sessions were presented, it can unfortunately not be claimed that SWB has now been accepted as a scheduling tool on a broad basis. The process of adoption of the SWB model is, however, ongoing, and further technology transfer actions will continue after this project has concluded.

It might be concluded from this that the use of SWB for real-time irrigation scheduling could be a realistic option for leading farmers and consultants rendering a scheduling service to irrigators. We do, however, believe that the training sessions were a good capacity building experience for most attendees, which should result in a positive impact on the country's water management in the longer term.

It is recommended that once the irrigation calendar technique has been refined and found to be acceptable by farmers, a popular article should be published to introduce it to potential users. Call centres could, for example, be established to generate calendars for farmers who cannot be serviced by SWB consultants in their areas. Such call centres could, for example, be established and manned by Water User Associations or Irrigation Boards, or as a business venture by consultants. Centres like these could also handle all SWB related enquiries and problems of users.

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APPENDICES

APPENDIX A

SWB modifications

1. **Model code** was cleaned up and put in order. This will facilitate:
   - Better reading and understanding of the code by future users and developers.
   - Easier further development of the code.

2. **Model interface** changes to allow selection of the mode of operation:

The SWB model includes 3 levels of operation or **modes**, which can be selected in the main menu:

- **Irrigation** mode, which is the basic mode to be used by farmers.
- **Consultant** mode, to be used by irrigation consultants and extension officers to do the initial field set up and settings for farmers.
- **Researcher** mode, which includes all options available in SWB to be used by university students, researchers and developers.
- In the **Irrigation** mode the farmer is now able to access his **Irrigation and Precipitation** and **Weather** data.

3. Model interface change to allow options for type of soil water balance model and irrigation system

The SWB model will run two types of soil water balance models, depending on the choice of the user:

- **Cascading** model based on the simple cascading approach.
- **Finite difference** model based on Richards' equation.

The type of soil water balance model can be selected in the **Field** form.The SWB model will run the **one-dimensional** or **two-dimensional** soil water redistribution, depending on the choice of irrigation system:

i) Sprinkle

ii) Pivot

iii) Flood

iv) Micro

v) Drip

The type of irrigation system can be selected in the **Field** form. If sprinkle, pivot or flood is selected, SWB will run the one-dimensional cascading or finite difference model, depending on the choice of soil water balance model. If micro or drip is selected, SWB will run the two-dimensional cascading or finite difference model, depending on the choice of soil water balance model.

The two-dimensional cascading model is, in reality, a quasi two-dimensional model that calculates the soil water balance for the wetted and non-wetted volume of soil separately. The two-dimensional finite difference model is based on Richards' equation.

4. **Model interface** to allow options for the type of crop model.

SWB includes three types of crop models:

- **Crop growth** model based on the calculation of dry matter partitioning to plant organs and leaf area.
- **FAO** model based on the FAO Kcb basal crop coefficients.
- **Tree** model based on the calculation of intercepted radiation from canopy size and leaf area density. The type of crop model can be selected in the **Field** form. For the **Tree model** the shape of the tree can be selected as either being ellipsoidal or an ellipse of which the base has been cut off horizontally.

5. In the **Field** form, the following changes were made:

- The **lower boundary condition** (free drainage or no drainage) can be selected for the two-dimensional finite difference model.
- The **fraction of roots** in the wetted volume of soil can be entered for both the two-dimensional cascading and finite difference models. This should improve

accuracy in the simulation of root water uptake and describe the effects of the inter-row crop area on rainfall use efficiency.

- **Irrigation system efficiency** can be entered. This is used in the calculation of the amount of water reaching the field from input data of irrigation.

6. Modifications to the **Soil** form:

- The user can enter **saturated hydraulic conductivity** per soil layer for the two-dimensional finite difference model. If these measurements are not available, the model calculates saturated hydraulic conductivity from the soil water retention function.
- When a new soil is created, the user can select the applicable field name from a lookup list.
- Limit root depth to maximum soil depth.

7. Modifications to the **Weather data** facility:

- The data import facility can now accommodate raw data files with more than 12 data columns.
- Weather data in the SWB database can be viewed graphically.
- Weather data in the SWB database can be exported to a text file to enable further data management (e.g. in spreadsheets).
- Improve weather data export / import functions.

8. Modifications to the **Results** output reports and graphs:

- Field and crop names are displayed on all screens and reports.A new column is added for **Daily ET** (sum of E and T columns) in the result output table.
- Legends are added for graphs that have more than one line type, e.g. **allowable depletion** and **deficit** lines on the SWB graph.
- A new output screen that summarizes simulation results on a single page is added. The screen displays the **SWB graph**, **Water content graph** and the **Recommendations** for a specific field. There is also space where **Notes** to the farmer can be typed in. Measured soil water content values are displayed

on the Water content graph. The screen can be printed or a consultant has the option to fax the page directly to his client from within SWB (only a modem is required).

- SWB graph: allowable depletion line can be selected as either a % of PAW or amount (mm), depending on the refill option selected.

9. Modifications to the **Recommendations**:

The **Root zone deficit** can now also be selected as an output option in the **Detailed Recommendations** (in addition to Profile deficit).

10. General Modifications:

- A group lookup is created for **Group simulations** in the Run screen.
- The **Simulation Results** table can be **exported** to a text file to enable further data management (e.g. in spreadsheets). This function is similar to the weather data export function.
- Soil water content data measured with the **Diviner** instrument can be imported into SWB. The measured data can be sent to the measured table or used to update the simulation (similar to neutron probe, tensiometer and gravimetric sampling).
- Field lookup functions for all calculators.
- Create gravimetric water content calculator.
- Automatic return to default form in databases.
- Bulk posting of simulation updates.
- Determination of model parameters by students in M.Sc. projects: crop parameters for canola, barley
- Improved neutron probe scheduler, which should be able to handle different raw data formats in a generic manner.
- Generic import function for measured SWC data (different instrument types).

- SWB irrigation calendar generation and printout facility. A Web site was created to support current and prospective SWB users. The SWB program and update versions of it can also be downloaded from the site. Currently the site is hosted under the NB Systems home page: **http://www.nbsystems.co.za/swb**

APPENDIX B

Consultant Course Name Lists

Name list for SWB Consultant Course: 20 – 22 November 2001, Pretoria

No	Name	Company	Fax no / e-mail	Tel no	Confirmed
1	Mr Banie Swart	Sasex	013 723 4237	082 654 3547	Yes
2	Mr Sarel van der Walt	Sasex	034 413 1299		Yes
3	Mr Hennie du Plessis	ARC	012 808 0353 / marap@vopi.agric.za	082 571 6488	Yes
4	Mr Tielman Roos	Dept Agriculture N Prov	015 295 5003	015 295 5004	Yes
5	Mr Elmar Deysel	Dept Agriculture N Cape	053 832 1030	082 873 0880	Yes
6	Mr Paul Farrell	PFBoerdery	058 256 1372 / jacofarrell@isat.co.za	058 256 1131	Yes
7	Mr Flip Steyn	McCain	013 665 1275 / fsteyn@mccain.co.za	082 825 7354	Yes
8	Mr Johan Koekemoer	McCain	013 665 1275	083 634 7928	Yes
9	Mr Dave Mynhardt	Private consultant	015 795 5395 / davemyn@cybertrade.co.za	082 921 4079	Yes
10	Mr Carlo Quass	NWK Lichtenburg		083 230 9283	Yes
11	Mrs Cornie Verwey	J.P. Verwey Skedul	Verwey@pop.co.za	082 897 8739 / 082 876 3772	Yes
12	Mrs Gail Andrews	Rand Water	011 900 2108 /	011 900 1580	Yes

			Gandrews@Randwater.co.za		
13	John Gordon	LIA	011 793 1131 / Johng@netdial.co.za	083 700 2965	Yes
14	Johan Stoop	Rand Water	011 900 2108	011 900 1580	Yes
15	Mr Basie du Toit	MKTV	013 262 2126	082 829 4867	Yes
16	Dr Robert Steynberg	MKTV	014 763 3793	014 763 3793	Yes
17	Mr Heilet Engelbrecht	MKTV	014 596 6419		Yes
18	Mr Herman von Willich	Hygrotech	013 262 2126		Yes
19	Mr Andreas Boon	CSIR	aboon@kingsley.co.za	082 740 4242	Yes
20	Mr Danie du Plessis	Consultant	ddp@lantic.net	083 564 9694	Yes
21	Mr ST Potgieter	Omnia	spotgiet@omnia.co.za	083 414 4595	Yes
22	Mr Dawid Fouché	Omnia	dfouche@omnia.co.za	082 923 0438	Yes
23	Mr Piet Mynhardt	LGVM	013 262 2446 / skedul@lantic.net		Yes
24	Mrs Edna Mynhardt	LGVM	013 262 2446 / skedul@lantic.net		Yes
25	Mr Rudolf Nel	LPM	015 533 0406	015 533 0144	Yes
26	Mr Johan vd Hoven	Extension officer - Brits	012 252 3993	082 780 9478	Yes
27	Dr Puffy Soundy	UP	012 420 4120 / psoundy@postino.up.ac.za	012 420 3215	Yes
28	Mrs Annemarie vd Westhuizen	UP	012 420 4120 / amvanderwest@tuks.co.za	012 420 4598	Yes
29	Mr Tshepo Maeko	UP	012 420 4120	012 420 4598	Yes
30	Ms Pulani Modisane	UP	012 420 4120	012 420 4598	Yes

31	Mrs Thembeka Mpuisang	UP	012 420 4120	012 420 4598	Yes
32	Ms Diana Marais	UP	012 420 4120	012 420 3218	Yes
33	Mr Philippe Lobit	UP	012 420 4120	012 420 4598	Yes

Name List for SWB Consultant Course: 25 – 27 March 2002, Elsenburg

No	Name	Company	Fax no	e-mail	Tel / Cell no	Confirmed
1	Charl le Roux	CSAfrica		cleroux@csafrica.co.za	021 8800885	Y
2	Owen Mandiringana	Univ. Fort Hare		OMandiringana@ufh.ac.za		Y
3	L Qongqo	Univ. Fort Hare		“		Y
4	Uys Meiring	Kynoch		uysm@loskop.co.za		Y
5	Andre Britz	Kynoch		BritzA@mil.kynoch.co.za		Y
6	Jannie Bester	Kynoch		BesterJ@mil.kynoch.co.za		Y
7	Johan Cronje	Omnia	058 813 2063			Y
8	Greg Ascough	ARC-Infruitec / ILI		grega@infruit1.agric.za		Y
9	Ockert Fourie	Omnia		ofourie@omnia.co.za		Y
10	Janco Jacobs	2-a-day		janco@tad.co.za		Y
11	Theresa Volschenk	ARC-Infruitec		theresa@nvbij1.agric.za		Y
12	Bertus Kruger	Agriplas		bkruger@agriplas.co.za		Y
13	Pieter Keuck	Dept Agric WCape		peterk@wcape.agric.za		Y
14	Rian Briedenhann	Omnia		(IPijl@omnia.co.za)		Y
15	Isabelle Pijl	Omnia		IPijl@omnia.co.za		Y
16	Chris Malan	Netafim		Chrism@Netafim.net		Y
17	Mias Pretorius	US			083 495 2701	Y

18	Piet Brink	Kynoch		Brinkp@mil.kynoch.co.za		Y
19	PD Koegelenberg	Vredendal Wynkelder		pd@namaqua.co.za		Y
20	Willem Botha	WinPro	023 626 3036	Bothaw@kwv.co.za	0834555193	Y
21	Johan Viljoen	WinPro	021 4130546	viljoenj@kwv.co.za	0828907446	Y
22	Briaan Stipp	WinPro	023 626 3036	Stippb@kwv.co.za	0834555196	Y
23	Anton Laas	McGregor Wynkelder	023 626 5074	Roodez@intekom.co.za	0824473946	Y
24	Leon Dippenaar	Graham Beck Wines	023 626 1922	farm@grahambeckwines.co.za	0834555194	Y
25	Francois Knight	Wine Managem. Syst.		fknight@winems.co.za		Y
26	Hennie Visser	Ashton Kelders		ashkel@mweb.co.za	083 556 1762	Y
27	Francois de Villiers	Stellenbosch Vinyards		lchristen@stellvine.co.za	(Laura)	Y
28	Johan Hewett	Stellenbosch Vinyards		lchristen@stellvine.co.za	(Laura)	Y
29	Robbie Childs	Sungro technologies	041 364 0927	rfmc@mweb.co.za	082 653 3032	Y
30	Megan A'Bear	Omnia		mabear@omnia.co.za		Y

Name list for SWB Consultant Course: 19 – 21 August 2002, Bethlehem

No	Name	Company	Fax no	e-mail	Tel / Cell no	**Postal address**
1	Wikus Boshoff	Pannar	016 3491206	bwikus@mweb.co.za	082 780 0117	Bus 1051, Heidelberg 1438
2	Div Bosman	Omnia	058 3038143	dbosman@omnia.co.za	082 457 6743	
3	Jose Carreira	Lone Tree Farms	058 3031439	Ltf @dorea.co.za	082 8027244	
4	Hentie Cilliers	Omnia		hcilliers@omnia.co.za		Bus 3884, Witrivier 1240
5	Bennie Dunhin	Pannar	053 5910762	bdunhin@intekom.co.za	082 411 1349	
6	Heinz Oellerman	Pannar		heinz.oellerman@pannar.co.za	082 7876245	Bus 19, Greytown 3250
7	Jannie Peyper	Omnia		janniep@omnia.co.za	083 2887131	Bus 1059, Potchefstroom 2520
8	Pieter Rademeyer	Pannar	056 2121906	pieter.rademeyer@pannar.co.za	082 7765583	Bus 426, Kroonstad 9500
9	Louis Pieterse	Pioneer / Irrig. Consultant	058 8633493	lpagric@xsinet.co.za	082 578 5614	Bus 460, Reitz 9810
10	Rikus Schoeman	Pioneer		Rikus.schoeman@pioneer.co za		

11	Johan van Heerden	(Reitz)	058 8632528	cjvanheerden@telkomsa.net	082 5707582	
12	Chris Viljoen	Consultant	018 2907500	chrisv@wmb.co.za	083 2716304	Bus 20954, Potchefstroom 2522
13	Jannie Willemse	Omnia	018 6327042	jwillemse@omnia.co.za	083 4627054	Bus 659, Lichtenburg, 2740
14	Andries Zandberg	Pannar	053 4742029	andries.zandberg@pannar.co.za	082 8094372	Bus 289, Magogong 8575

APPENDIX C

SWB Consultant Course Programme Example

Programme for SWB Consultant Course: 20 – 22 November 2001

Day 1: Tuesday 20 November 2001

09:00 Registration / Tea / Coffee

09:30 Welcome – Prof PS Hammes

09:40 Introduction and Course Arrangements – Dr M Steyn

09:50 Philosophy behind SWB – Prof JG Annandale

User-friendly, hi-tech approach

SPAC principles

Discussion

10:30 Tea

10:50 Brief demo of SWB – Dr M Steyn

3 levels

Expectations for consultant, tertiary level student, irrigator

Measured data, updates, statistics

Discussion

11:30 Soil water relations – Prof JG Annandale

Soil water content and potential concepts (θ, w, Ψ)

Plant available water (PAW), FC, WP

Campbell retention curve

12:30 Lunch

13:30 Soil water modelling – Prof JG Annandale

Interception, runoff, redistribution, percolation, evaporation

14:15 Soil – parameter estimation – Dr M Steyn

FC, WP, θi, dz, ρb

Drainage factor, drainage rate

Runoff curve number

15:00 Tea

15:20 Practical exercise: SWB installation and running a simulation – Dr M Steyn

Install SWB

Run simulation

Get simulation results, interpret recommendations

16:00 Practical exercise: Soil parameters – Dr M Steyn

Calculate soil parameters from raw data

Set up a new soil, enter calculated data

Effect of soil properties on simulation results

16:50 SWB Technology Transfer Project – Dr G Backeberg, WRC

17:00 Cocktail

Day 2: Wednesday 21 November 2001

08:30 Crop water relations – Dr N Jovanovic

Water uptake – Ψ gradient

Water loss

Crop modelling – Dr N Jovanovic

Thermal time, DM production, assimilate distribution

Difference between crop model and FAO approach

10:30 Tea

10:50 FAO model – Dr N Jovanovic

Principles

11:30 Case study: Crop parameters – Dr M Steyn

FAO parameter estimation

Growth model parameter estimation

12:30 Lunch

13:30 The atmospheric environment – Prof JG Annandale

Radiation balance

Energy balance

Pennman-Monteith equation

FAO reference ET

Modelling the atmospheric component – Dr N Jovanovic
Input data required
ETo calculator

15:00 Tea

15:20 Practical exercise: Set up and run a new simulation – Dr M Steyn
Set up a new AWS
Set up a new field
Run a simulation
Interpret simulation results and recommendations

16:40 Hardware and software philosophy – Dr N Benadé
Databases used
Computer requirements
Copyright and protection

17:00 Braai

Day 3: Thursday 22 November 2001

08:30 Practical exercise: Special features – Dr M Steyn
Measured data inputs
Update simulations
Import AWS data
Create a new FAO crop

10:00 SWB users manual and the help file – Dr N Jovanovic

10:30 Tea

10:50 Advanced Topics – Dr N Jovanovic
Weather generator
Finite difference model
Chemical equilibrium
2D tree model

11:30 Discussion / the way forward – Dr M Steyn

12:00 Course evaluation – Dr M Steyn

12:25 Presentation of certificates

12:30 Lunch

13:30 Departure

APPENDIX D

Evaluation Form
SWB CONSULTANT COURSE

In order to assess the success of the course and improve future courses, please rate the following aspects or questions by marking the appropriate scale points:

Scale:	1= Very poor	2=Poor	3=Reasonable	4=Good	5=Very good

1.	General course arrangements		1	2	3	4	5
2.	How would you evaluate the course content of the following?						
	a.	Brief SWB demo	1	2	3	4	5
	b.	Soil water relations lectures	1	2	3	4	5
	c.	Soil parameter estimation lecture	1	2	3	4	5
	d.	Crop water relations lectures	1	2	3	4	5
	e.	The atmospheric environment lectures	1	2	3	4	5
	f.	Hardware and software philosophy	1	2	3	4	5
	g.	SWB users manual and help file lectures	1	2	3	4	5
	h.	Practical exercises	1	2	3	4	5
3.	Standard of the presentations		1	2	3	4	5
4.	Were the course objectives met?		1	2	3	4	5
5.	Has the course met your expectations?		1	2	3	4	5
6.	New or worthwhile information gained		1	2	3	4	5
7.	Course organisation		1	2	3	4	5
8.	Length of course		1	2	3	4	5
9.	Course venue		1	2	3	4	5
10.	Food		1	2	3	4	5
11.	Professional contacts made		1	2	3	4	5

12. What changes, do you think, could help to improve similar courses in the future?

……………………………………………………………………………………………

……………………………………………………………………………………………

13. Do you think you will be able to set-up simulations and help farmers schedule with SWB?

…………………………………………………………………………………………………

14. Will you try to use SWB?

…………………………………………………………………………………………………

15. If you intend servicing clients with SWB, would you appreciate assistance from the research team?

…………………………………………………………………………………………………

16. If so, what form should this assistance take?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

17. Other general comments (use reverse side of page if necessary)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

APPENDIX E

Course Evaluation Results

SUMMARY: NOVEMBER 2002 CONSULTANT'S COURSE EVALUATION

Scores given for questions 1 to 9 of evaluation form

Question	Average score	Maximum Score	Minimum Score	Standard Deviation
1	4.4	5	3	0.62
2a	3.9	5	3	0.58
2b	4.2	5	3	0.50
2c	4.1	5	3	0.60
2d	4.1	5	3	0.66
2e	4.1	5	3	0.68
2f	3.8	5	3	0.61
2g	3.9	5	2	0.55
2h	3.7	5	2	0.74
3	4.3	5	3	0.60
4	4.0	5	3	0.72
5	3.9	5	2	0.80
6	4.5	5	3	0.63
7	4.3	5	3	0.64
8	3.9	5	2	0.76
9	4.4	5	3	0.56
10	4.5	5	3	0.57
11	4.1	5	3	0.78

Answers to questions 2 – 4:

Question	YES	NO	Indecisive
2	17	3	8
3	28		2
4	26		

Answers to questions 12, 16 and 17:

Question	Answer	Number
12	More practical exercises	15
	Show demo first	3
	Show help first	2
	Interpretation of results	2
	Show economics	1
	Case studies	1
	Link theory to model	1
	System evaluation	1
	English + Afrikaans	1
	More soil input	1
	More theory	1
	Wider scope of attendees	1
	More crop and parameter theory	1
16	e-mail or telephone enquiries	17
	Visits (training)	5
17	Fertilization recommendations	1
	More user-friendly	1
	Ridge planting (furrow irrigation)	1
	Tree model	1
	Less input	1
	Fix bugs	1

EVALUATION RESULTS: SWB Consultant Course: 19 – 21 August 2002, Bethlehem

Table 1a: Evaluation of the consultant's course at Bethlehem by participants. Average, standard deviation, maximum and minimum marks are reported for each question (1 = very poor; 2 = poor; 3 = reasonable; 4 = good; = very good).

Questions	Average	Std Dev.	Max.	Min.
1. General course arrangements	4.1	0.5	5	3
2. How would you evaluate the course content of the following				
- Philosophy behind SWB	4.3	0.5	5	4
- Brief SWB demo	4.1	0.6	5	3
- Soil water relations lectures	4.1	0.7	5	3
- Soil water modelling and parameter estimation lecture	3.9	0.8	5	3
- Crop modelling lecture	3.8	0.7	5	3
- Case study: Crop parameters	4.0	0.6	5	3
- The atmospheric environment lectures	4.1	0.7	5	3
- SWB users manual and help file lectures	3.9	0.8	5	2
- Hardware and software philosophy	4.0	0.9	5	2
- Advanced topics lecture	3.6	0.6	5	3
- Practical exercises	4.1	0.6	5	3

3. Standard of the presentations	4.0	0.7	5	3
4. Has the course met your expectations?	3.8	0.8	5	2
5. New or worthwhile information gained	4.1	0.7	5	3
6. Course organisation	4.1	0.4	5	4
7. Course venue	4.2	0.6	5	3
8. Food	4.1	0.9	5	2
9. Professional contacts made	4.1	0.6	5	3

Table 1b: Evaluation of the consultants courses at Bethlehem by the participants. The figures indicate the number of participants answering a specific question.

Questions	Response		
Should the duration of similar courses in the future be shorter, longer, or kept the same?	Shorter	Longer	Same
	1	4	9
Have you used SWB before this course?	Yes	No	Indecisive
	1	13	-
If you have not used SWB before, will you try to use it after this course?	Yes	No	Indecisive
	12	1	1

What changes, do you think, could help to improve similar courses in the future?			
- More practical exercise	2		
- More basic theoretical information	2		
- Less theory on model background	1		
- Target the audience interested in specific crops	2		
Do you think you will be able to set-up simulations and help farmers schedule with SWB?	Yes	No	Indecisive
	11	0	3
If you intend servicing clients with SWB, would you appreciate assistance from the research team?	Yes	No	Indecisive
	14	0	0
If so, what form should this assistance take?			
- E-mail and telephone	10		
- Visits (training)	3		
- Backup of data	-		
- Full assistance, discussion (questions-answers) forum, help desk	1		
- Solving practical problems	2		
- Input data	-		
- Evaluation and interpretation of data	-		
- Update versions through Web	1		
- Troubleshooting	2		

Other general comments	
- Good course – learned a lot / refreshed knowledge	3
- Afrikaans course requisted	3
- Course too enhanced	1
- Complete step by step guide required	1
- SWB is too complicated for farmers, takes too long to set up for many clients	2
- Require a recipe similar to BEWAB, which can be updated 2 weekly	1

APPENDIX F

Example of Certificate

University of Pretoria

Faculty of Natural and Agricultural Sciences

This is to certify that

CJ Dreyer

has successfully completed the

Soil Water Balance (SWB)
Irrigation Management Consultant's Course
sponsored by the Water Research Commission

20 – 22 November 2001

Course Leader

Accreditation Manager:CE at UP

Water Research Commission

APPENDIX G

Name Lists For Farmer Courses

Name list for SWB Irrigator Course - Gromar Landbou Akademie, Groblersdal: 12 March 2002

No	Name	e-mail	Tel / Cell no	Confirmed
1	Tania Badenhorst	jacnia@loskop.co.za	082 567 1694	Y
2	Kobus Badenhorst	jacnia@loskop.co.za	083 285 5473	Y
3	Johan Barnard			Y
4	Danie Becker	taratibo.mweb.co.za	082 879 2532	Y
5	Kobus Beukes			Y
6	Johannes Bezuidenhout		082 424 9569	Y
7	Hermanus Botha		082 827 6950	Y
8	Johan du Preez	jdup@lantic.net	082 745 0560	Y
9	Basie du Toit		082 829 4867	Y
10	Francois Fuls		082 410 0819	Y
11	Tienie Grobler		082 443 1027	Y
12	Stephan Kloppers		082 956 3387	Y
13	Henk Knouwds		082 935 4992	Y
14	Shayne McIntyre	hpieters@lantic.net	082 752 7064	Y
15	Ernest Nell		082 825 7689	Y
16	Gerhardt Risseeuw	risseeug@lantic.net	082 371 2226	Y
17	Kobus Risseeuw	risseeuw@lantic.net	082 567 1902	Y
18	Frans van Deventer	taratibo.mweb.co.za	082 473 5648	Y
19	Albert Viviers		082 379 1321	Y

Name list for SWB Irrigator Course: TSB, Malelane, 15 – 16 April 2002

No	Name	Company	Fax no	e-mail	Tel / Cell no
1	Francois Botha	SASEX	013 790 0231	bothaf@tsb.co.za	013 790 0230 082 654 3548
2	Arno Cilliers	Kaapmuiden Sitrus			082 440 2939
3	Gerhardt Davies	Senekal Sukier Boerdery	013 790 7303	davies.g@mweb.co.za	083 228 0903
4	Francois Olivier,	SASEX	082 338 3843	olivier@sugar.org.za	082 338 3760
5	Rènald Radley	Radley Landgoed	013 790 0466	stratagri@mweb.co.za	082 821 3019
6	Wilscott Radley	Radley Landgoed	013 790 0466	radleylg@mweb.co.za	082 412 2633
7	Jaco van Gass	Ficus Boerdery	013 790 4542		013 790 4542 082 333 1633
8	Marius van Rooyen	Dept Landbou	013 752 2841	marius@laeveld1.agric.za	082 872 3967
9	Thomas Smit	Martiens Landgoed	013 790 7544		082 872 3967
10	Charles Esser	DouwJan Boerdery	013 790 7544	douwjan@mweb.co.za	082 601 4076

APPENDIX H

Programme for SWB Irrigation Management Course

07:30 Registration and Coffee

08:00 Welcome, Introduction, Course Objectives and Arrangements – Piet Mynhardt

08:10 Video – Piet Mynhardt

08:40 Economic importance of irrigation scheduling – Basie du Toit

09:00 SWB theory – Prof John Annandale

Philosophy behind SWB

SPAC principles

Soil water relations

Crop water relations

The atmospheric environment

10:00 Tea

10:30 Brief demo and features of SWB – Dr Martin Steyn

3 levels

Expectations for consultant and irrigator

Measured data, simulation updates

Other tools: neutron probe scheduler, tensiometer scheduler, etc.

11:00 Soil – parameter estimation – Dr Martin Steyn

FC, WP, θi, dz, ρb

Drainage factor, drainage rate

Runoff curve number

How to calculate soil parameters from raw data

11:30 Using Neutron Probe data to obtain soil parameters – Piet Mynhardt

12:00 Practical SWB exercise: running a simulation – Dr Martin Steyn

Run an existing simulation

View simulation results

Customize graphs and recommendation outputs

Interpret recommendations

13:00 Lunch

14:00 Practical exercise: Set up and run a new simulation – Dr Martin Steyn

Set up a new soil

Set up a new AWS

Set up a new field

Run the simulation

View simulation results

Interpret recommendations

15:00 Tea

15:20 Demo: Special features – Dr Martin Steyn

Measured data inputs

Update simulations

Import AWS data

16:00 Advanced Topics – Dr Nebo Jovanovic

SWB users manual and the help file

Crop FAO and Growth parameters

16:20 Hardware and software philosophy – Dr Martin Steyn

Computer requirements

Copyright and protection

16:30 Course evaluation – Dr Martin Steyn

16:40 Discussion / the way forward – Prof John Annandale

17:00 Presentation of certificates

17:15 Braai

APPENDIX I

Outline of Tertiary Level Irrigation Course

Irrigation Management - Principles and Practices

1. Introduction

    Water utilization in agriculture

    Historical development of irrigation

    Irrigation globally

    Irrigation in South Africa

    Course outline

2. The Soil Environment

    Introduction and learning objectives

    Soil water content and measurement

    Soil water potential concept, its components and measurement

    Soil water retention

    Soil hydraulic properties

    Soil water dynamics

    The soil water balance

    Simple modelling of the soil water balance

    Finite difference model

    Drainage

    Exercises

    Advanced topics

3. The Atmospheric Environment

    Introduction and learning objectives

    The radiation balance

    The energy balance

    The Pennman-Monteith equation

    Weather data acquisition (standard weather stations)

Pan evaporation

Exercises

Advanced topics

4. Plant Water Relations

Introduction and learning objectives

The soil-plant-atmosphere continuum

Plant available water

Plant water stress

Measurement of plant water stress

Exercises

Advanced topics

5. Irrigation Management

Introduction and learning objectives

Irrigation scheduling approaches:

Soil based

Plant based

Atmospheric based

Integrated approach

6. Mechanistic irrigation scheduling

The SWB model

Exercises

Advanced topics

7. Estimation of Crop Water Requirements for planning purposes

Introduction and learning objectives

Water-yield functions

The Green book

SAPWAT model

BEWAB model

Exercises

Advanced topics

8. Irrigation systems

    Introduction and learning objectives

    Classification of systems

    Surface

    Sprinkle

    Micro

    Management aspects

    System uniformity

    Exercises

    Advanced topics

9. Fertigation

    Introduction and learning objectives

    Principles

    Management aspects

    Exercises

    Advanced topics

10. Saline Irrigation Water Management

    Introduction and learning objectives

    Classification of Irrigation water quality

    Classification of Soil salinity

    Crop salt tolerance

    Determining solute content in the soil

    Sustainable irrigation with saline water

    Exercises

    Advanced topics

APPENDIX J

Tertiary Level Course Evaluation

Summary of user feedback done by Telematic Learning and Education on 27 August 2002

Total number of students who completed an evaluation form: 16

Feedback from students:

- Enjoyed most about the program:
- Work at own pace and can go back – read it again until you understand.
- Well structured, very organised.
- Language not too difficult. (x2)
- It is user-friendly (x2)
- Simple and effective
- Understand work better than most books
- Good graphics and layout (x6)
- Not too much confusing detail presented in the program
- Good examples are presented
- Brief and to the point
- Script font is easy to read
- Fast access to any question (faster than any books)
- Everything related to irrigation is in here.
- The program allow you access to other references e.g. FAO website.
- Good vision of screen – icons are clear.
- I enjoyed weather data acquisition most because I am now really able to visualize what different weather instruments look like (x2)

Enjoyed least about the program:

- Some things did not work – 8 pages of 7.
- Should display links to other software or other pages in different colour.
- Did not know how to go back the first time.
- Little detailed information is presented.

- The pan evaporation section
- Some of the symbols are not clearly visible - better if you increase/enlarge the font size.
- Directions on how to exit at some parts, e.g. Chapter outline

Problems:

- Must go back to the menu every time – should get used to it.
- Moving through pages isn't possible with wheel on mouse.
- No exit button on main menu.
- Links are of same colour than other text.
- Forward button is not clear.
- Navigation on Chapter Outline page is not clear.

Suggestions for improvement

Links	• Make links another colour • 3rd menus also other colour to indicate that there are other options available • Terms, technical words included in text (also present in glossary) be hyper linked so that the explanation can be viewed on the same page instead of going back and forward to the glossary.
Navigation	• Moving through pages with mouse wheel button • Rather have "Next page" or Previous page" than <> • Do not want to click on menu to return (3rd menu items) • Give students more instructions. E.g. On the weather apparatus menu page, add instructions telling students to click on the titles in the menu below to obtain information about the different weather apparatuses. A student also suggested having roll over images (mouseovers) over each weather instrument on that menu page so they can

	see what each instrument looks like.
Text on graphics	Not always clear – make brighter or darker
Help	• Include help file • A help file would be valuable to tell students how the program works.
Space on slides	Use the space on all slides to its full potential – there are some slides with only 2 sentences on.
Equations	Highlight the equations better – the blue text on blue rectangle doesn't make it stand out clearly.
Calculations	For some calculations, maybe the value of some known plants can be given, e.g. grass reflect more sunlight than maize, thus reflective constant is more. There should be decided in which countries the program will be sold and water use values for their major crops must be given.
Course map	I suggest that the program have some icon, which could help you to get directly to the page you want to find.
Pan evaporation	Better the pan evaporation has more details, say how it can be installed and the way how to take readings in the form of picture.
More details	The program I accessed is more of a short notes, so for better understanding of the subject I suggest it to be broadened.
Objectives	Set the objectives of the programme
Levels	Present these ideas at understandable level, i.e.: • Student level (scientific) • Farmer level
Printing	Page by page printing
Animations	One student commented that she would have liked to see movement/interactivity, to understand some of the processes better; otherwise she said there will be too much reading and students get bored.
Examples	One student suggested making use of practical examples of some of the content. Examples of equations to illustrate the

	principles and for better and clearer understanding. When something is illustrated and people understand it, it is not an equation any more; it is something you can actually use.

Would you have liked a Help section explaining how to use the program?

Yes	8
No	4
Unsure	1
Not completed	3

Did you find the navigation easy?

Always	9
Sometimes	7
Not at all	

APPENDIX K

Irrigation Calendar Approach

The approach followed to generate irrigation calendars can be summarized as follows:

1. Obtain long-term daily weather data for the specific site.
2. Import data into SWB.
3. Use SWB to calculate for each day of the year the average minimum and maximum temperatures, as well as average wind speed, radiation and vapour pressure, if available.
4. Set up field and soil for site-specific conditions, including irrigation frequency option, e.g. irrigate at fixed frequency once every 5 days.
5. Complete the farmer's details (name, etc) under Address and link to the specific field. This will be printed on the header of the Irrigation calendar.
6. Complete the following information:
   - Number of shallow wetting front detectors (WFD's) in the field
   - Number of deep WFD's in the field
   - Irrigation response factor = % by which irrigation must be adjusted up / down, depending on WFD response
7. Under the Run screen
   - Select "Generate irrigation calendar"
   - Run an "auto irrigation type" simulation, using the irrigation frequency option selected in the field form, i.e. if a fixed frequency of 5 days is selected, the model will run for 5 days, and then assume that the irrigation amount is equal to the calculated deficit after 5 days. Thus if the deficit after 5 days is 25mm, SWB will assume that 25mm is irrigated and the deficit will become zero, etc.
8. At the end of the simulation run, SWB will recommend the irrigation quantities for each of the irrigation dates (e.g. at 5-day intervals).
9. These calendar-type recommendations can then be printed out (see Example).

10. The farmer has to adjust the irrigation amount according to WFD response and rain. SWB has to do these calculations beforehand and print on the calendar as follows:
    - If fewer than half of the shallow WFD's have tripped after the previous irrigation, increase the irrigation amount (calculated by SWB) by the response factor, e.g. if the response factor is 30% and the recommended amount is 20mm, the irrigation requirement becomes 26mm
    - If more than half of the shallow and fewer than half of the deep WFD's have tripped, use the recommended amount.
    - If more than half of the shallow and more than half of the deep WFD's have tripped, the irrigation amount (calculated by SWB) must be reduced by the response factor, i.e. if the response factor is 30% and the recommended amount is 20mm, the irrigation requirement becomes 14mm
11. For Drip and Micro irrigation, the Irrigation column falls away on the calendar printout.
12. For Drip and Micro irrigation, all the irrigation amounts must be given in hours (not mm).
13. For pivot irrigation, under Notes a table is printed with summary of pivot speed setting versus mm irrigation.

APPENDIX L

Other Technology Transfer Actions

Technology transfer actions other than planned courses: Meetings with individuals and organisations

No.	Name	Company / Organisation	Action	Date
1	F Steyn	McCain Foods	SWB training	
2	I Find	McCain Foods	SWB demo, discussions	Jan 2001
3	SWB project team	NB Systems	Planning meeting - SWB modifications	Jan 2001
4	Robbie Childs	Consultant – E.Cape	e-mail assistance on SWB	Jan & Feb 2001
5	P Mynhardt	Consultant – Mpumalanga	Planning meeting - SWB modifications	Jan 2001
6	Robbie Childs & Wouter Vermaak	Consultants – E.Cape	Meeting with SWB project team at NB Systems: SWB modifications and training	Feb 2001
7	Banie Swart	SASEX - Komatipoort	SWB modifications, setup and training	Mar 2001
8	F Steyn	McCain Foods	SWB setup and training	April 2001
9	H Teboekhorst	McCain Foods	SWB training, report	May 2001
10	SWB project team	NB Systems	Planning meeting - SWB modifications	June 2001
11	B Kruger	Agriplas	SWB meeting, planning	June 2001
12	SWB project team	NB Systems	SWB modifications	July 2001
13	F Steyn	McCain Foods	SWB setup and training	July 2001
14	Banie Swart	SASEX- Komatipoort	Visit client, Naas Gouws, for SWB setup and	Sept 2001

			training	
15	C Kgonyane	ARC-Roodeplaat	Discuss potato data for SWB parameters	Aug 2001
16	C Quass	NW Co-op Lichtenburg	Meeting, discuss, demo SWB	Aug 2001
17	Paul Farrell	Farmer - Clarens	Visit: load new SWB software version, setup and training	Aug 2001
18	Robbie Childs & Wouter Vermaak	Consultants – E.Cape	Visit by SWB team: SWB modifications and training	Sept 2001
19	Proff P Mnkeni, Raaths	Fort Hare University	Introduce to SWB, discuss tertiary training package, possible co-operation.	Sept 2001
20	SWB project team	NB Systems	SWB modifications	Oct 2001
21	SWB project team	NB Systems	SWB modifications	Nov 2001
22	P Mynhardt	Consultant – Mpumalanga	Meeting - SWB modifications	Feb 2001
23	SWB project team	NB Systems	SWB modifications	Feb & Mar 2001
24	W Safara	NAFU	SWB training	Mar 2002
25	P Mynhardt	Consultant – Mpumalanga	SWB assistance – weather data import	Mar 2002
26	SWB project team	NB Systems	SWB modifications: x 3 visits	Mar 2002
27	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications	Apr 2002
28	F Boshoff	Leopard Creek Malelane	SWB enquiry; send SWB CD	Apr 2002
29	S de Wet	Ninham Shand Bloemfontein	SWB enquiry; send SWB CD	Apr 2002
30	Dr JJ Bornman	Kynoch Hydro	SWB demo	Apr 2002

31	HS Bosman	Farmer Vaalwater	SWB demo & CD	May 2002
32	SWB project team	NB Systems	SWB modifications: x 2 visits	May 2002
33	Banie Swart	SASEX - Komatipoort	SWB assistance – weather data import	June 2002
34	Banie Swart	SASEX - Komatipoort	SWB assistance	June 2002
35	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications	Jul 2002
36	SWB project team	NB Systems	SWB modifications: x 2 visits	July 2002
37	Dries Duvenhage	Consultant – Louwna area	SWB demo	Aug 2002
38	F Steyn	McCain Foods	SWB assistance	Aug 2002
39	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications	Aug 2002
40	SWB project team	NB Systems	SWB modifications	Aug 2002
41	Chris Viljoen	Environmental Consultant	SWB demo & CD	Aug 2002
42	Plant Production class	UP graduate students IV year	SWB demo	Sept 2002
43	H du Plessis	Researcher, ARC-Roodeplaat	SWB assistance	Sept 2002
44	SWB project team	NB Systems	SWB modifications	Oct 2002
45	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications	Oct 2002
46	Banie Swart	SASEX - Komatipoort	SWB assistance	Oct 2002
47	Patrick Ooro	KARI, Kenya	SWB demo: 15 reserachers	Oct 2002
48	SWB project team	NB Systems	SWB modifications: x 3 visits	Nov 2002
49	W Sefara	Dept Agric Limpopo	SWB demo, training & CD	Nov 2002

50	D Cousens	Ubombo Sugar Swaziland	SWB demo & CD: 2 persons	Nov 2002
51	GW Gerald	Zambia Sugar	SWB demo & CD: 2 persons	Nov 2002
52	Paul Farrell	Farmer - Clarens	New SWB software version & assistance	Nov 2002
53	M Smith	FAO	Visit, SWB discussions	Dec 2002
54	F Steyn	McCain Foods	SWB assistance	Nov 2002
55	SWB project team	NB Systems	SWB modifications	Dec 2002
56	Banie Swart	SASEX - Komatipoort	SWB assistance	Dec 2002
57	Deon van Gass	Ficus Boerdery, Komatipoort	SWB assistance – visit	Dec 2002
58	Thomas Smit	Martiens Landgoed	SWB assistance – visit	Dec 2002
59	Banie Swart	SASEX - Komatipoort	SWB assistance	Dec 2002
60	SWB project team	NB Systems	SWB modifications	Jan 2003
61	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications	Jan 2003
62	W Safara	Dept Agric Limpopo	SWB assistance	Feb 2003
63	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications	Feb 2003
64	SWB project team	NB Systems	SWB modifications	Feb 2003
65	N du Sautoy	Consultant OTK	New SWB CD	Feb 2003
66	G Venter	Consultant Groblersdal	SWB assistance, modifications	Feb 2003
67	P Mynhardt	Consultant – Mpumalanga	SWB assistance – weather data import	Feb 2003
68	D Ferreira	Loskop Irrigation Scheme	Weather data availability	Feb 2003

69	F Steyn	McCain Foods	SWB assistance	Feb 2003
70	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications, new CD	March 2003
71	SWB project team	NB Systems	SWB modifications	March 2003
72	G Kotze	SA Maltsters (SAB)	SWB demo & CD, possible cooperation	Mar 2003
73	Robbie Childs	Consultant – E.Cape	SWB assistance– weather data import	Apr 2003
74	F Steyn	McCain Foods	SWB assistance	May 2003
75	G Kotze	SA Maltsters (SAB)	Discuss cooperation	May 2003
76	SWB project team	NB Systems	SWB modifications x 21 visits	Apr – Dec 2003
77	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications	May 2003
78	G Kotze	SA Maltsters (SAB)	Visit Taung: Barley trials fof SWB parameters	Jun – Oct 2003
79	F Steyn	McCain Foods	Cooperation: SWB parameters for potatoes	Aug 2003
80	G Kotze	SA Maltsters (SAB)	Visit Hatfield barley trials	Aug 2003
81	F Steyn	McCain Foods	Visit Bronkhorstspruit field trials: SWB parameters for potatoes	Aug 03 – Jan 04
82	A Nel / J Heymans	ARC-GCI	SWB assistance	Sep 2003
83	C Jarmain	CSIR	SWB assistance	Sep 2003
84	D Haarhof	GWK Douglas	Discuss scheduling service with SWB	Oct 2003
85	W Safara	Dept Agric Limpopo	SWB assistance	Oct 2003
86	A Rugumayo	Makerere Univ, Uganda	SWB assistance	Oct 2003
87	D Haarhof	GWK Kimberley	Discuss SWB training	Oct 2003
88	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications – visit	Nov 2003
89	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications	Nov 2003
90	P Langelier	CIRAD	WFD's & Irrigation calendars – visit	Nov 2003

91	P Mynhardt	Consultant – Mpumalanga	SWB assistance – weather data import	Dec 2003
92	Robbie Childs	Consultant – E.Cape	SWB assistance, modifications	Dec 2003
93	A Wiid	GWK	SWB assistance, weather data import	Dec 2003
94	D Mynhardt	Consultant – Hoedspruit	SWB assistance	Jan 2004
95	P Mynhardt	Consultant – Mpumalanga	SWB assistance	Jan 2004
96	P Joubert	Hanna SA	SWB purchase	Jan 2004
97	A Skelton	Pannar	SWB purchase	Jan 2004

Technology transfer actions other than planned courses: Exhibitions, demonstrations and presentations

No.	Name	Locality	Action	Date
1	Lowveld Co-op / Agriplas	Nelspruit	SWB exibition, advertise courses	Mar 2001
2	SABI Congress	Warmbaths	SWB exibition, advertise courses	Sep 2001
3	Chinese delegates	Pretoria (UP)	Irrigation scheduling lecture, SWB demo	Des 2001
4	SASCP Congress	Cedara	SWB exibition, advertise courses	Jan 2002
5	SASCP Congress	Cedara	Presentation: SWB Technology Transfer Porject: J Annandale	Jan 2002
6	Kynoch	Groblersdal	Presentation: Irrigation Management Principles & SWB Demo	Mar 2002
7	ARC Potato course	Roodeplaat	Presentation: SWB Irrigation scheduling of potatoes: JM Steyn	Oct 2002

8	ICID congress	Montreal, Canada	Presentation: SWB Technology Transfer Porject: JG Annandale	July 2002
9	LEVSA congress	Bloemfontein	Presentation: SWB modelling: JG Annandale	Sept 2002
10	SASCP Congress	Stellenbosch	Presentation: SWB Technology Transfer Progress: JM Steyn	Jan 2003
11	SASCP Congress*	Stellenbosch	Presentation: Multimedia teaching tool: NZ Jovanovic	Jan 2003
12	SASCP Congress	Stellenbosch	Presentation: SWB parameters for Canola: JM Steyn	Jan 2003
13	SASCP Congress	Stellenbosch	Presentation: SWB Calendar irrigation schedules: J Nkgapele	Jan 2003
14	All Gro conference	Hartebeespoortdam	Presentation: SWB Irrigation scheduling of wheat: JM Steyn	Feb 2003
15	FAO consultation	Rome, Italy	Presentation: SWB modelling: JG Annandale	Feb 2003
16	Potatoes SA	George	Presentation: SWB Irrigation scheduling of potatoes: JM Steyn	Jul 2003
17	GWK	Douglas	Presentation: SWB Irrigation scheduling: JM Steyn	Oct 2003
18	Farmer's Day	Taung	Presentation: Use of irrigation calendars and wetting front detectors to manage irrigation: TC Maeko	Oct 2003
19	GWK	Kimberley	Training on the use of SWB – 4 participants: JM Steyn	Dec 2003
20	SASCP Congress	Bloemfontein	Presentation: SWB Irrigation Calendars for resource-poor farmers: JM Steyn	Jan 2004

* Awarded the prize for the best paper presented at the congress