SOIL MOISTURE TECHNOLOGY

WASTING WATER - WASTING PROFITS

Gopher®

soil moisture profiling system

Version 9.2

Windows 95/98/2000/NT/XP

NOW INCLUDES AN ULTRA SIMPLE PERCENTAGE CALIBRATION

"ANOTHER NEW DAY HAS DAWNED ON IRRIGATION MANAGEMENT" ™

SOIL MOISTURE TECHNOLOGY Pty Ltd
Post Office Box 93
COOROY 4563 Queensland AUSTRALIA
Technical support line 1300 301 362 (AUSTRALIA)
Phone +61 7 5442 5833 Fax +61 7 5442 6913
Email odysseydataflow@optusnet.com.au
Web site www.soilmoisture.com.au

GOPHER ®

Pat.Appln.No.PO2915
Pat.Appln.No.PO7004

TECHNICAL HANDBOOK

SOILS AND WATER

PROFITABLE IRRIGATION

Soils are composed of five main components:

Mineral particles The inorganic fraction of the soil derived mainly from rocks by weathering.

Organic materials These are composed of dead and decaying plants, animals and animal products.

Water The soil solution in which the nutrient elements for plants are dissolved.

Air Fills the voids between soil particles that are not filled by water.

Living organisms These range in size from microscopic to small animals.

Soils are different from each other because they have different proportions of these components, because the components are arranged in different ways and because the particles in their inorganic fractions have been affected to different degrees by weathering. They therefore have different size ranges and are made up of different minerals.

Because of these variations, the different types of soils hold different amounts of water that plants can use, and also require different watering techniques depending on the infiltration rate of water into the soil and the crop type being irrigated.

To grow, plants in soil need to have.

1) **Water**
2) **Air**
3) **Nutrients**
4) **Sun light**

The application of irrigation water at the correct time and in the correct amount will improve the economic viability of an irrigated crop and ensure maximum economic yield. This will also ensure the effective use of our limited water resources.

The soil moisture profiler developed and manufactured by Soil Moisture Technology has been designed to give the irrigation farmer a measurement tool that will economically provide soil moisture measurement information to enable him to schedule his irrigation system optimally.

The aim of correct irrigation management is not only to be able to determine when to water but also to know how much water to apply. The Gopher enables you to do this by measuring the complete soil moisture profile every 100mm from the soil surface to below the root zone.

THEORY OF OPERATION

The **Gopher** Soil Moisture Profiler uses the proven and sensitive technique of measurement of the dielectric constant of the soil plus water to determine the moisture content of the soil. As the water content of the soil increases, the resultant measured dielectric constant increases.

The dielectric constant of a material is defined as the ratio of the electric flux density produced in the material to that produced in free space (i.e. a vacuum) by the same electric force. The dielectric constant of air is normally taken as one (1). Thus the dielectric constant of a substance is the ratio in which the capacitance between two electrodes is increased when the space between them is filled with some other medium instead of air. In the case of the soil moisture measurement it is soil and water.

The dielectric constant of dry soil is typically four (4), and that of water is eighty (80). The measurement of the combined dielectric constant of the soil and water offers a very sensitive determination of soil moisture content. Variations in electrical conductivity of the soil moisture due to dissolved salts have very little affect on the measurement because the measuring frequency used is very high.

It has been shown, for an irrigated crop, that production per unit volume of water can in most cases be improved dramatically with accurate management of irrigation water. To do this, the moisture content of the soil in the root zone must be known. The **Gopher** Soil Moisture Profiler provides a low cost means to acquire this information.

EQUIPMENT DESCRIPTION

Introduction

The **Gopher** Soil Moisture Profiler is a microprocessor controlled measurement system with an LCD dot matrix display, for display of graphs and information, and a 16-key keypad for operator interface.

WARNING !

The Gopher Soil Moisture Profiler and the soil moisture sensor are not completely waterproof and should never be handled with wet hands or left exposed to the weather or irrigation sprinklers. The equipment is robust, however it should always be handled with care. The sensor staff cable should never be used to pull the staff from the

access tube. The 9-way connector must always be unplugged by holding the body of the plug. Never remove the plug by pulling the cable as this will eventually damage the cable.
The Gopher or the sensor should never be left unprotected in full sunlight. This will cause an excessive temperature rise and may damage the LCD display in the Gopher. If the sensor is left out in the sun, large temperature increases in the sensor can produce unstable readings because of expansion of the PVC housing.

Power for the microprocessor and sensor head is derived from four super heavy duty batteries located under the battery case lid on the underside of the **Gopher**.

Gopher Sensor Head

When shipped, the sensor head is unplugged from the measurement rod. To assemble, plug the sensor head into the 3-pin connector at the end of the measurement rod. Slide the locking ring over the socket and turn the ring approximately 1/3 of a turn clockwise (looking down at the sensor). Do not force the plug and socket, visually check the connector alignment before mating the plug and socket. The locking ring should be easy to twist to the locked position. Using force will damage the locking ring key lugs and will make the connector unserviceable. They should be easy to plug together and lock. If not, then the connector may have been damaged and should be returned for service to Soil Moisture Technology.

A small length of self sealing tape is provided with the sensor to **tape over the locking ring** and body of the connector to secure it and ensure that the sensor head cannot be accidentally disconnected from the measurement staff when it is in the access tube.

The tape should be applied by stretching it as it is applied. The length should increase by approximately three times when applied correctly. The tape should be applied in a clockwise direction and extend over the bottom of the staff, the locking ring and onto the socket in the sensor body. If this tape needs to be replaced and a supply of the self sealing tape cannot be located then standard PVC insulation tape can be used.

The sensor head should always have the small piece of 50mm pipe that it was shipped in, placed over it for protection when being transported to lessen the chances of damage.

REMEMBER, the sensor head is fragile and should always be treated with care. High temperatures can occur within the sensor if it is left in the full sun. This can cause errors in the measured soil moisture data due to expansion of the housing and temperature difference between the sensor and the PVC access tube. If the sensor temperature is well above the shade temperature, it should be placed in the access tube or in the shade for approximately 10 minutes before recording a profile.

Measuring Staff

The sensor measuring rod is calibrated in 100mm (10cm) increments. This distance is the

interval between measurements when recording a soil moisture profile.

The 9-pin 'D' connector on the end of the sensor cable mates with the 9-pin socket on the **Gopher** Soil Moisture Profiler.

GOPHER ACCESS TUBE INSTALLATION

Different soils require different installation techniques.
Soil Moisture Technology have developed a low cost simple soil drilling system for access tube installation in most soil types. This system will be supplied with all new Gopher orders. The kit consists of a steel drilling tube, a 12mm 'T' bar and an access tube insert and 'U' bolt clamp.

DRILL FIRST AND THEN PUSH PIPE IN

The simplest method for access tube installation in most soils is to drill a slightly undersized hole and then use the access tube itself to ream the hole to the exact size of the PVC access tube.

For most soils the inverted 40mm PVC end cap is adequate to reinforce the bottom of the PVC access tube. In very heavy clay soils the access tube leading edge may require reinforcing with a steel insert so that it is effective in acting as a cutter to ream the hole to the exact size of the PVC pipe as it is twisted and pushed into the hole. A dimensioned drawing is available from Soil Moisture Technology if this insert is required.

When using this method to install the access tube, the hole must be drilled approximately 20% deeper than the access tube insertion depth. This allows room at the bottom of the hole for the soil that is reamed from the wall of the drilled hole. For example a one metre access tube hole should be drilled to approximately 1.2 metres.

The method of inserting the access tube into the hole should be a combination of pushing and twisting. The twisting action helps to cut the extra soil from the side of the access tube hole. In soils containing clay the wall of the hole should be wet with water before access tube insertion to make the access tube insertion practical. If this is not done the amount of force required may damage the access tube. The water makes the clay "plastic" and ensures easy insertion of the access tube.

The 12mm steel bar is used as a 'T' bar for the access tube insert. The PVC insert is pushed into the top of the PVC access tube up to the ridge in the centre of the insert. The clamp is then placed over the PVC pipe so that the 'U' bolt is positioned approximately 12mm from the top of the PVC pipe. The nuts are then tightened until the PVC insert is held firmly.

WARNING!! do not over tighten the clamp as this will permanently damage the top of the PVC access tube. The 12mm diameter steel rod is then inserted through the two holes in the top part of the PVC insert. This rod is then used to twist and push the pipe into the soil.

When the access tube has been pushed into the soil to the correct depth, the clamp and insert can be removed and the PVC cap placed on top of the access tube.

Very light sandy soils that are dry will require wetting before attempting to drill the access tube hole. If this is not done, the walls of the hole may collapse and make the installation impossible.

CLAY or SILTY SOILS

In clay or silty soils a small amount of water should poured into the hole as it is being drilled, this helps soften the soil if it is dry. If the soil is very dry it is recommended that the soil be soaked with water prior to attempting the installation of the access tube.

SLURRY METHOD

If the hole is drilled to the same size as the PVC pipe (60.5mm) or very slightly larger a slurry of the soil removed from the access tube hole is placed in the hole to act as a gap filler as the access tube is pushed into the hole. The excess clay slurry is forced out of the hole between the soil and the PVC pipe as the pipe is pushed into the hole. NOTE. If the soil texture changes significantly over the access tube depth, this slurry method should not be used as the clay that is smeared onto the side walls of the hole from the slurry will change the soil moisture reading.

HARD SILTY or CLAY SOILS

Silty or clay soils that are very hard when dry will require wetting before attempting to install the access tube. If this is not done there is a high risk that the above installation techniques will not work as the soil will be too hard and may damage the PVC pipe when it is inserted into the hole or make it impossible to drill the hole.

It is recommended that these soils be wet thoroughly before attempting to carry out an access tube installation. The water will soften the soil and make the installation in this type of soil a lot easier. The water should either be applied to the soil the day before installation is to take place or a small amount of water can be poured into the hole as it is being drilled.

STONEY or GRAVELY SOILS

Stoney or gravely soils require an oversized hole to be drilled and the stones removed from the soil and the soil is then re-packed into the hole in the same order as it was removed. The access tube is then installed into the center of the re-packed soil using the standard installation method.

Care must be taken that the soil is also tamped down very firmly to ensure that the original soil density is retained. If this is not carried out correctly then the measured soil moisture will be different from the surrounding soil because of either air voids in the re-packed soil column, changes in density of the soil or a different soil texture to the surrounding soil.

ASSEMBLY OF ACCESS TUBE SOIL CUTTER

The access tube cutter comes in five parts, the steel cutter already has a piece of one inch (1") PVC pipe mounted in the top of the cutter. This pipe has a PVC socket for the second long piece of pipe to be glued into. The 'T' top to the cutter handle consists of a PVC tee and two short handles that have to be glued into the sides of the tee. All pipe joints should be cleaned with PVC pipe cleaner before they are glued together. The PVC solvent cement requires about 4 to 6 hours to set. It is preferable to leave the cutter for 24 hours once it is glued together.

The DRILL FIRST and THEN PUSH access tube installation technique using the standard soil cutter is the preferred and simplest installation method and is suitable for most soils. It prevents the possibility of contamination from different textured soils in the profile as the access tube reams a clean cut hole as it is pushed into the hole that has been drilled. It also does not disturb the soil surrounding the access tube. Because of this the access tube installation is successful every time.

MICRO-GOPHER

The Micro-Gopher sensor head is supplied taped to the side of the Gopher staff. To install the sensor onto the end of the staff the following procedure should be carried out.

1 Carefully remove the protective packing from the sensor head.

2 Loosen the grey cable gland at the top of the staff until the cable can be moved freely through the gland.

3 Screw the sensor head onto the end of the staff by rotating the staff clockwise. **DO NOT ROTATE** the Micro-Gopher sensor as this action may cause the cable to jam in the staff.

4 Re-tighten the cable gland at the top of the staff once the sensor has been screwed onto the staff. **Do not pull the cable as this may damage the sensor.**

The new Micro-Gopher sensor is very robust, however the sensor and staff should always be treated with care. It is a good idea to transport the sensor inserted into a short length of 15mm PVC pipe, this will protect the sensor surface from physical damage. Rough handling will eventually damage the sensor housing and make it impossible to insert the sensor into the access tube.

The length of the staff between the depth markings and the centre of the sensor has been lengthened so that the length of access tube **above the ground is now 10cm instead** of the 7cm as was the case for the 50mm GOPHER access tube.

MICRO-GOPHER ACCESS TUBE INSTALLATION KIT

An access tube auger installation kit is included with the Micro-Gopher. This kit consists of the following items:-

1 One 19mm auger bit with threaded brass coupling on the top of the auger shaft.

2 One 1.2 metre aluminium auger shaft extension.

3 Two pieces of PVC pipe for attaching to the PVC tee on the top of the aluminium auger shaft extension.

4 Two 15mm class 15 PVC access tubes complete with sealed bottoms and top PVC caps.

5 One nylon plug for driving the access tube into the drilled hole.

ASSEMBLE THE AUGER

Screw the auger into the threaded socket at the end of the aluminium tube. Then glue the two short handles into the tee piece at the top of the aluminium auger shaft extension.

DRILLING THE MICRO-GOPHER HOLE

Select the site for the access tube installation and start drilling the hole by rotating the auger. The soil that is on the auger flight must be emptied every 5 to 7 cm that is drilled, this will ensure that a clean straight hole is drilled and that the auger flight is not overloaded with soil. If this happens the auger will be very difficult to extract from the hole. Care should be taken when drilling the hole that the auger shaft is always straight and in the centre of the hole. If this is not done then the drilled hole may not be straight and this will cause problems in installing the PVC access tube. The standard access tube supplied with the Micro-Gopher is 1.13 metres long.

The hole that is drilled for the access tube is slightly smaller than the diameter of the PVC pipe. The installation procedure reams the hole to the exact size of the PVC pipe. This ensures that the access tube and soil contact is perfect every time. Because of this reaming action the hole must be drilled slightly deeper than the final depth of the access tube.

This allows room at the bottom of the hole for the soil that is shaved of the walls as the access tube is driven into position. Approximately 10% deeper than the length of the access tube that will be installed in the soil is adequate for most soils. Even if the hole is not drilled quite deep enough, you will find that the access tube can be driven into the correct depth in most soils. This is another advantage of the small size of the Micro-Gopher.

INSTALLING THE ACCESS TUBE IN THE DRILLED HOLE

If your soil contains clay or silt, then the hole should be filled with water before attempting to install the access tube into the hole. The addition of water in the hole ensures that the clay becomes slippery and plastic and makes the installation of the access tube pipe very easy. If this is not done the pipe may jam in the hole and make the complete installation impossible.

In sandy soils the addition of water after drilling is not necessary as the access tube can generally be pushed into the hole with very little resistance. If the soil has a clay layer at the bottom and you have drilled into this, then some water should be added to the hole before attempting to install the access tube. In these sandy duplex or triplex soils the water should be very carefully poured into the centre of the hole, otherwise sand may be washed from the top of the hole and fill the clay region and make installing the access tube impossible.

Very sandy soils should be thoroughly wet before attempting to drill the access tube hole. If this is not done the sand may slide into the hole and make it impossible to drill. Very hard clay or silty soils should also be wet before the hole is drilled. The amount of water required to wet the soil from the surface to the bottom of the hole to be drilled is approximately 20 litres.

The bottom of the access tube is fitted with a pointed PVC plug. This helps to guide the access tube straight down the drilled hole when the pipe is being driven into the hole. **The black nylon access tube driving plug should be placed in the top of the PVC access tube**. The pipe should then be pushed into the hole by hand as far as it will go. After it reaches a point where you can not push it any further by hand, it should then be driven in using a hammer. The length of pipe left standing above the ground should be **10cm.**

After the pipe is installed the sensor should be inserted into the access tube to test for any possible damage that may occur if too much force is used when the pipe is hammered into the hole. If the sensor moves smoothly over the entire access tube length then the installation is now complete. The calibration of the sensor to the soil should now be carried out. The calibration of the sensor should be carried out after the soil has reached FULL POINT. The time for the water in the soil to reach FULL POINT is covered in the table below.

Field Capacity or FULL POINT delay.

	SAND	LIGHT SANDY LOAM	SANDY LOAM	LOAM	CLAY LOAM	CLAY
STABILISE TIME	1 to 2 hours	2 to 4 hours	3 to 6 hours	8 to 12 hours	24 hours	24 to 48 hours

If the site is to be re-calibrated then the soil must be brought up to Field Capacity before the calibration is carried out. To achieve this the soil must be watered with enough water to bring the entire profile depth up to Field Capacity. If the soil at the 10cm depth has dried out more than the deeper depths, this can be adjusted in your computer after the next irrigation.. This change in calibration must be transferred back to your Gopher recorder. If you do not, the change will be over written when you down load the next data from that site.

PUNCHING ACCESS TUBE HOLE for MICRO-GOPHER

In very heavy clay soil or light sandy soils, punching a hole into the soil with a steel rod and then driving the access tube in often works better than drilling a hole with the auger. The outside diameter of the steel rod should be 19mm.

For the Micro-Gopher, because of the very small size of the tube hole, or in the case of the punched hole where no soil is removed from the hole, and the soil texture is not known it would be helpful to drill a separate larger hole so that the soil texture over the entire profile can be examined and recorded into the site header.

SOIL MOISTURE TEXTURE GUIDE

The following table is a field guide to soil moisture content. The values in the left column are a percentage of field capacity. The approximate Field capacity values are in millimetres of water per 100mm of soil.

Percent moisture remaining from field capacity	**Loamy sands and sandy loams** **approx FC = 15mm (Coarse texture)**	**Very fine sandy loam and silt loam approx FC = 30mm (Medium texture)**	**Silty clay loams and clay loams** **approx FC = 43mm (Fine texture)**
0 to 25%	Dry, loose, flows through fingers	Powdery, sometimes slightly crusted, but easily broken down into a powdery condition	Hard, baked, cracked; difficult to break down into a powdery condition
25 to 50%	Appears to be dry, will not form a ball with pressure	Somewhat crumbly, but holds together with pressure	Somewhat pliable, balls under pressure
50 to 75%	Tends to ball under pressure, but seldom holds together when bounced in the hand	Forms a ball, somewhat plastic, sticks slightly with pressure	Forms a ball, ribbons out between thumb and forefinger, has a slick feeling
75 to 100%	Forms a weak ball, breaks easily when bounced in hand, will not slick	Forms a very pliable ball, sticks readily	Easily ribbons out between thumb and forefinger, has slick feeling
100% Field capacity	Upon squeezing no free water appears on soil, but wet outline of ball is left on hand; soil sticks to thumb when rolled between thumb and forefinger	Same as sandy loam	Same as sandy loam
Saturated	Free water appears on soil when squeezed	Same as sandy loam	Same as sandy loam

The importance of writing this soil log cannot be over-emphasized. Future interpretation of soil moisture values require that the soil type be known. Failure to record this information can result in a guessing game if a problem with the recorded soil moisture values becomes evident some time in the future. If data is sent to Soil Moisture Technology for evaluation this soil log must be included. The soil types recorded in this soil log must also be entered in the log header when the site is being set up in the **Gopher** program in your computer.

If large objects such as tree roots or stones are evident that cannot be easily removed when the hole is being drilled then it is generally better to start a new hole. Do not drill another hole within approximately 300mm from the previous one.

The depth of measurement should be equal to the expected root zone of the plants being irrigated plus 200 to 300mm. This allows the measurement of the moisture profile beyond the root zone so that you can be sure that you are not over watering. Without this additional measurement depth you can not accurately measure the total water penetration depth into the soil.

Gopher Access tube length example:
PIPE TYPE 50mm class 6

1) Moisture measurements to 1500mm
   Access tube length = 1500 + 40 + 70 = 1610mm

2) Moisture measurement to 1000mm
   Access tube length = 1000 + 40 + 70 = 1110mm

3) Moisture measurement to 400mm
   Access tube length = 400 + 40 + 70 = 510mm

Micro-Gopher Access tube length example:
PIPE 15mm Class 15

1) Moisture measurements to 1500mm
   Access tube length = 1500 + 30 + 100 = 1630mm

2) Moisture measurement to 1000mm
   Access tube length = 1000 + 30 + 100 = 1130mm

3) Moisture measurement to 400mm
   Access tube length = 400 + 30 + 100 = 530mm

The height of the sensitive area of the sensor head is approximately 50mm for the Gopher and 70mm for the Micro-Gopher. The above calculations are based on the sensor being centred in the 100mm section of the profile being measured. The first measurement covers the first 100mm of soil from the surface. Although measurements can be made closer to the soil surface, it is not recommended due to the variable bulk density at this shallow depth.

Once the hole has been drilled and the soil samples taken the PVC access tube can be cut to the correct length and placed in the hole.

Standard 50mm Gopher Access tubes testing.

If additional access tubes are required they must be cut to the correct length and sealed with a 40mm PVC end cap. The size uniformity and water tightness of all access tubes must be tested before they are installed into the ground. Failure to carry out these tests may result in damage to the sensor and also result in erroneous data collection. Use the sensor to test the size uniformity of the access tube. The pipe size must be such that the sensor can be pushed freely over the entire length of the access tube. If this can not be done the pipe should not be used. The water tightness of the end cap seal should be tested by filling the pipe with water and allowing it to stand full of water for at least 5 minutes. Check that there is no water leaking from the end cap. After this test dry the inside of the pipe thoroughly with paper towel wrapped around the end of a piece of wooden dowel or fencing wire.

The 40mm PVC end cap is a loose fit in the 50mm PVC pipe. The inside of the pipe and the outside of the end cap need to be coated with PVC pipe cement and allowed to dry (approximately 5 minutes). Re-coat the inside of the pipe as well as the end cap and push the end cap into the pipe - the rounded end of the cap outwards. Another method is to apply PVC insulation tape to the wall of the end cap to fill in the excess gap between the fitting and the pipe. Apply as many turns of the tape to give a snug fit between the pipe and the end cap. Then glue the fitting as detailed above.

IMPORTANT NOTE

The inside of the PVC pipe should only be painted with the solvent cement to a depth of 30mm. At no time should the pipe be placed with the solvent cement coating uppermost. If this is done the glue may run down the inside of the pipe and make it impossible to insert the sensor head without damaging it. After the end cap has been inserted into the pipe it should be stood vertically with the end cap downwards until the solvent cement has started to harden (approximately 15 minutes).

Use a sharp knife or file to clean and chamfer the top inner and outer edge of the PVC pipe.

Note - do not use a standard 50mm end cap for the top cap on the access tube. The end caps supplied in the **Gopher** kit by Soil Moisture Technology Pty Ltd have had the internal diameter enlarged. This will prevent the end cap becoming stuck on the end of the pipe. It will also prevent water from being sucked into the tube during irrigation or rainfall events. These are available from Soil Moisture Technology. The Micro-Gopher top cap is made from a 20mm PVC end cap and a short piece of 20mm PVC pipe. A piece of plastic foam is placed in the end cap to prevent insects from getting into the access tube.

Micro-Gopher Access tube testing.

The Micro-Gopher access tube should be tested in the same way as the standard Gopher access tube. Water leaks or non-standard pipe sizes will mean the time taken to install the access tube will be wasted.

SITE TESTING FOR GOPHER and MICRO-GOPHER

Testing of the access tube must be carried out after installation to ensure that it has been installed correctly.

The first test is to check the access tube for physical deformation. This will only normally occur if to much force is used to drive or twist the access tube into the hole.

Place the sensor head into the access tube and secure the guide cap onto the top of the access tube. Rotate the guide cap as you push it onto the access tube to ensure that it is seated correctly. Make sure the gland on the guide cap is not done up too tight as this will make inserting the sensor into the access tube difficult and will give you the wrong impression of the condition of the access tube.

Push the sensor slowly from the top to the bottom of the access tube. The physical resistance between the sensor head and the access tube should be constant over the entire length of the pipe. If the sensor head becomes tight in the access tube, then the access tube has been deformed and must be re-installed using a new PVC access pipe. If this deformation of the access tube is not eliminated it will eventually cause damage to the sensor head and will also produce errors in the measured soil moisture levels.

If the access tube installation passes this physical test the next procedure is to check the uniformity of contact between the access tube and the soil. The soil profile log that was recorded during drilling of the access tube hole will give an indication of the soil moisture variation that should be expected over the soil profile. If water has been used to aid the insertion of the access tube in clay soils then the profile should be fairly even.

Adjust the staff position so that the horizontal bar under the number 1 on the staff is just visible.

Plug the cable from the sensor into the **Gopher** profiler.

Press the 'ON' key. The **Gopher** will turn on and display:

```
SOIL MOISTURE
TECHNOLOGY
Version 9.0  Sn2xxxx
```

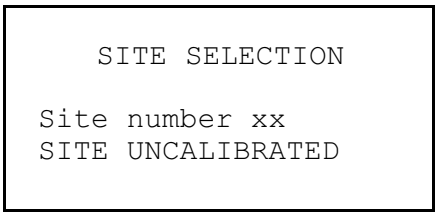
```
Battery 6.200 volts
Time 14:35:56
Date 03:02:2003
Key ENT for next
```

Press the 'ENT' key. The display will show:

The battery voltage should be within the range of 5.4 to approximately 6.2 volts. The date and time should indicate the current real time and date. If this is not correct, refer to the section for setting up the real time clock.

Press the 'ENT' key. The display will show the read sensor direct menu entry.

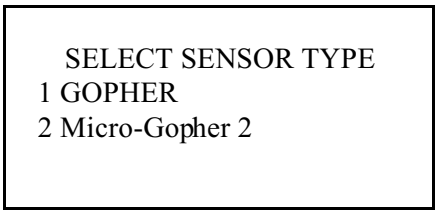
Press the 'ENT' key. The site number and calibration details will be shown. If the site has been used before then the previous calibration data must be erased before attempting to calibrate the site.



The **Gopher** data storage memory is organised to store 48 profiles from 54 different sites. Each site should be identified by writing the site number on the access tube cap using a waterproof pen.

Depress the INC or DEC key until the site number shown is the number of the site that has just been installed.

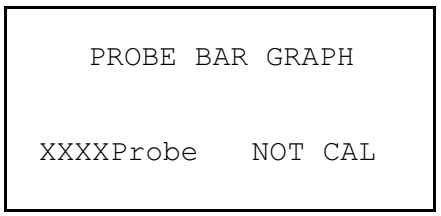
Press the 'ENT' key. The display will show:



The Micro Gopher will have a 2 or 1 depending on the when the sensor was manufactured and the number that you entered when the Gopher firmware was up-dated, this number is marked on the staff.

Key 1, 2 or 3 depending on the sensor type that is being used.

Press the 'ENT' key. For an un-calibrated site the display will show:



The horizontal bar graph displays graphically the moisture levels read by the probe.

The sensor must be connected to the Gopher recorder before entering this program, if this is not done an alarm will sound that warns that the sensor is not connected.

Move the sensor from the 100mm mark **slowly** to the bottom of the hole, observing the bar graph as you do. The movement of the bar will be indicative of the soil moisture and should agree with the physical observations of the soil moisture when the access tube hole was being drilled.

Variations from the expected soil moisture levels could be caused by any of the following:

1) Air pockets in the soil, caused by problems during the drilling of the access tube hole or during the insertion of the access tube.

2) Large stones or tree roots adjacent to hole.

3) Clay layers in the soil may cause readings to increase.

4) Gravel or sandy layers in the soil profile will cause readings to decrease. The amount that the reading decreases will depend on the degree of texture change in the soil.

Any large unexpected variation would indicate a problem due to either of the first two items on this list. Anomalies of only a few percent are within the estimation accuracy of the field determination of the soil moisture.

Clay layers if they are wetter than the soil above will cause the reading to increase. This is expected and normal.

If you added water to the access tube hole before the access tube was installed then the soil moisture profile should be fairly even, the only major variations should be due to texture changes in the soil.

CALIBRATION OF SOIL AND SENSOR

The sensor output varies with the soil type. This is largely due to particle size variation and particle size distribution in the soil. The sensor must be calibrated to match the soil that is being measured. Soils of similar texture will generally produce similar calibration results.

The most accurate method to calibrate the sensor is in the soil that is to be measured. To achieve this an automatic down-hole calibration program has been developed for the **Gopher**. This allows the sensor to be calibrated to your soil type. The initial calibration uses the estimated moisture content value that was recorded when the access tube hole was being drilled or the known Full Point or Field Capacity for your soil if the calibration is being carried out after an irrigation.

The two options that can be selected when calibrating the sensor to the soil being measured through the access tube are:

1) Down hole single point calibration.

2) Down hole multi point calibration.

DIFFERENT FULL AND REFILL VALUES

If the soil texture is similar over the depth that is being calibrated then a single point calibration is the simplest and easiest way to carry out the calibration. If your soil profile is considerably different over the depth of the profile being measured then in order to accurately calibrate the sensor for each soil type, the soil characteristics must be known. **If the NEW PERCENTAGE CALIBRATION is used, this information is not required. This makes accurate calibration extremely simple.** If the soil profile has clay below the root zone of your plants then the calibration for this depth is easily changed in your computer and the changed calibration transferred back to your Gopher.

The soil characteristics can be determined using the SOIL FIELD CAPACITY DETERMINATION method described later in the handbook.

If these values are not known then the best method is to do a single point calibration for a single textured soil and then after the next irrigation the moisture profile can be examined to determine the moisture storage capacity of the soil over the depth being measured. Small variations in the measured soil moisture can be due to slight changes in the bulk density of the soil, stones or plant roots close to the access tube.

These anomalies will cause the measured soil moisture to vary **slightly** from point to point.

If you change the Full and Refill Point value, you must have tested values for the soil at these depths. If you do not have accurate values for these points in the profile this will cause errors in the summed soil moisture values for the depth of the profile. This is because the changed Full and Refill values will not reflect the actual true soil characteristics adjacent to the access tube.

There are two solutions to this variation in the soil moisture profile:-

1 Take a soil sample approximately 30 to 50cm away from the access tube and at the same depth that the variation is evident. Then measure the actual Full Point for the

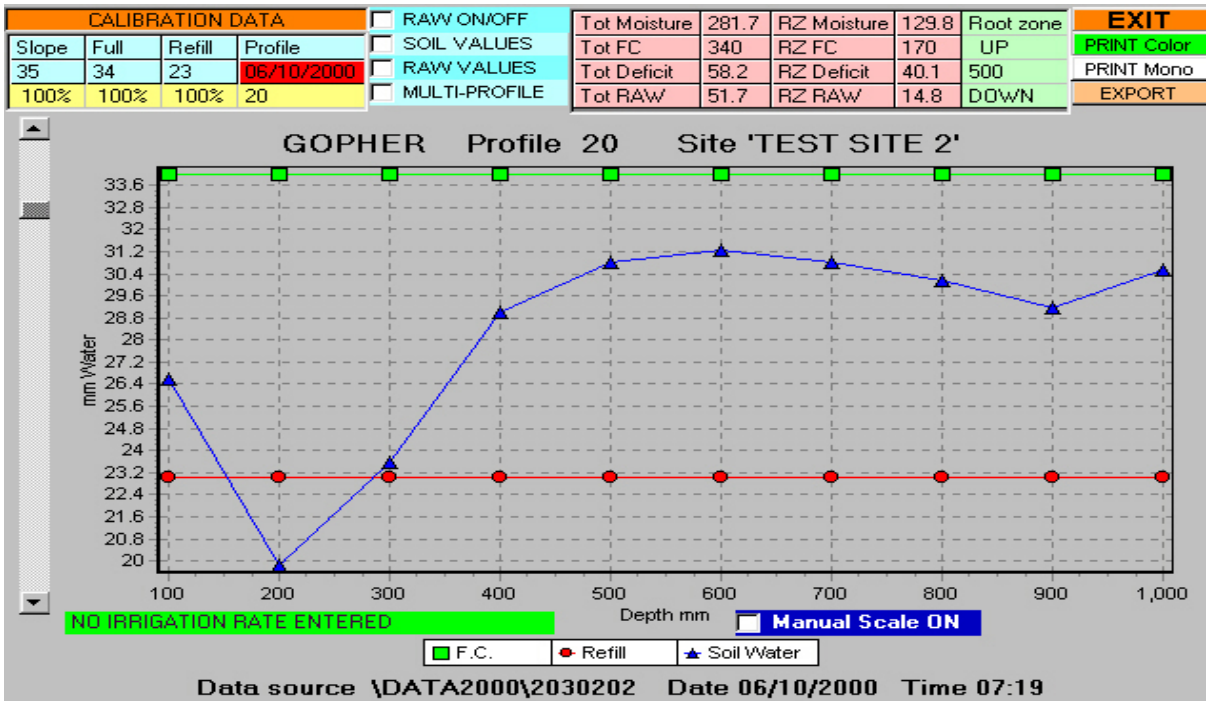
soil using the SOIL FIELD CAPACITY DETERMINATION. This method is described later in this handbook. This procedure will also give you a value for the actual soil moisture content at this depth, this value can be used to trim the calibration.

2 If the Field Capacity (Full Point) is different from the soil above and below this point then the Field Capacity and Refill point should be changed to match this value. If the soil Field Capacity results are very similar to the soil above or below this point, then the changes are due to something physical in the soil. To improve the accuracy of the average soil moisture value for the soil at this depth, the slope or calibration value should be changed to make the measured value recorded with your Gopher agree with the calibration value generated from the soil sample.

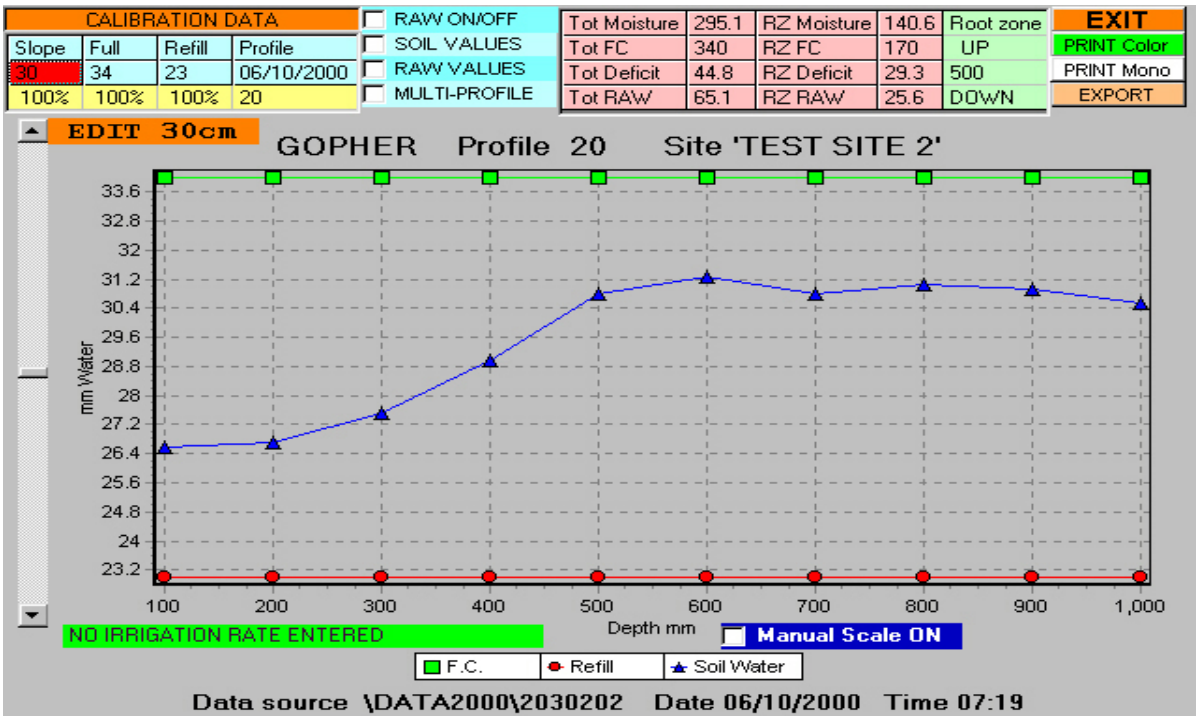
If the measured soil moisture value goes down by a large percentage or even close to zero, while the other points in the profile are up at the known Full point for the soil, then it is not possible to change the sensor calibration to make the reading accurate. This sort of variation in the soil moisture reading is generally caused by stone or air pockets and generally requires re-installation of the access tube. If it is caused by stones then you can either ignore the dip in the soil moisture value or drill a larger hole and remove the stones. Then the soil is re-packed into the oversized hole and the access tube reinstalled. This is described in the access tube installation section.

In some clay soils, one other problem can occur. If the clay is sticky a hole can occur adjacent to the access tube. This generally only occurs in very sticky clays. This hole will fill with water after an irrigation. This will cause the measured value to go very high. As the water drains away the value will then move down towards zero. If this problem is below the root zone of your plants then the easiest answer is to ignore the anomaly. This can only be done if the plant root zone does not go down to this depth. If the plant has feeder roots at this depth and the depth is also included in the summed readily available water, then the access tube should be re-installed.

The following profile graphs show examples of soil moisture variation in the same textured soil.



The graph above shows a decrease in soil moisture 10 20 and 30cm. The results of a soil



sample indicated that this change was in fact not true. The calibration for these two points was then changed after the soil at these two depths had been tested. The calibration change was based on soil samples that were tested for Field Capacity and current moisture values. This change in calibration will now give accurate results for this site.

GOPHER & MICRO-GOPHER CALIBRATION

The calibration procedure on the Gopher has been simplified to make the process of calibration more straight forward. (eliminates key strokes.) The program now displays a selection of six (6) major soil texture classifications that you can choose from and then asks for the approximate soil moisture content at the point in the profile that is being calibrated. The process of setting the calibration constant (SLOPE) in the Gopher is now automatic. All values can still be edited to adjust for variations from the basic six (6) major soil classifications. The soil calibration can now also be entered as a percentage calibration value. That is the Full Point is entered as 100% and the refill as a nominal 60%. This removes the necessity to determine the actual Full Point and Refill Point in actual millimetres.

CALIBRATION PROCEDURE

Select CALIBRATION ENTRY from the menu. Key <ENT> the display will show:

```
SITE SELECTION

Site Number  XX
```

The program provides storage for 54 soil moisture monitoring sites. Each site can have up to 48 profiles with up to 15 soil moisture readings in each profile.

Select the site number to be calibrated by using the INC or DEC keys on the keyboard. Key <ENT> to select the site number. The last line on the display will show if the site has already been calibrated. If it has the program will go into a preview mode and show the previous calibration data for the site. To enter new calibration data into a previously calibrated site you must first erase the existing calibration data using the ERASE program.

NOTE: The site access tube or cap should be physically numbered with a water proof marking pen to avoid later possible confusion in remembering the site number when you arrive at the site to record a profile.

```
CALIBRATION SITE  XX
Root zone mm     500
Profile points    10
```

First the root zone depth for the summed data calculation is entered in millimetres. This number must be in multiples of 100mm, the default shown in the display is 500. Next the number of profile points that are to be measured is entered, the maximum number that can be entered is 15, the default that is shown in the display is 10.

Remember the profile measured depth must be greater than the root zone depth that you enter.

The screen will then prompt for you to enter the sensor offset. This number is marked on the label on the Gopher sensor. The Micro-Gopher or Ferret sensor have the Offset marked at the top of the staff. This number is the un-calibrated value that the sensor will read in soil with zero soil moisture.

Because there are now three different types of sensors that can be attached to the Gopher the calibration program now prompts you to enter the type of sensor your are using for the site that is being calibrated. The list that is displayed is as follows:-

```
SELECT SENSOR TYPE
1  ORIGINAL GOPHER
2  Micro-Gopher 2
3  FERRET
```

Key the number that corresponds to the sensor type that you are using. This selection sets up the sensor reading program so that the results are similar irrespective of the sensor type. Once a site has been calibrated using the new version 9.0 this sensor type information is stored in the calibration data for that site.

The sensor read program for the Ferret has been changed to increase the sensitivity of the Ferret reading. This change will require that the site you use for your Ferret will have to be re-calibrated. The offset value of the Ferret also has to be re-measured so that the readings are correct with the new program. This can be done by placing some oven dried soil in a container. Place the Ferret probe into the soil and read the probe RAW data value. The depth of soil must be sufficient to cover the top of the Ferret sensor by about 50mm. The READ SENSOR DIRECT mode is used for this measurement.

This sensor prompt will also appear when you enter either the READ SENSOR DIRECT, RECORD PROFILE or TIMED RECORDING program for sites that have been calibrated using earlier versions of the Gopher program.

The PC software now enables you to define the sensor you are using for each site that has already been calibrated, to do this you enter the 'EDIT EXISTING site header' and make sure the sensor type option that is displayed in the SENSOR TYPE list is the sensor type that you are using for that site. The standard Gopher sensor will be selected by default. To change the sensor type simply click on the option button. This information must then be transferred back to the GOPHER and will be stored in the calibration information for that site. To do this you select 'SEND site data to GOPHER' from the main menu on your PC software and transfer the edited site data back to your Gopher. This makes the sensor type selection permanent in the Gopher and you will not be prompted for this information for this edited site again.

CALIBRATION METHOD

Select ether the NEW PERCENTAGE CALIBRATION or VOLUMETRIC CALIBRATION.

CALIBRATE SITE xx
1 PERCENT CALIBRATE
2 VOLUME CALIBRATE.
KEY 1 or 2

The New percentage calibration is based on the Full Point or Field Capacity being automatically set at 100% when you do the calibration. Full Point or Field Capacity is the maximum amount of water that the soil will hold against gravity.

The major advantage in using percentage calibration is that you do not have to do a soil analysis to get accurate results, because the percentage calibration removes the requirement for detailed soil testing over the total profile depth. When the soil is at Full Point the calibration is set automatically to 100%. If after the calibration you find that the soil was not exactly at Field Capacity the calibration can be edited on your computer and transferred back to the Gopher.

With most soils the Refill Point or the end of the Readily Available Water in the majority of soils is approximately 60%. When the soil moisture goes below this limit the plants can not easily extract the moisture from the soil. Clays have less available water because of the large percentage of extremely fine particles in the soil.

To change a site from Volumetric calibration to Percentage calibration. The site in the computer must be first be selected for a new season in your computer. This will archive the existing data so that you can always go back and look at the old data. The computer will then transfer the existing calibration to the Gopher. This existing calibration must be erased in the Gopher before you re-calibrate the site in the Percentage mode. Enter ERASE PROFILE DATA then select 1 ERASE CAL. ONLY. This will erase the existing calibration and allow you to re-calibrate in the Percentage mode.

If you only have a few profiles in each site and want to change to percentage calibration and leave the existing profiles in the Gopher. Then select ERASE PROFILE DATA in the Gopher. When the erase options are displayed, select 1 ERASE CAL. ONLY. This will erase the existing calibration data and allow you to re-calibrate in the Percentage mode. The existing data will now be displayed as Percentage on the Gopher and your computer.

	SAND	LIGHT SANDY LOAM	SANDY LOAM	LOAM	CLAY LOAM	CLAY
FC	12	18	27	32	42	45
Refill	7	11	16	19	30	36
RAW	5mm	7mm	11mm	13mm	12mm	9mm
Full %	100%	100%	100%	100%	100%	100%
Refill %	58%	60%	59%	59%	69%	79%
% RAW	42%	40%	41%	41%	31%	21%

If the access tube installation is a new site then the easiest way to install the access tube is to saturate the soil before installation . This is very important in clay soils. Dry clay can be very hard and also sticky. This will make the access tube installation very difficult. However if the clay soil has been saturated then the installation of the access tube will be easy because clay when it is wet is very slippery.

One simple way to achieve this is to either, place a piece of PVC pipe on the point where the access tube is going to be installed or form a soil dam around the site. Then fill the soil dam or container with water. The water must be allowed to drain away before you refill the container. The dam or PVC pipe must be filled a number of times to ensure that the soil is wet all the way down to the depth that the access tube is to be installed.

After the installation the soil must be left until the moisture content has ceased moving and is at Field Capacity. The table gives a guide as to how long it will take for the water in the soil to become stable and suitable for calibration.

	SAND	LIGHT SANDY LOAM	SANDY LOAM	LOAM	CLAY LOAM	CLAY
STABILISE TIME	1 to 2 hours	2 to 4 hours	3 to 6 hours	8 to 12 hours	24 hours	24 to 48 hours

If the access tube is existing and you want to re-calibrated using the percentage calibration then the soil must also be brought up to Field Capacity before the new calibration is carried out. To achieve this the soil must be watered or irrigated with enough water to bring the

entire profile depth up to Field Capacity.

The **method** of calibration must be selected next. The display shows a selection of:-

```
CALIBRATE SITE xx
1  SINGLE POINT CAL.
2  MULTI-POINT CAL.
```

The single point calibration can be chosen if the soil texture **does not change very much** over the depth that is to be measured. Multi-point calibration for volumetric calibration requires detailed knowledge of the soil texture at each 10cm interval in the measured profile.

With the NEW percentage calibration method the soil details are not required. This makes the calibration extremely simple. If the soil texture changes over the depth to be measured, then multi-point must be used.

Let us assume that single point calibration has been selected. With the Volumetric calibration the screen now shows a list of 6 different soil types. This is not shown for the percentage calibration, because the method of calibration for the percentage does not require the soil type.

```
1 Sand          4 Loam
2 LS Loam       5 Cl Loam
3 Sa Loam       6 Clay
```

LS Loam is an abbreviation for Light Sandy Loam, **Sa** Loam is an abbreviation for Sandy Loam and **Cl** Loam is an abbreviation for Clay Loam.

Key the number that best fits the soil texture of the site being calibrated. Then key ENTER to move on. The display will now show the description of the selected soil on the top line. The standard value for Field Capacity and Refill points is on the third line. If percentage calibration has been selected then the Field Capacity value will be 100% and the Refill value will be 60%. The Refill value can be edited if you know that the soil Refill value is either a higher or lower percentage. The Field Capacity value of 100% should not be changed because the method of calibration automatically sets the calibration to 100%.

For Volumetric calibration you can change Field Capacity and the Refill if you know that the value is different from the standard values. Line two instructs you to 'EDIT Field Capacity'. The bottom line has an arrow under the Field Capacity value indicating that this is the number that can now be edited. The reason that this editing facility has been included is that even though soils can be classified into broad categories, there will be differences within those categories for actual soils. The only way to accurately determine the actual Field

Capacity of your soil is to either have a soils laboratory sample your soil or use the Soil Moisture Technology Field Capacity soil testing method to determine the actual value of the moisture content of your soil at Field Capacity. If you do not have actual values for your soil then the default values should be used as a starting point. These values can always be edited later in your computer and transferred back to your Gopher.

Either accept the default or enter the value that you or a soils laboratory have measured. After entering the value key ENTER. The second line of the display will now prompt you to EDIT the Refill value. The arrow will move below the Refill value. The Refill value is the number of millimetres of water that remain in the soil at the target point for irrigation. That is when the soil moisture reaches this point it is time to irrigate. The value that is displayed is a value that is 50% of the soil moisture range between wilting point and Field Capacity. This value of 50% is the nominally accepted target value to start irrigation. Different crop types can tolerate, and in some cases benefit, from the Refill Point being either higher or lower than this nominal 50% value.

The display will now prompt you to key ENTER if you are satisfied with the values displayed. If you want to go back and change either of these values then press the CLEAR key. If this is done the program will return to the soil selection frame.

You are now prompted to enter the approximate value of soil moisture at the depth that is being calibrated. If the calibration is being carried out just after an irrigation then the number that is displayed (FIELD CAPACITY) should be accepted as the soil will be very close to the Field Capacity value. If you know that the soil is drier than the Field Capacity value, then enter the value that you estimate is the current soil moisture value. If you are unsure of the soil moisture value there are two ways to go.

1 Tip approximately 10 litres of water around the access tube and after allowing time for the water to drain into the soil and reach Field Capacity do the calibration.

2 Make as close a guess as you can and then trim the value in your computer after recording a profile after the next irrigation.

Key enter to move on.

In single point calibrations the sensor should be placed at either the 20 or 30cm point, (2 or 3 on the staff) as the soil at this depth will generally be closer to the estimated moisture content, based on either time since the last irrigation or the estimate made when the access tube hole was being drilled, assuming the calibration is being carried out immediately after installation of the access tube.

The Gopher will now display the raw data value from the sensor and prompts you to key ENTER when the probe is set in the access tube and the reading is stable. When ENTER is depressed the display will show the soil calibration constant or SLOPE. If the soil selection or entered values makes it impossible to calibrate the sensor to the soil values that have been entered, then a warning message will be displayed that the calibration can not be carried out.

Key ENTER and the program will return to the CALIBRATION menu item.

The displayed SLOPE can be modified if you know from past experience that it should be different for the soil that you are calibrating.

WARNING!! Do not change the slope unless you know from past experience what the value should be for the soil being calibrated. The value of the calculated slope will range from approximately 25 to 35 for heavy soils and approximately 40 to 50 for very light sandy soils. For the percentage calibration it may vary from 40 to 150.

The site is now calibrated if a single point calibration was selected. If MULTI-POINT calibration was selected then the process is repeated for each point in the soil profile.

At the end of the calibration process you will now be prompted to store the calibration in memory YES/NO. If you key 2 for NO then the calibration data will be abandoned, if you key 1 for YES then the data is saved in memory and the program returns to the menu entry point.

Single point calibration is normally the most practical method of field calibration. Multi point calibration requires soil samples to be cored at each 100mm point in the soil profile. Analysis for soil moisture and bulk density determinations has to be carried out on each sample. Percentage calibration does not require soil analysis and gives you a high degree of accuracy.

The cost of such measurements would be prohibitive, as these measurements should be done for each access tube location or where there is a soil texture variation from site to site. The improvement in accuracy is generally not required in soil moisture measurements that are used as an aid to irrigation management. The only time the extra cost and effort would be warranted is in research where a high degree of accuracy is required.

The actual point by point calibration can always be checked after an irrigation and adjusted in your computer. This adjustment is then transferred back to your Gopher to make the change permanent.

REMEMBER THE OVERALL AIM AND PURPOSE OF MEASURING THE SOIL MOISTURE PROFILE IS:

1) To measure the soil moisture profile from the surface through the root feeding zone and below the root zone to ensure that adequate water is being applied during irrigation.

2) To be able to measure and see graphically the effectiveness of the irrigation schedule. The effect of under watering will be obvious from the recorded profile because the soil moisture in the root feeder zone will not be brought up

to field capacity. The resulting profile from over watering will also be obvious in that soil moisture levels well below the root zone will increase after irrigation cycles.

From the data recorded with the **Gopher** you will be able to determine the effectiveness of your irrigation management program. You will also be able to see graphically evidence of under watering and over watering. You can then adjust your irrigation times so that the amount of water applied is sufficient enough to bring the root zone depth up to field capacity.

To determine depth of infiltration of the irrigation water and to also verify the value of field capacity it is important that a profile be recorded shortly after an irrigation cycle. The time allowed for the water to penetrate into the soil before you record a profile will depend on the soil type. Sandy soils show a high rate of water movement and water drainage and equilibrium is reached in generally less than one day. Heavy soils have a much lower rate of water movement and may take 24 to 48 hours before water movement into the soil has reached equilibrium. Recording several profiles after an irrigation cycle will show the rate that the water is penetrating into the soil.

Calibration data must be entered before the **Gopher** can be used to record a site profile and calculate water balance.

Different soil types are capable of storing different amounts of soil water for plant use. The moisture storage characteristic is related to the properties of particle size, particle size distribution, structure and texture. The relationship between soil type and moisture content at field capacity is at best empirical and can vary even within the same soil type.

Published data has been produced from extensive field testing of the soil types found in a large number of agricultural regions or locations. Your local Agriculture or Primary Industries department will have the soil classification and field capacity data for most soil types and agricultural areas in Australia.

DETERMINING THE TEXTURE OF A SOIL

Soils may be classified into the various textures by the following method:

1) Take a small sample of soil sufficient to comfortably fit in the palm of your hand. Discard any stones from the sample.

2) Moisten the soil with water, a little at a time, and knead it until there is no apparent change in the feel of the ball. The moisture content should be such that the ball just fails to stick to your fingers.

3) Inspect the sample to see if sand is visible; if not, it may still be felt as the sample is worked.

4) Next, squeeze the sample hard to see whether it will form a cast, and if so, whether it

is durable or falls apart readily.

5) Finally, squeeze it out between the thumb and forefinger with a sliding motion and note the length of self supporting ribbon that can be formed.

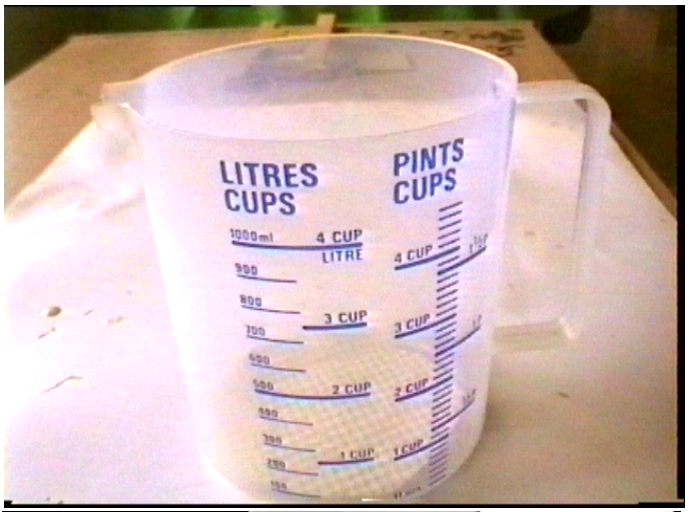
Sands	No coherence; cannot be moulded; single grains stick to fingers.
Loamy Sands	Form fragile casts that just bear handling; give short (6 mm)ribbons that break easily; discolours fingers.
Fine Sandy Loam	Form casts that will just stand handling; fine sand can be felt, and Loams otherwise feel smooth, may feel greasy if much organic matter is present; will form ribbons 15 to 25mm long.
Silty Loams	Coherent but will crumble; very smooth and silky; will form ribbons 25mm long.
Clay Loams	Form coherent casts with a rather spongy feel; plastic when squeezed between thumb and forefinger; smooth to manipulate; will form ribbons 40 to 80mm long.
Clays	Smooth, plastic casts; some resistance to manipulation (toughness); form ribbons at least 80mm long depending on heaviness of the clay. Sand grains can be felt in some clays which form ribbons 40 to 50mm long.

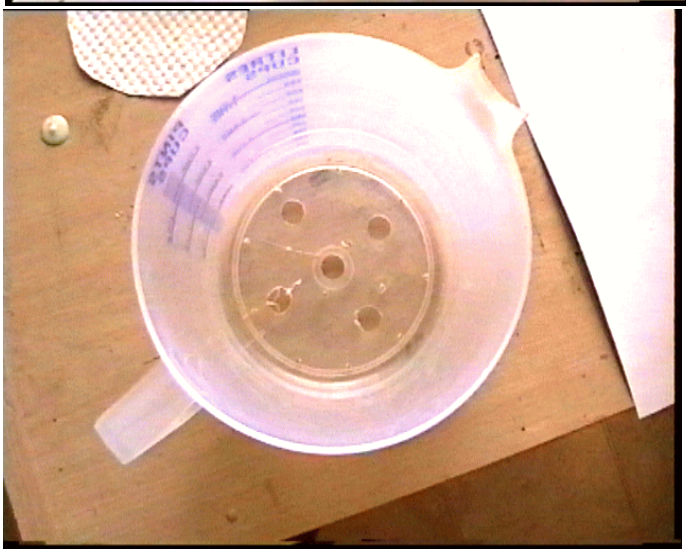
The range of soil types described in literature can be quite large, some soil classification charts have a large number of different soil types listed, but the lists are so long that they can become very confusing.

SOIL FIELD CAPACITY DETERMINATION

The determination of the Upper Storage Limit or Field Capacity value for a particular soil type using the texture of the soil as the guide, does not necessarily mean the soil will conform to the standard value for that particular soil type. The Field Capacity or water-holding capacity of a soil is the amount of water the soil can retain after drainage. It is dependent on the number of small pores in the soil. Hence, fine textured soils tend to have a higher water-holding or Field Capacity than coarse soils.

The accuracy of any soil moisture measuring device is dependent on the calibration that is applied for the soil that is being measured.





A simple method has been developed by Soil Moisture Technology, using a standard 1 litre measuring jug. This measurement method gives far more accurate results than estimating the Field Capacity value based on visual soil texture classifications, as the particle size range and particle size distribution with the soil can vary from site to site and is difficult to estimate accurately by visual inspection.

The measurement jug has five 10mm holes drilled in the bottom to allow the excess water to drain away when the Field Capacity determination is in progress.

ADDITIONAL EQUIPMENT REQUIRED

4) A fan forced oven capable of maintaining 105°C or a microwave oven is required to dry the soil sample.
5) Oven or microwave tray capable of holding the 2Kg soil sample when it is being dried.
6) Kitchen scales with a full scale weight of 3 or 5 Kg.

The Gopher PC program version 9.0 now contains a section that is designed to do all the calculations from the soil moisture measurement data and then print a hard copy and also store the data on disk file on your computer. The saving of data on your computer enables previous soil data to be recalled and displayed from any site that has been measured.
Two different methods can be used in the PC program to determine the soil characteristics:-

1 Bulk soil sampling.
2 Cored soil sampling using a coring tool.

The bulk soil sampling method calculates both the soil moisture content of the sample when it was taken and also the bulk density and Field Capacity or Upper Storage Limit of the soil sample.

The cored sample method using a soil sample corer determines the actual soil moisture of the sample when it was taken and also the bulk density of the soil to be calculated. This method is very useful in determining the compaction status that may be occurring in soil due to either natural causes or the passage of farm machinery or human traffic. The Field

Capacity or Upper Storage Limit of the soil cannot be determined using this method.

BULK SAMPLE METHOD

The soil sample of approximately 2-3Kg should be taken from the depth where you require the Field Capacity determination. The sample should be within the same watering zone where the Gopher access tube is located, but not so close to the access tube that it will cause the soil drainage pattern to change. If the irrigation method is "under tree" or "over head" sprinklers then the soil sample could be taken from near an adjacent tree or vine.

Verification that the soil texture from the sample site is the same as the site where the Gopher access tube is installed is essential to ensure accuracy and usefulness of calibration of the soil in relation to the actual Gopher access tube site. To enable the results to be used to set the Field capacity and verify the calibration accuracy of the Gopher, a profile should be recorded at the same time as the sample is taken.

The soil sample should be immediately placed in a sealed container to prevent loss of moisture during the time of transport from the field to the location of the drying oven where the measurements are to be made.

Note. The results can be entered directly into your computer if you are using version 8.4 or higher. The data can also be saved or printed at any stage of the calibration process and then re-loaded when you have more data to enter. Each soil sample is identified by the Gopher site number and the depth in centimetres that the sample was taken from.

First weigh the empty oven or microwave tray and record this weight. Then the moist soil sample should be placed into the oven tray and the tray and soil weighed together. This will be used to determine the actual soil moisture value at the site from which the soil sample was taken.

The soil in the tray should now be placed into the oven with the temperature set to 105°C. To ensure that the soil sample is dry it should be left in the oven for 24 hours. At the end of this time the oven should be turned off and the soil left in the oven until it is cool. This will help to prevent re-absorption of moisture as the soil cools.

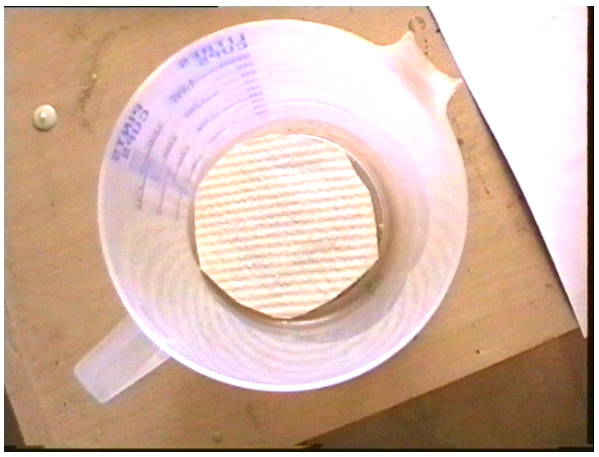
If a microwave oven is to be used the rate of heating of the soil will be very high, care must be taken that the soil sample is not overheated as this will eventually burn any organic material in the soil and change the resulting texture of the soil. The soil should be heated in the microwave for no more than 3 minutes and then allowed to cool and then weighed before heating again.

At the end of each heating burst the sample should either be removed from the microwave, or the microwave door opened to allow evaporating water to escape from the soil. If this is not done condensation may form on the roof of the microwave and drip back into the soil sample.

When the weight of the soil sample does not change it can be assumed to be dry. As the soil dries the time of each heating burst in the microwave should be reduced to avoid overheating.

Any clumps of soil should be broken up as the soil is dried, doing this after each heating burst in the microwave reduces the problem of very hard lumps forming in clay or silty soils.

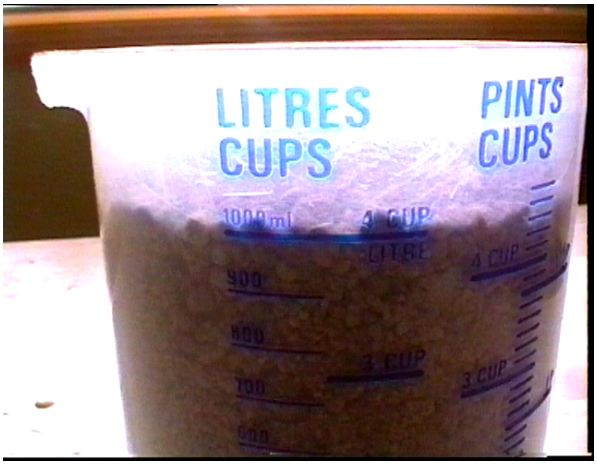
When the soil is dry any remaining clumps in the soil must be broken down by using a piece of wood to pound the soil. The soil and container should now be weighed and the weight recorded in the table.



The measuring jug should have a single sheet of paper towel placed in the bottom of the jug to cover the water drainage holes. The jug with the paper towel in place should now be weighed and the weight recorded. A typical weight for the Decor one litre measuring jug and paper towel is approximately 83gms. Now the dried soil should be added to the jug until the soil level is in line with the 1 litre mark. The soil should now be shaken down by lifting the jug and tapping it on the surface of a bench top. This action should be repeated until the soil height does not change any more. The soil level should then be topped up to the one litre mark again and the shaking down process repeated. This should be repeated until the soil level does not change. The dry soil and container should now be weighed and the weight recorded.

The remainder of the dried soil sample will be used to absorb the excess water from the bottom of the soil container until the weight of the soil in the container reaches a constant value. This is when all moisture movement within the soil has ceased and the soil is at Field Capacity.

Water should now be added to the soil. For very light sands add approximately 290mL. For loams add approximately 330mL and clays approximately 450mL. The heavy soils will require the water to be added in several lots as the space left at the top of the jug is not sufficient for the volume of water that the soil will absorb. Before the water is added the measuring jug should be placed in a container to collect the excess water that freely drains out of the bottom of the jug. Leave the jug in this container for about 1 hour. If water does not drain from the bottom of the jug then more water should be added to the top of the jug after the water has soaked into the soil.



The movement of the water down through the soil can be observed through the walls of the jug. The water will move down through sands at a very fast rate, sandy loams will be slower and clay or silty soils will be very slow. The

rate at which the water moves through the soil is an indication of the soil's hydraulic conductivity or its ability to transmit water.

When all free water has drained from the soil, that is the water is no longer dripping from the bottom of the container, the container should be placed on top of the remaining dried soil sample. The soil should be piled up into a heap to improve the natural drainage from the drain holes in the container into the dry soil below.

The surface of the soil in the jug should now be smoothed and levelled using a small spoon or knife, any soil that adheres to the smoothing tool should be scraped from the tool and returned to the jug so that the weight of the soil in the jug is not altered.. The soil volume should now be read from the graduated scale on the side of the jug. This value is the cubic volume of the soil and will be used to determine the bulk density of the soil. Record this volume in the table in your computer.

A cover should now be placed over the jug to prevent evaporation from the surface. A suitable material for this is plastic food wrap or a plastic lunch bag. Approximately every 1 to 2 hours for light soils and 4 to 6 hours for heavy soils, the soil container should be removed from the soil drain mound and weighed. Any soil sticking to the base of the jug should be carefully brushed off before weighing. This process should be repeated until the weight does not change between successive weight measurements. This is when the soil in the container has reached Field Capacity and all drainage has ceased.

Sands will reach Field Capacity in a couple of hours, sandy loams may take up to 24 hours and heavy loams and clays may take one to two days. When the weight is constant the plastic cover on the jug should be removed and the soil and jug final weight recorded. After entering the last weight depress the enter key to cause the program to do the final calculation and display the results in the table in your computer.

This data should be saved to file and also a hard copy should be printed. The soil texture name can be changed after starting the calibration by clicking on the soil texture display panel. You will be prompted to enter a texture name for the soil. This will then be displayed in the soil texture display panel and saved with the other calibration data when saved to file.

CORED SAMPLE METHOD

To change the PC setup to the table that has been set up for core sampling, click the mouse pointer on the panel that displays BULK SAMPLE. The caption in this panel will change to CORED SAMPLE and the heading in the table on the computer screen will also change to a format suitable for cored sample bulk density analysis.

Before the soil coring sampler is used the weight of the coring cylinder should be measured and recorded so that it can be entered into the Soil calculator when a soil sample is being measured. The volume as stated by the manufacturer should also be noted.

Note. Core samples should not be taken in very wet or very dry soils.

The soil sample should be taken according to the manufacturer's recommendations if a commercially produced core sampler is used. If the corer has been manufactured locally, then the following procedure should be used. The core sampler should have a volume of approximately 700 to 1000 cubic centimetres.

1 Prepare a flat surface in a sampling pit (either vertical or horizontal).
2 Press or hammer the core sampler into the soil.
3 Remove the core with the sample from the site, cut the soil flush with a sharp knife at both ends, cut off any roots with a pair of scissors.
4 Put the core and sample into a plastic bag and seal it. Keep the sample in a cool place, to prevent evaporation from the sample during transportation.

The procedure of coring soil samples does have some inherent problems due to soil crumbling or compressing during the sample taking process. For this reason it is recommended that a commercial coring unit be purchased, if this method of determining bulk density is to be used.

Note. Core sampling in gravelly or stony soils is not recommended. A replacement method is more suitable for this type of soil structure. This technique is not simple and should be carried out by either the Department of Agriculture or a commercial consulting company.

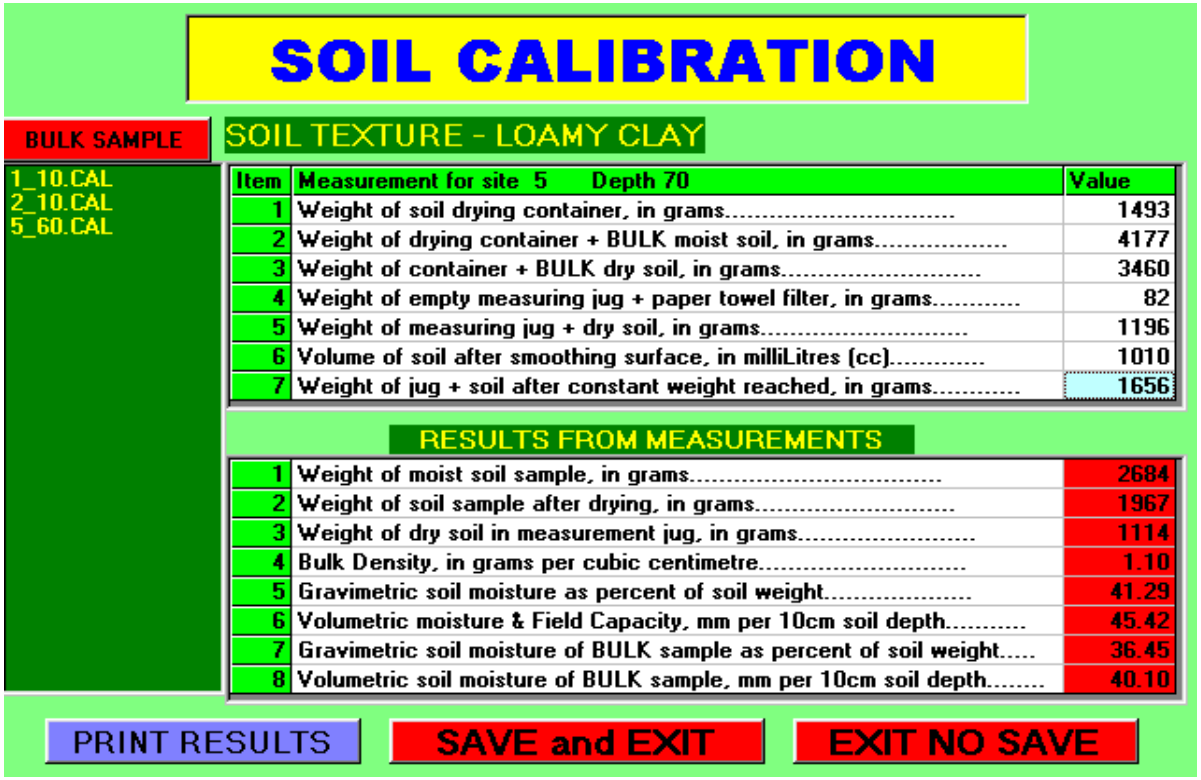
The method for determining the soil moisture value and bulk density is as follows.

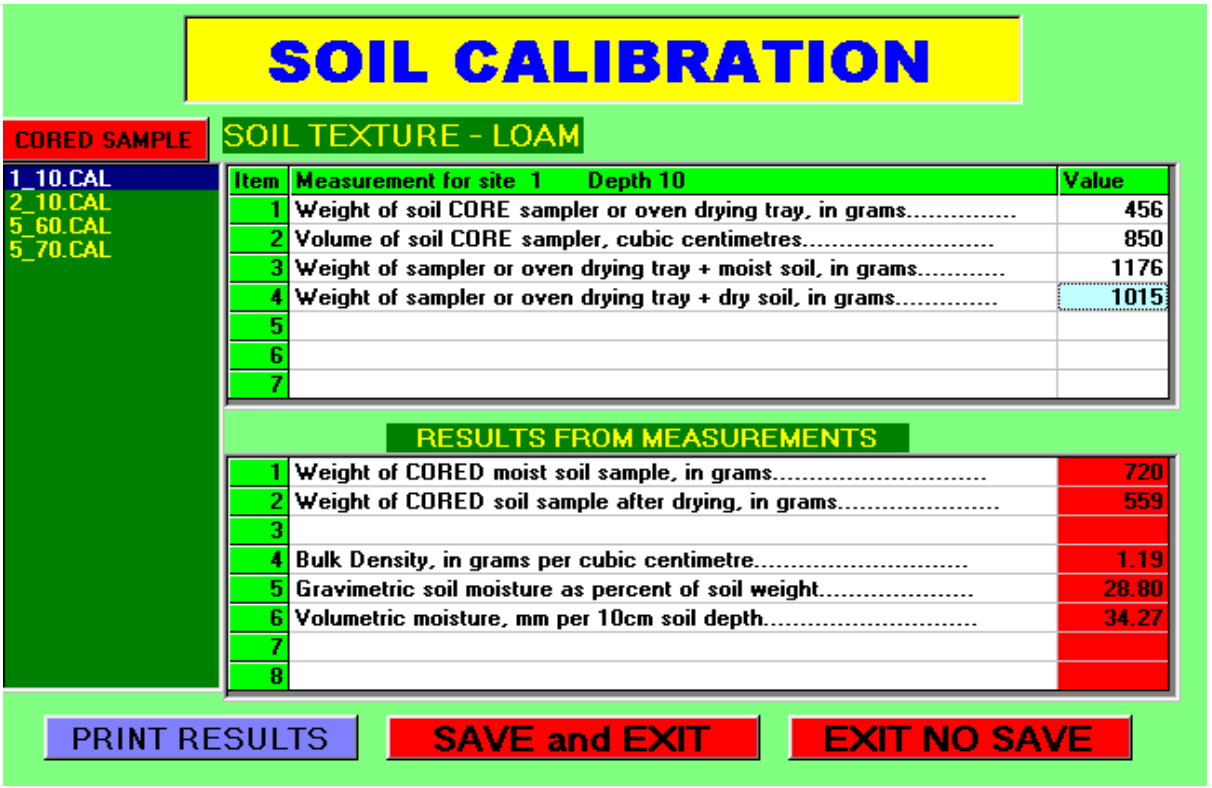
Remove the soil sample from the plastic bag and weigh the corer and soil sample together. Record this weight in the computer chart.

Note if the corer is not suitable for use in an oven or if a microwave is to be used for drying the sample then the sample should be removed from the corer and placed into a suitable tray. The tray should be weighed before the soil is placed into it. This weight should be entered into the table in cell one instead of the corer weight. The tray and soil sample should now be weighed and the weight entered into the chart.

The soil sample should now be dried either in an oven at 105 degrees for 24 hours or in a microwave using the same technique as is used for the bulk soil sampling technique described above. When the soil is dry the final weight of the soil plus container should be entered into the table.

The results from the calibration will now be displayed. These show the bulk density of the soil sample and both the gravimetric and volumetric soil moisture content of the soil at the time the soil sample was taken. These can be saved to disk file and also printed out to obtain a hard copy.





Note. Any of the data that has been saved to disk can be recalled by clicking the mouse pointer on the file name in the list at the left of the PC screen. The data can then be edited and re-saved and also printed. If you do not want to save the changes then click on the **EXIT NO SAVE** button.

INFILTRATION RATE METHOD

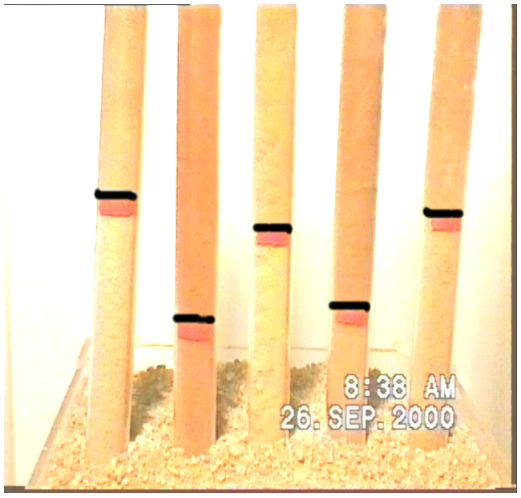
In this method the depth of infiltration of a measured volume of water into a column of oven dried soil is used to calculate the Full Point or Field Capacity of the soil sample.

This picture shows five (5) different soil types being tested. The container for the soil is 25mm Acrylic tube. This tube can be purchased from Soil Moisture Technology.

The dried soil is poured into the tube and then shaken down until the soil does not compress any more in the tube.

The 10 millilitres of water is added to the column. The time taken for the water to almost stop penetration into the soil will depend on the soil type. Sand will come to equilibrium in 4 to 6 hours. Loams and Clay and Silty Loams will take up to 24 hours.

To determine when the vertical movement of water in the soil has almost stoped the depth should be measured at 2 hour intervals. If the water movement over this time is less than 2 millimetres and the elapsed time is in the order of the times stated above then the soil can be assumed to have reached Field Capacity or Full Point.

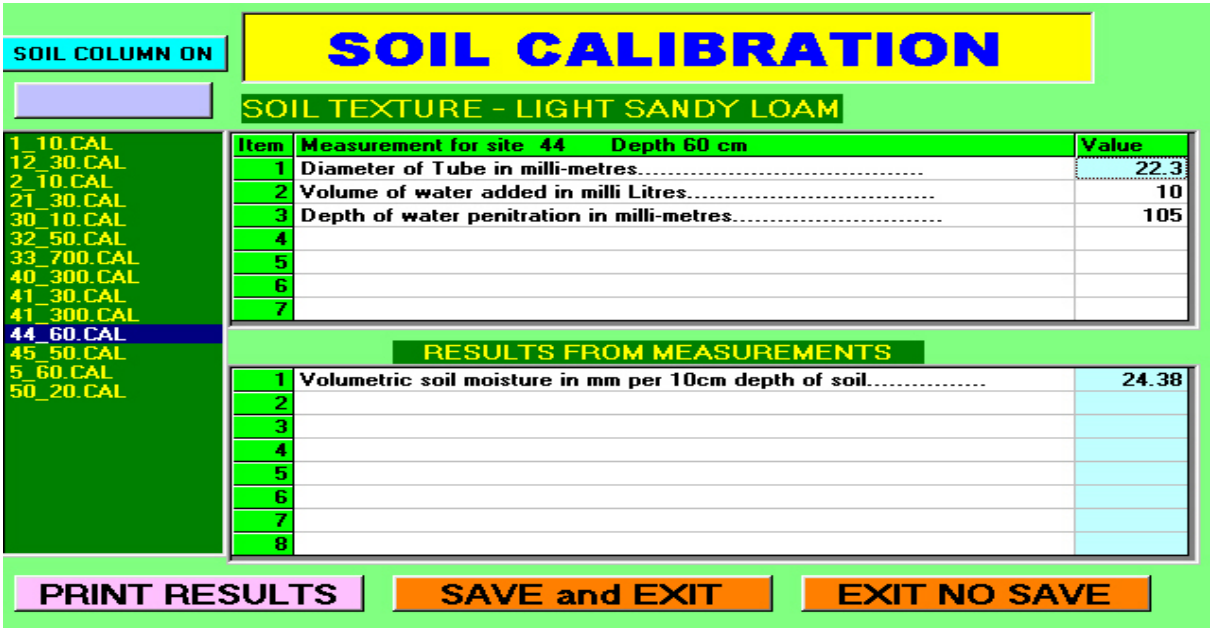


The depth of water penetration should now be measured and entered into the calculator in the PC program. The program mathematics uses metric measurements.

The depth of water penetration in the samples shown to the left has been marked with a black line.

Enter the CALIBRATION CALCULATOR by clicking on the option button from the main menu. Then when you enter the program click on the SOIL COLUMN button at the top left of the screen. The depth value and diameter of the tube being used are now entered into the calculator in the Gopher PC program. Key enter after the depth value has been entered.

The program will then calculate and display the Field Capacity of the soil being tested.



GOPHER OPERATION

DATE AND TIME CHANGES

When the Gopher batteries are changed or the Fimware has just been updated, the Real Time clock in the Gopher may change. The program now displays the current Date and Time after either of these operations and BEEPS until you verify that the time and date are correct. If the time or date are wrong then key 2 for NO. The program will go to the TIME and DATE set up procedure where you can enter the correct values. This avoids the problem of accidentally missing an incorrect date or time setting after a battery change.

SENSOR ERROR

A faulty sensor or cable not fully connected can cause bad values to be recorded in a soil moisture profile. Even though the PC and Gopher software corrects this problem, we have now added an alarm to the Gopher program that is sounded if the reading from the sensor falls outside the normal range that should occur from normal soil moisture measurements. The advantage of this is that the operator is made aware of any problem immediately. The cause of bad sensor readings may be due to water in the access tube or the plug becoming disconnected from the Gopher or the sensor. If a profile is being recorded then the recording is aborted. In the READ PROBE DIRECT MODE the program also sounds the alarm. In both cases after the ENT key is depressed the Gopher program returns to the MENU.

PLACING THE GOPHER SENSOR IN AN ACCESS TUBE

Remove the top cap from the access tube. Inspect the inside walls of the access tube to ensure that moisture has not condensed on the tube wall. If moisture is present on the tube wall it must be dried using a piece of paper towel wrapped around the 10mm dowel that was used to tamp the soil into the access tube hole. A small nail or screw inserted into the dowel at the end will hold the paper towel in place. Failure to remove any moisture in the access

tube will result in the recording of data that is false. If the sensor becomes wet due to this it will also cause errors in any other profile that is recorded while it is wet.

Carefully insert the sensor into the access tube, taking care that the sensor body does not rub against the top edge of the tube as it is pushed into the tube. If this happens the covering on the sensor may be damaged and could eventually cause failure of the sensor.

NOTE: The Gland locking nut on the sensor guide cap should be adjusted so that sensor staff moves smoothly through the gland.

Place the sensor guide that is on the sensor staff over the top of the access tube, rotating it as you push the cap onto the tube. Push the cap firmly home.

Set the sensor height so that the bar under the number one(1) on the measuring rod is in line with the top of the gland on the sensor guide cap that has been placed onto the access tube.

NOTE: If the covering on the sensor head becomes damaged the sensor should be returned for service. Do not attempt to repair a damaged head, as this may cause the sensor head to produce erroneous results.

The **Gopher** Soil Moisture Profiler is menu driven.

MENU PROGRAMS

READ SENSOR DIRECT

RECORD PROFILE

GRAPH SOIL PROFILE <Profile for site - selected profile

HISTOGRAPH SLICE <Histograph for site at selected depth

HISTOGRAPH SUM <Summed soil moisture value to selected root zone

WATER BALANCE CALC <Calculated to selected root zone depth

CALIBRATION ENTRY

RESET TIME CLOCK

ERASE PROFILE DATA

TIMED RECORDING

When the **Gopher** is turned on by pressing the ON key on the key pad the current version of the **Gopher** program version and the serial number will be displayed.

BATTERY VOLTAGE The second page of the display shows the battery voltage and the date and time stored in the real time clock. With new extra heavy duty batteries the voltage should be approximately 6.200 volts. When the battery voltage has fallen to 5.5 volts or lower the batteries should be replaced. After the batteries have been replaced the time and date should be checked when the **Gopher** is turned on. If either is incorrect they must be reset. Data recorded with an incorrect date setting will cause errors in the water use values when they are calculated. Displayed Histographs will also have errors.

If the battery voltage is allowed to fall below approximately 5.3 volts a warning will be displayed that the batteries are flat and must be replaced.

NUMBER ENTRY FROM KEYBOARD

There are two modes used in the program. The first is number selection by using the INC and DEC keys to activate a counter to count up or down. If the INC or DEC keys are held down during site and profile selection, the numbers will change rapidly. The ENT will select the displayed number - the EXIT/OFF will return to the main menu.

The second is where numbers are entered via the keypad. If an incorrect entry is made, the CLEAR key will erase the last digit or as many digits as required to correct the entry. Key ENT when the entry is complete. Where a number has a default or is to be repeated, then that number is displayed when the input is prompted. To accept the displayed number, key ENT. To change the number, key the new number and then key ENT.

REAL TIME CLOCK SETTING

Before the **Gopher** is used for the first time the internal clock has to be set. Failure to do this will result in errors in the graphing and water use calculations. As mentioned at the start of the Gopher operation description the Gopher program now includes an alarm that is sounded whenever the batteries are changed or the Gopher program is up-dated. This alarm requires that you check the date and time and verify that they are correct.

Power up the **Gopher** by pressing the ON key. Move through the menu using the <INC> key until the menu item RESET TIME CLOCK is shown.

Key ENT to select the menu item. This display will show:

```
RESET TIME CLOCK
YEAR  YYYY     xxxx
Month in year  xx
Day in month   xx
```

The display will first prompt for the current year as a 4 digit number.

Key ENT to move to the next month in the year entry.

Enter the month in the year.

Key ENT to move to the day in the month entry.

Enter the day in the month.

Key ENT to move to the time entry.

```
RESET TIME CLOCK
Hours     XX
Minutes   XX
ENT TO START CLOCK
```

Enter the current hour of the day, the clock format is a 24 hour system, so the hours must be entered in that format. Then the minute of the hour.

The display will prompt you to key ENT to start clock. This enables the clock to be started when the seconds are zero. To use this feature set the minutes to the next minute and wait until the seconds are zero. Then key ENT.

For example, if the time is 11:12:15 set the clock to 11:13 and wait until the second on your watch or time source is zero, then key ENT.

The real time clock is displayed each time the power is turned on to the **Gopher**. It should be checked to ensure it is set correctly.

READ SENSOR DIRECT

The site number is selected first by using the INC and DEC keys. Key ENT to select the site. The bar graph for the soil water will now be displayed.

This program is used when a "look" at the profile is required without logging any values.

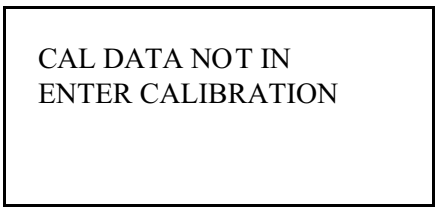
If calibration data has not been entered for the site number selected, NOT CAL will be displayed under the bar graph. If calibration is present then the water volume figure in millimetres per 100 millimetres depth of soil is calculated from calibration data entered for the first 100mm profile point.

If the site has been calibrated as a percentage calibration then the soil moisture will be shown as a percentage.

LOG PROFILE

This program records a profile of the soil moisture over the depth that has been selected in the CALIBRATION ENTRY program. Note: Each consecutive point in the profile **must** be recorded every time a profile is logged. The memory used in the **Gopher** profiler is NON-VOLATILE flash memory. This type of memory cannot be changed once data has been recorded, without first erasing data for a site using the erase program.

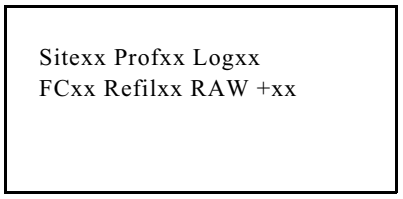
To record a profile first select the site number. The bottom line of the display will tell you if a site has calibration data entered:



If you select a site number that has not been set up with calibration data the soil moisture profile cannot be recorded. The program will prompt:

Note: The program will advance direct to the calibration entry if there was no calibration data found.

The next available profile number is selected automatically. The display will show:



If the site has been calibrated in the Percentage mode the values will be displayed as percentages.

The bar graph represents the moisture in the soil based on the calibration that has been entered.

The top line of the display shows:

site number, profile number and the current log number that has been recorded. The log number will be blank until the first profile point has been recorded.

The second line of the display shows:

The field capacity value that has been entered in the calibration data in millimetres of water per 100mm of soil depth for the depth being measured.

The refill point that has been entered in the calibration data. This is also in mm of water per 100mm of soil depth.

The last figure is the amount of water or soil solution that is left above the refill point at the depth being measured.

The next line is the bar graph. This graph is calibrated to read to the maximum soil water values anticipated from the entered calibration data.

The bottom line of the display shows:

The amount of soil water (in mm per 100mm of soil) at the depth being measured and the amount of water that has been used from the field capacity value.

To record a profile, first install the sensor in the access tube as described previously in this handbook. Set the sensor height so that the bar under the number one (1) on the measuring rod is in line with the top of the gland on the PVC guide cap on the top of the access tube.

To record the first (next) value depress the LOG key on the keypad. Release when the **Gopher** sounder beeps. The value will be recorded and the LOG counter will advance to 01.

Lower the sensor to position 2 and depress the LOG key. Repeat for all profile points.

To avoid accidental erroneous recording of a profile, the data is first stored within the microprocessor. Once all the points in the profile have been recorded you will be prompted to store or discard the profile. It is important the you look at the data critically as it is being recorded. Data that has errors in it will cost time and money to rectify.

STORE THIS DATA KEY 1 YES 2 NO

If you key 1 for YES the data will be stored in memory. If you key 2 for NO the program reverts back to the head of the LOG PROFILE and is ready to record a new profile without saving the previous profile.

After all the data has been recorded it will be displayed as a vertical bar graph over the entire profile.

The height of the vertical bars is proportional to moisture content of soil from just under the refill value to just above field capacity. The depth of the access hole increases from left to right. Each bar represents 100mm of the moisture profile.

Key ENT to clear the graph. The water balance calculation will display:

Depth XXXX Field XXX Water XXX Refil XXX

This is for the depth that has been selected for the root zone in the calibration. The INC and DEC keys can be used to increase or decrease the summed depth for the water balance calculation.

If the site has been calibrated in the percentage mode. PERCENT will be displayed above the Refill value.

Key ENT to return to MAIN MENU.

GRAPH DATA

The graphing program in the **Gopher** provides three different graphing routines:

1 Graph soil Profile

2 Histograph Slice

3 Histograph Sum

GRAPH SOIL PROFILE

Select the site number, the last recorded profile number will be displayed after the site number is selected. You can select a different profile number if required. If you select a profile log that is empty you will be prompted to select again.

The bar graph vertical scale covers from just below refill point to just above the field capacity value that was entered in the calibration data. Profile depth is on the horizontal axis. Each vertical bar represents the moisture value for that 100mm section of the profile. The INC and DEC key may be used to scroll through all the profiles that have been recorded for that site.

Incorrect calibration of a site can cause apparent problems in the graphing programs in the **Gopher**. Because the screen has limited vertical resolution the data has been displayed so as to give maximum resolution of the soil moisture data. If the calibration has not been carried out correctly you may end up with either a blank screen or a screen that is totally blacked out. This indicates that the soil moisture values are either below the refill point or above field capacity. If this is the case you can change the calibration in the PC program after visual examination of the data. It can then be transferred back to your **Gopher** to adjust the calibration values in the Gopher's memory. This is covered fully in the section in this book on the PC program.

HISTOGRAPHS

As each successive profile is recorded, a time progression is being built up of the rate of depletion of water from the soil at the various depths within the profile. This is similar to placing ten (10) sensors in a one metre deep access tube at 100mm intervals and recording the available water with respect to time.

The Histographs are used to estimate the time interval before the next irrigation cycle and also to display the usage pattern from different depths in the soil by the plants being irrigated.

This is one of the most attractive and powerful features of the **Gopher** Soil Moisture Profiler. For example, with twenty (20) access tubes, a single **Gopher** becomes the equivalent of a data logging system with 200 sensors - at a fraction of the price of any other soil moisture recording system.

HISTOGRAPH SLICE

The Histograph slice provides a slice through all the profiles recorded for a selected site at a selected depth. The INC and DEC keys can be used to move the slice up or down the hole. This gives a pictorial view of water use trends at different depths in the soil profile.

HISTOGRAPH SUM

The Histograph sum provides a summed graph down to the root zone depth. The depth of this summation can be changed as the program is entered. The value that is in the calibration file is displayed. To accept this value key ENT, to change the value enter a new depth value from the key pad.

WATER BALANCE CALCULATION

Select the site that you require. The last recorded profile number will be displayed. This can be changed before entering the program by depressing the INC and DEC keys. If you select a log that is empty you will be prompted to select gain.

The water balance data will be displayed to the root zone depth that was entered in the calibration. If the site has been calibrated in the NEW percentage calibration mode then PERCENT will be displayed. All the values will be as percentages. To recalculate the water balance to a different depth in the profile depth, depress the INC or DEC key. The data will be recalculated for the new depth.

```
Depth XXXX
Field  XXX
Water  XXX Refil XXX
USED   XXX RAW   XXX
```

The number at the top right hand corner is the depth in millimetres that is being used for the calculation. The total field capacity of the soil to the depth selected is shown on the next line. The actual measured water content to the root zone depth is displayed on the next line. The bottom line is equal to the amount of water that has been used. This is the value that is required in millimetres of irrigation precipitation to bring the soil back up to field capacity.

The right hand side of the display shows firstly the summed refill capacity. This is the amount of water that would be in the soil if the moisture levels were at refill point for the entire depth being displayed.

The last number is the amount of water left in the soil over the displayed depth that is above the refill point; that is, the amount of available water above refill that the plant can use. This water is also commonly called Readily Available Water (RAW).

ERASE PROFILE DATA

The memory of the **Gopher** Soil Moisture Profiler is capable of storing an enormous amount of data. However eventually the memory space allocated for a site will become full or you may wish to change the calibration data. If the memory space allocated for a site becomes full you will not be able to store any more data before erasing the site.

If you want to keep the data that has already been recorded (this is recommended) then it should be transferred to a PC before the memory for that site is erased. The section on the PC program handbook describes how this is done.

```
1 ERASE CAL. ONLY
2 ERASE ALL PROFILES
3 ERASE ONE PROFILE
4 ERASE ENTIRE SITE
```

The site erasure program provides three options when selecting a site for erasure:

`Option 1` erases the data stored in the calibration section of the site only. This allows a site to be re-

calibrated without erasing existing profile data.

Option 2 erases all of recorded profile data. The calibration data is retained.

Option 3 erases one profile only. If a bad profile has been recorded and stored in memory it can be erased. The remaining profiles in the site are then re-packed into the vacant position in memory.

Option 4 erases the entire site, calibration data as well as all recorded profile data.

If you wish to retain the current data in the **Gopher**, but still wish to record more data for the same site after the available memory for that site has been filled, a new site could be set up to continue the recording for this site without having to erase the old data. Or the directory in your PC can be changed, and future profile data will be save in the new directory.

The PC program version 9.0 now contains a new season program that provides an easy way to carry out this operation.

In version 9.0 of the PC program the EDIT SITE header also allows multiple directories to be set up for data from each site. This allows archiving of data from sites and restarting the log using the same site number. Data archived in this way in the PC can be recalled at any time and displayed graphically or as numeric values through the print site program. Archived files can also be concatenated or joined together in the graphing program. Several seasons can be joined together and graphically displayed.

To erase either calibration or profile data or both for a site, after first saving the data in your PC, select ERASE PROFILE DATA from the menu. Data that has been accidentally erased can always be restored into your **Gopher** if it has been saved into your PC.

Select the site number to erase. Then key CLEAR to confirm that you wish to continue the erase program. Any other key will abort the erase program. The program will prompt you with a four option menu as mentioned above. Depress a key (1 to 4) to select the required option.

The erasure will then proceed. The display will prompt when it is completed. Key ENT to return to the MAIN MENU.

TIMED RECORDING

There are occasions when continuous timed recording is required to enable determination of rate of water penetration or water use on a continuous timed basis over several days.

To enable the **Gopher** to provide facilities to carry out this measurement, a TIMED RECORDING mode can be selected from the **Gopher** operating program (graphing and printing facilities for this mode are available from within the PC program).

The sensor is placed in the access tube at the required depth. The gland nut on the access tube cap is then tightened to ensure that no water can enter the access tube through the gland. It is only necessary to tighten this gland with your hand. Do not use a spanner as this may damage the gland and is not necessary. The **Gopher** must be placed in a waterproof container if it is to be left out in the field during an irrigation cycle or if rain is expected. If neither of these events are expected then it may be adequate to wrap the **Gopher** in glad wrap or place it in a plastic bag. This will offer protection against dew. If the site is in full sunlight a sun shield should be placed over the **Gopher** to ensure it is not in direct sunlight as this may cause damage to the LCD display.

To set up the timed recording, select the program from the menu (after erase profile data). Any site number can be used for this facility and it is recommended that an unused site number beyond those that are normally used for profile recording be used. Remember the site number must have calibration data entered before it is used. If you have previously used that site for timed recording then the program will prompt you that the data has to be erased before new data can be recorded. Key CLEAR to erase the data. Select the erase mode (normally 2). The data will now be erased.

Enter the depth at which the recording is to be made, for example, 400. This depth entry is important as the **Gopher** looks up the calibration data for that depth and uses this data to calculate the water content of the soil. It is also required for reference when the data is being processed in your PC.

Enter the sensor scan time in minutes. Normally the default of 15 minutes is adequate.

The maximum time span that can be recorded will depend on the scan interval that is entered in the setup. The number of readings that can be recorded is 858. If a 15 minute scan time is selected (default) the recording will cover a maximum time of 8.9 days. If 30 minutes is set then the recording will cover a maximum time of 17.8 days.

The display will now show the number of millimetres of water at the sensor depth before the recording starts.

Depress the LOG key to start the log.

To terminate the log prior to downloading the data to your PC, press the ON key. The **Gopher** beeper will sound and the display will show;

LOG TERMINATED.

The **Gopher** can now be unplugged from the sensor and taken to your PC for downloading.

The downloading procedure is the same as for normal profile recording with one exception. The program has the facility to concatenate several blocks together. If data already exists for the site in the PC, then you will be prompted to either:

1) add the data onto the end of the existing file;
or
2) write over the existing data.

If you use the add-on facility it enables you to view the data as an event progresses, and then continue recording another block of data with the **Gopher**.

NOTE The data in the **Gopher** must be erased before a new block can be started.

To graph the data in the PC program, select Timed Recording graph from the GOPHER GRAPH menu.

KEYPAD - Key Description

0 to 9 keys for number entries

decimal point reserved for future use

ENT terminates a number entry or selects a menu item.

INC increments a number on the LCD display, a graph or depth.

DEC decrements a number on the LCD display, a graph or depth.

LOG records a value from the sensor in the profile log mode or calibrate mode. Starts the timed log program.

CLEAR Erases a digit entry when the **Gopher** is in the number entry mode.

EXIT/OFF will exit a program and/or power down the **Gopher.**

ON will turn on the **Gopher** power. This is the only key that is active once the **Gopher** has been powered down.

SENSOR HEAD AND MEASUREMENT STAFF

The standard Gopher sensor head has two black centering spacers at the top and bottom of the sensor element. These are designed to keep the sensor central in the 50mm PVC access pipe. If the spacers become damaged they should be replaced. Spares are available from Soil Moisture Technology. The spacers have an adhesive backing and can be replaced in the field.

The sensor area between the two spacers is robust, but the sensor should always be treated with care. A small piece of 50mm PVC pipe was used to protect the sensor in shipment to

you. This should be used to protect the sensor while it is being transported from site to site.

The measurement rod has a PVC end cap and gland mounted on it. This end cap and gland are designed to keep the measurement rod vertical. It must be placed over the top of the 50mm PVC access pipe while a profile is being measured.

The Micro-Gopher sensor is more robust than the Gopher sensor, however it still should be treated with care, to avoid damage.

BATTERIES

The **Gopher** uses 4 x AA size extra heavy duty batteries. When the profiler is powered up the battery voltage is displayed along with the time and date. The batteries should be replaced when the voltage falls below 5.4 volts. A battery flat warning will be displayed if the battery voltage is allowed to fall below this voltage.

Under normal use the batteries will last for many months. When the batteries are changed the time and date should be checked to make sure they are still correct. THIS IS IMPORTANT as data recorded with an incorrect date will cause graphing and water use errors when the data is displayed in your PC.

UNDERSTANDING SOIL MOISTURE MANAGEMENT

A complete reference on soil moisture, plant usage and irrigation management is beyond the scope of this handbook. There are many publications that provide detailed irrigation management and planning information.

If you require assistance with setting up or managing your irrigation system, Soil Moisture Technology are available to supply you with technical assistance or if you require on site assistance, can supply the name of a qualified consultant in your district.

The amount of available water in the soil will vary from soil to soil and also with different plant types and weather conditions.

Water is lost from the soil in two ways:

1. EVAPORATION: Moisture evaporated from the soil surface.

2. TRANSPIRATION: Water lost from the plants mainly during daylight through stomata which are openings in their leaves.

The combination of evaporation and transpiration is called

EVAPOTRANSPIRATION

When water is transpired from a plant a deficiency of water is created inside it. This causes the plant to raise more water from the roots. The water comes from the soil.

Plants have very little difficulty extracting water from the soil when the soil moisture is at field capacity. However as more water is removed from the soil the remaining water is held in smaller capillaries so the plant is less able to extract it from the soil. Also the rate at which the plant can extract the water decreases as the amount of water held in the soil decreases.

Eventually the plant is unable to extract enough water from the soil to make up for transpiration losses and as the water in the cells of the leaves becomes depleted they will become floppy and wilt.

The point at which this happens in terms of available water in the soil will depend on prevailing weather conditions which determine the rate of water usage by the plant.

Plants grow most vigorously when they are never short of nutrients, water and oxygen in the soil.

When plants have less water than they require they are said to be under water stress. Plants grow less when they are subject to water stress because they tend to shut down to retain the water they have. This in turn reduces the rate of photosynthesis and consequently the rate of plant growth.

Water stress causes permanent damage to the plants and reduces their rate of growth and production and hence the financial return for the farmer.

The other extreme is over-watering to ensure plants never suffer water stress. The continuous maintenance of high soil water levels will restrict the oxygen supply to the plant roots, leach nutrients below the root growth area and eventually aggravate pollution by leaching fertilisers into the ground water so that over-watering is also financially counter-productive.

To achieve **MAXIMUM ECONOMIC YIELD** the irrigation management schedule must be set so that the moisture level in the soil is always cycled between and maintained within the range of refill and field capacity. This will ensure optimum growth and consequently the most profit for the grower.

The minimum soil moisture level that must be maintained will vary according to the type of crop that is being grown, the irrigation strategy, the soil type, the aspect of the land and the current weather conditions.

It is generally accepted that for optimum growth the soil water depletion should not be allowed to exceed about 50-60% of the available water between field capacity and wilting point for most crops. This figure may be varied to suit or tailor the growth and character of the fruit being produced.

The point at which a decision to irrigate is made will depend on evaluation of the amount of water left in the soil at the different depths of the soil profile. For young plants the top few hundred millimetres are all that is important so that irrigation timing and the amount of water will be based on what is left in the soil to this depth and the rate it is being used.

The **Gopher** provides you with a measurement of the amount of water that is in the soil over the entire (or part) of the measured profile.

The amount of irrigation water that is required to bring the soil back to field capacity can now be obtained from the displayed information. The amount of water that is required is displayed as water **used**. Remember to set the depth indicator to the depth of the root zone of the plants being irrigated before reading the required water from the water used calculation.

As a profile library is built up for a particular site and crop, the point at which irrigation is started may be varied to achieve optimum results.

To enable irrigation times to be calculated the rate of precipitation from the sprinklers being used must be known. This can be measured by placing either a small plastic rain gauge or metal tin such as a soft drink can or fruit tin to collect the water from the sprinklers over a known time, for example 30 minutes. The height of the water in the can is measured with a measuring tape. This is the number of millimetres of water that the irrigation sprinkler is spraying onto the soil. If the measurement was 30 minutes then the number of millimetres must be multiplied by two (2) to give millimetres per hour.

The spray pattern of the sprinkler should be carefully observed to ensure that placement of the measuring tin or gauge is typical of the entire sprinkler distribution pattern. If the sprinkler has a very low angle of spray then you should dig a hole in the soil and position the can so that the top lip is only a few millimetres above the soil surface.

This procedure should be carried out at several sites in the irrigated area to ensure that the value used presents a true average of the area being irrigated. The irrigation time can then be translated direct from the precipitation required.

The precipitation required is read from the USED value on the water balance calculation screen.

e.g. Precipitation rate from sprinklers = 12mm per hour
Required precipitation to restore field capacity = 89mm
Irrigation time = 89/12 = 7.4 hours

EXPLANATION OF TERMS

SATURATION

Saturation is when all air voids in the soil have been filled with water. Any additional water applied to the soil will form ponds on the soil surface.

FIELD CAPACITY or FULL POINT
Field Capacity is the maximum amount of water a soil can retain against gravity and drainage. It is therefore the 'full' point to be aimed at in irrigation. To determine the field capacity of a soil, the soil should be saturated and then allowed to drain. This will take several hours in sandy soil and up to several days in loamy or clay soils.

REFILL POINT
Refill Point is that point between Field Capacity and Wilt Point (nominal 50%) that is to be used as the indicator as to when irrigation should be commenced. Refill Point is also defined as the level to which available water can be allowed to decline before significant stress is beginning to be experienced by the crop.

WILT POINT
Wilt Point is the amount of soil moisture which is insufficient to maintain the plant's water requirement, the plant will be stressed and start to wilt. With the addition of water to the soil the plant will recover although it will suffer damage.

PERMANENT WILTING POINT
Permanent Wilting Point is that point at which the plant wilts and will not recover; it begins to wither and die.

AVAILABLE WATER
That part of the water in the soil that can be absorbed by plant roots. Available Water is the difference between the amount of water held at Field Capacity and water remaining in the soil when the plant starts to wilt.

MAXIMUM AVAILABLE WATER
Maximum Available Water is the difference between the amount of water held in a soil at Field Capacity and water remaining when plants reach permanent wilting point.

READILY AVAILABLE WATER (RAW)
Readily Available Water is the difference between the amount of water held in a soil at Field Capacity and water remaining in the soil when the soil moisture has reached refill point.

SOIL WATER
Water contained in, or in transit by drainage through, the soil.

WATER LOGGED
The condition of a soil which is saturated with water and in which most or all of the soil air has been replaced. This condition is detrimental to plant growth.

INFILTRATION RATE
The rate at which water moves downward into the soil.

PORE SPACE
The fraction of the bulk volume or total space within soils that is not occupied by solid particles.

EVAPOTRANSPIRATION
Evapotranspiration is that collective term for water lost from the soil surface by evaporation and the water used by the plant. Most of this transpired water is lost through stomata which are openings in the leaves that allow carbon dioxide to enter the plant and oxygen to leave.

GRAVIMETRIC WATER CONTENT
Gravimetric Water Content is water content of a soil sample expressed as a percentage of the oven dry weight of the soil. A sample of soil is collected and stored in an air tight container. The soil is then weighed before drying in an oven for 24 hours at 105 degrees. The soil is then weighed when dry. The soil moisture content can then be calculated and the gravimetric soil water calculated as a percentage.

SOIL BULK DENSITY
Soil Bulk Density is the apparent density of soil. The bulk density is expressed as the weight of the oven-dried soil per cubic centimetre of volume. The bulk density is useful in evaluating the pore space and density of the soil. The bulk density value can be used to generate the volumetric water content of the soil by multiplying the gravimetric water content by the bulk density.

VOLUMETRIC WATER CONTENT
Volumetric Water Content is the volume of water per known volume of soil. This is the water volume we relate to in terms of irrigation precipitation. The Volumetric water content of the soil is the gravimetric value multiplied by the bulk density.

SOIL AERATION
The process by which air in the soil is replenished by air from the atmosphere. In a well aerated soil, the soil air is similar in composition to the atmosphere above the ground. The rate of aeration is dependent on the change of the volume of water in the soil. It is important to ensure that the dynamics of water content movement in the soil are as large as possible. That is, the cycling of water content between field capacity and refill point will ensure good aeration of the soil.

SOIL TEXTURE
The coarseness or fineness of soil material as it affects the behaviour of a moist ball of soil when pressed between the thumb and forefinger. It is generally related to the proportion of soil particles of differing sizes (sand, silt clay and gravel) in a soil, but is also influenced by organic matter content, clay type and degree of structural development of the soil.

SOIL MOISTURE CHARACTERISTIC
The Graphical relationship between soil water content and soil water potential for a given

soil. It may vary widely, depending on the texture, structure and pore size distribution of the soil. The relationship is used to indicate the ease or difficulty of removing water from the soil at different soil water contents and can therefore be important in relation to soil structure and plant growth studies.

SOIL TEXTURE GROUP

A major category of soil texture as set out in the following table:

Texture Groups	***Texture Grades***
Sands	sand; loamy sand; clayey sand;
Sandy Loams	sandy loam; fine sandy loam; light sandy clay loam;
Loams	fine sandy loam; silt loam; sandy clay loam
Clay Loams	clay loam; silty clay loam; fine sandy clay loam;
Light Clays	sandy clay; silty clay; light clay; light medium clay;
Medium-Heavy Clays	medium clay; heavy clay.

Gopher®
PC PROGRAM VERSION 9.2

PROGRAM INSTALLATION

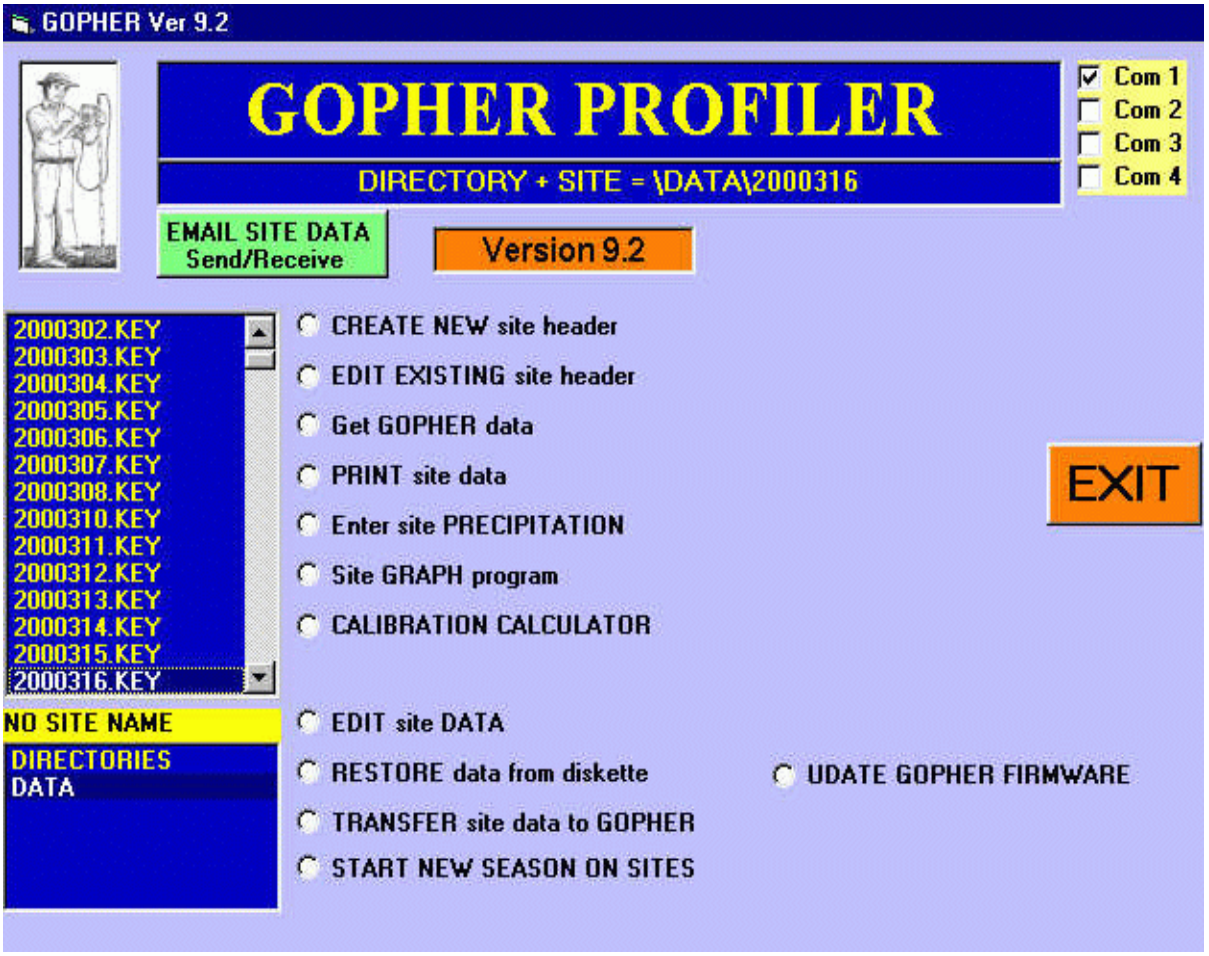
If you are re-installing either the same version or a new version from 3 disks then the previous version must be removed. To do this click on the START button from the Windows desk top then move the mouse pointer up to settings, then click on Control Panel. When the Control panel is loaded click on the ICON, ADD/REMOVE PROGRAMS. A list of programs will be displayed, scroll down until you find the GOPHER program. Click on this and then click on the button ADD/REMOVE. The current version of the Gopher program will now be removed. If this is not done the new version or re-installation will not be correct.

This removing of the program does not erase any data files in the Gopher program.

Click on start from the task bar in Windows, then click RUN. Type A:\SETUP in the command box and click on OK.
If the software is on a CD type the drive letter for your CD, then type :\Gopher9\SETUP in the command box and click on OK.
SETUP will start the installation in the default directory Gopher. It is recommended that you do not change the default directory from the default of **Program Files\ Gopher** as this will cause problems when data is being transferred from a previous version.

Insert each of the numbered disks when prompted if you are using diskettes.

To run the program click on the **Gopher** icon in the Programs menu.



MENU OPTIONS DETAILS

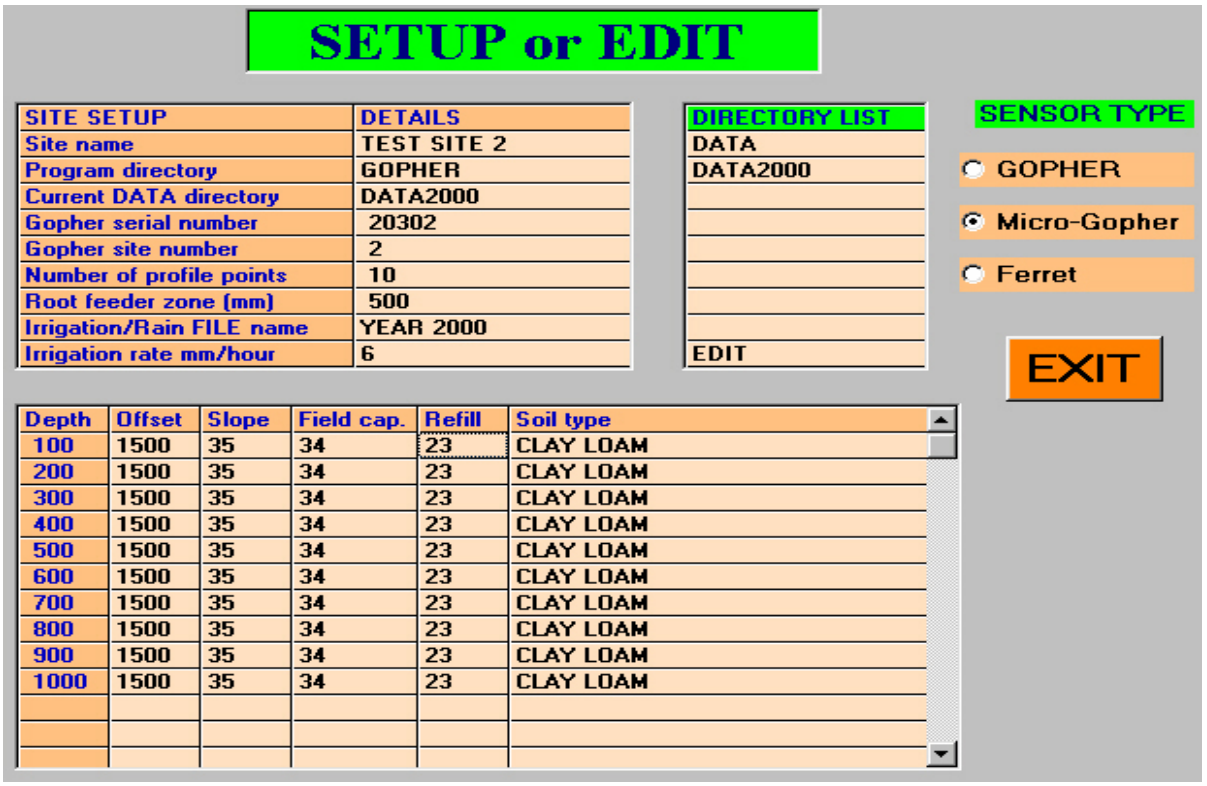
CREATE NEW site header

Each site has a site header. This header contains all the information relating to each site. This can be set up before a data is transferred from the **Gopher** or the program will set up a default header when the first data file is transferred to your PC. Some of the entries must be set up after the first block of data has been transferred from your **Gopher**.
A typical site is shown below. The top section of the data base has the following entries.

Site name	This is a descriptive name for the site
Program directory	Default GOPHER directory for GOPHER program
Current DATA directory	The data directory where data from this site is stored
Gopher serial number	The Gopher serial number
Gopher site number	The site number that is used in the Gopher
Number of profile points	Number of profile points in the recorded profile
Root feeder zone (mm)	Depth of the root zone of the plants being irrigated
Irrigation/Rain FILE name	Name of the file in which irrigation will be entered
Irrigation rate mm/hour	Precipitation rate for the irrigation system + rain

The Irrigation/Rain FILE name is the name of the file that is to be used to enter irrigation/rain and

growth rates for this site. This file can be shared between several or all of your sites. This will depend on whether the irrigation volumes and times are the same for each site. If they are not then a separate file name must be used for each irrigation area.



The lower data base is the calibration data that is contained in the data file from the **Gopher**. This data can be edited by clicking on a cell and then entering a new value. This should only be carried out if you have calibrated data from soil samples. Guessing at values to make graphs look better will produce meaningless data. The soil log that was recorded when the access tube was drilled must be entered in the right hand column.

On the top right is the directory data base. Data can be archived by changing the name of the directory that is to be used to save incoming data from the **Gopher**. If for example you change the directory name to DATA99. Click on the 'Current DATA directory' cell, then type the new directory name then key <Enter>. The directory name will appear in the data base list on the right side of the screen. Take care when typing directory names as they will be created on your hard disk when the program exits.

To delete a wrongly entered name before you exit the program, click on the EDIT cell then on the directory name to be deleted. Then click on the correct directory name before you exit this program.

DATA DIRECTORY SELECTION

The previous data in different directories can now be selected from any of the data display sections of the program. The directory selection is temporary and does not change the current directory that has been selected for data downloads. This will eliminate the possibility of accidentally overwriting a previous seasons data by downloading data from your Gopher into the wrong directory. The SITE

name is now also displayed above the directory list. To enable this feature all existing data files must be recalculated. There are two ways to do this the first is to load the data from your Gopher to your PC. This automatically causes a recalculation of existing data or you can enter the 'Edit existing site header' program. When the data is displayed click on any cell in the top left hand data block and then re-enter the existing value in the selected cell. Then click exit, this will cause the data to be recalculated if you click on YES to update the data files .

NOTE with either method the site name must have been entered in the second cell in the data block before the update is initiated.

WARNING. If you change the directory selection while in the EDIT EXISTING site header, remember to change the directory back to the current one before you input data from your Gopher. If you don't, the file in the selected directory will be overwritten by the data coming in from the Gopher. When a new directory name is added to a site the old data MUST always be backed up on diskette to guard against such a catastrophe. Do this before the new directory is created.

The EDIT EXISTING site header menu option displays previously saved data when entered as is shown in the above example.

Get GOPHER data

This option will retrieve data from any **Gopher** that is connected to the serial port of your computer. When the **Gopher** program is used to retrieve data from a **Gopher** for the first time you will be asked to nominate the serial port that is to be used for data transfer.

The display will show 48 check boxes. Click on the sites you wish to download then click on the box under the check boxes to start the data retrieval process. You will first be prompted to indicate if you want to write over any existing data that may exist. This is a blanket **yes** to overwriting all existing data files. If you select NO you will be prompted at the end of each file transfer to write over an existing data file if it exists. If the site does not exist you will be prompted to enter the directory where the data will be saved.

If the data file is a timed recording and a file already exists for that site, you will be prompted to add on to the existing file or overwrite the existing data. Click on the required button. Normally you will add on if the data is from the same monitoring session.

When the data transfer is completed, remove the serial cable from the **Gopher**. **THIS IS IMPORTANT.** If this is not done the batteries will be flattened prematurely.

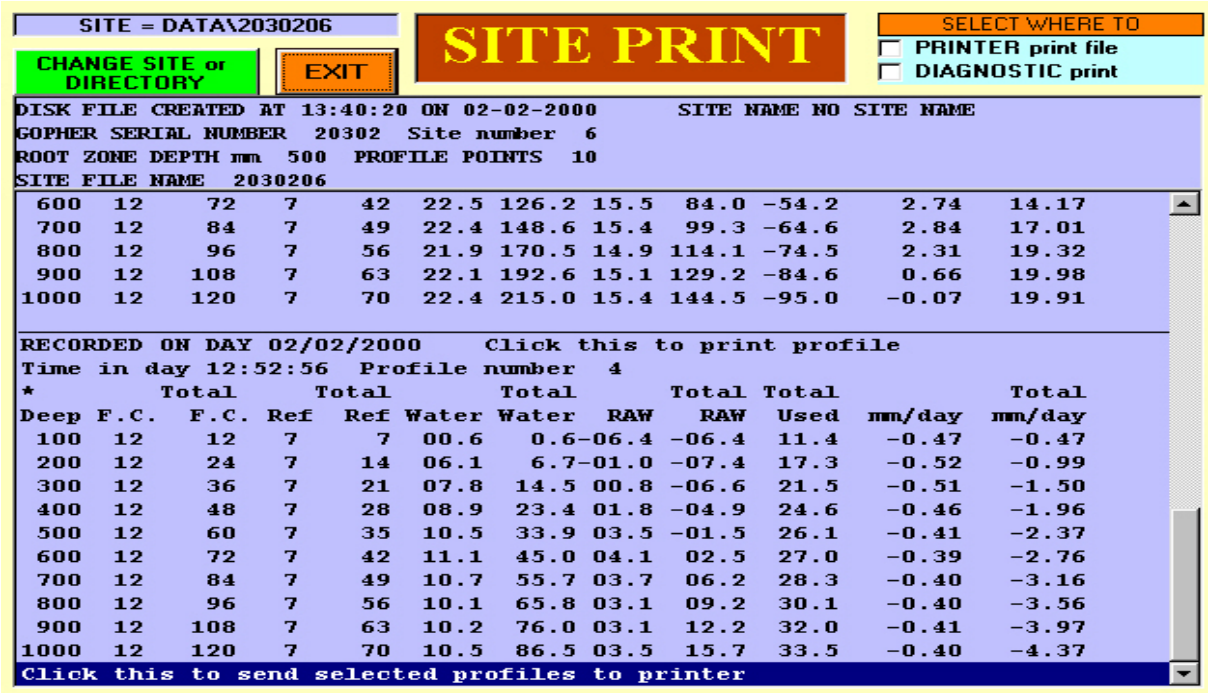
BAD DATA DETECTION

The program now checks the incoming data from the Gopher. If a bad value has been recorded due to water in the sensor head, sensor failure or the wrong number of profile points has been entered during re-calibration, the program will now display a warning message and assign a zero moisture value to that bad or missing profile point.

PRINT SITE DATA

The site print program allows printing of site data to the screen or printer. A diagnostic printout is

also available. This is used when raw data is requested for problem solving by Soil Moisture Technology.
The site selected is shown on the top left side of the screen. This can be changed by clicking on



SELECT SITE. A site list will be displayed. To select a site, point with the mouse and click on the required site.

If a hard copy is to be sent to the printer, click on the PRINTER check button under WHERE TO on the right side of the screen.
To scroll through the data on the screen, drag the scroll bar on the right hand side of the display or click on the UP or DOWN arrows at either end of the scroll bar.

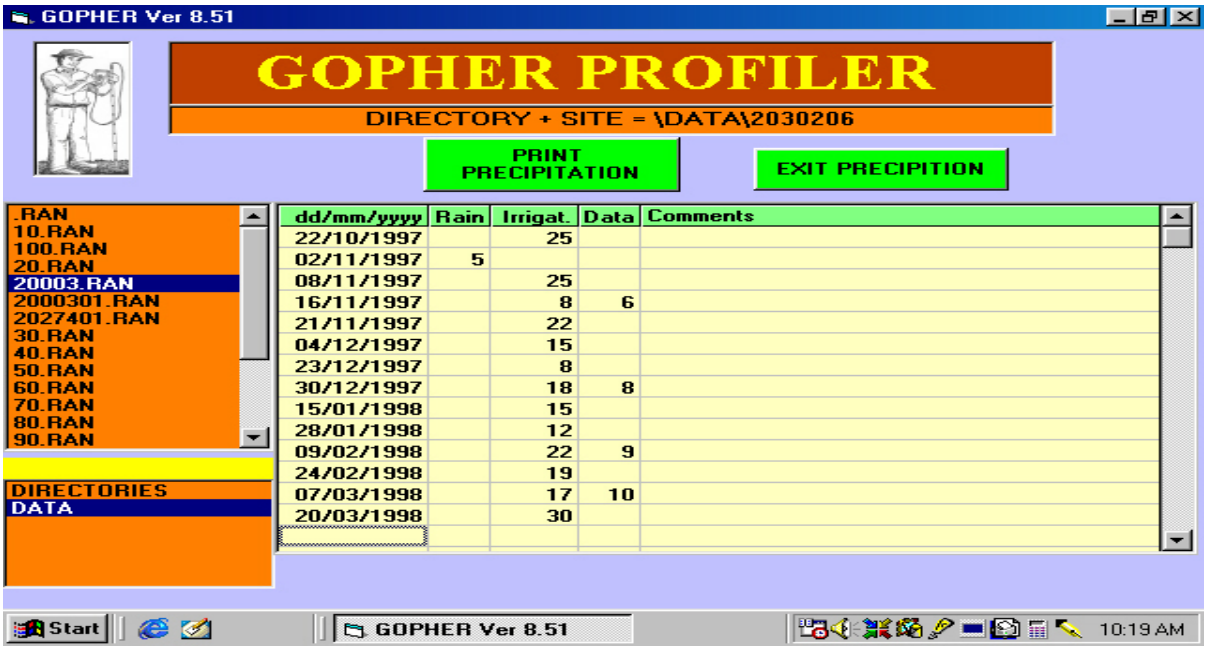
If you only require to print selected profiles to your printer, click on the first line at the head of the profile where the message 'Click this to print profile' is printed. When you have selected all the profiles you wish to print then scroll to the last line and click on 'Click this to send selected profiles to printer.'

The data in the display shows all the information that has been retrieved from the **Gopher**. The last two columns show the water use per day. If two profiles are recorded with only a short interval between them and the soil moisture increases as a result of an irrigation then the water use figures will be enormous. The program calculates the water use per day so that is the profiles are 2 hours apart and the soil moisture increases by say 10mm then the water use per day will be calculated as 24/2 * 10 = 120mm per day. The example in the video tape is even larger than this.

The water use data shows how much water is being used per day at each point in the measured profile. This gives a very detailed picture of the water use at each level in the soil. The water use figures will decrease as the available water in the soil decreases and the plant has to work harder to extract the moisture from the soil.
Click on EXIT to return to the main menu.

ENTER SITE PRECIPITATION

The precipitation data base has provision for four data entries. The date of the event, irrigation water



volumes, rainfall events and a physical measurement such as fruit size. These are graphed in the summed Histograph for that site.

Click on the first next empty cell. Enter the date in the format shown in the cell header then the irrigation /rainfall or measurement parameters.
The Precipitation data base now also includes a comment column. This allows entry of weather conditions and notes regarding the current irrigation or crop condition. Provision has also been added to allow the data base to be printed out. The print out also includes a monthly tally of rainfall and irrigation volumes as well as total values for rainfall and irrigation volumes for the entire data base. When a precipitation data base is opened for the first time with the new program, there may be some rubbish printed in the comments fields. To remove these simply click on the cell and then depress the space bar on your key board. This will remove the unwanted text from the screen and the file when you exit the program.

SITE GRAPH PROGRAM

The site graph program now has a manual scale feature. This enable the vertical scale to be held constant. If this feature is turned off or on for a site then this is remembered, so that when this site is selected again it will be turned off or on depending on the mode last selected.

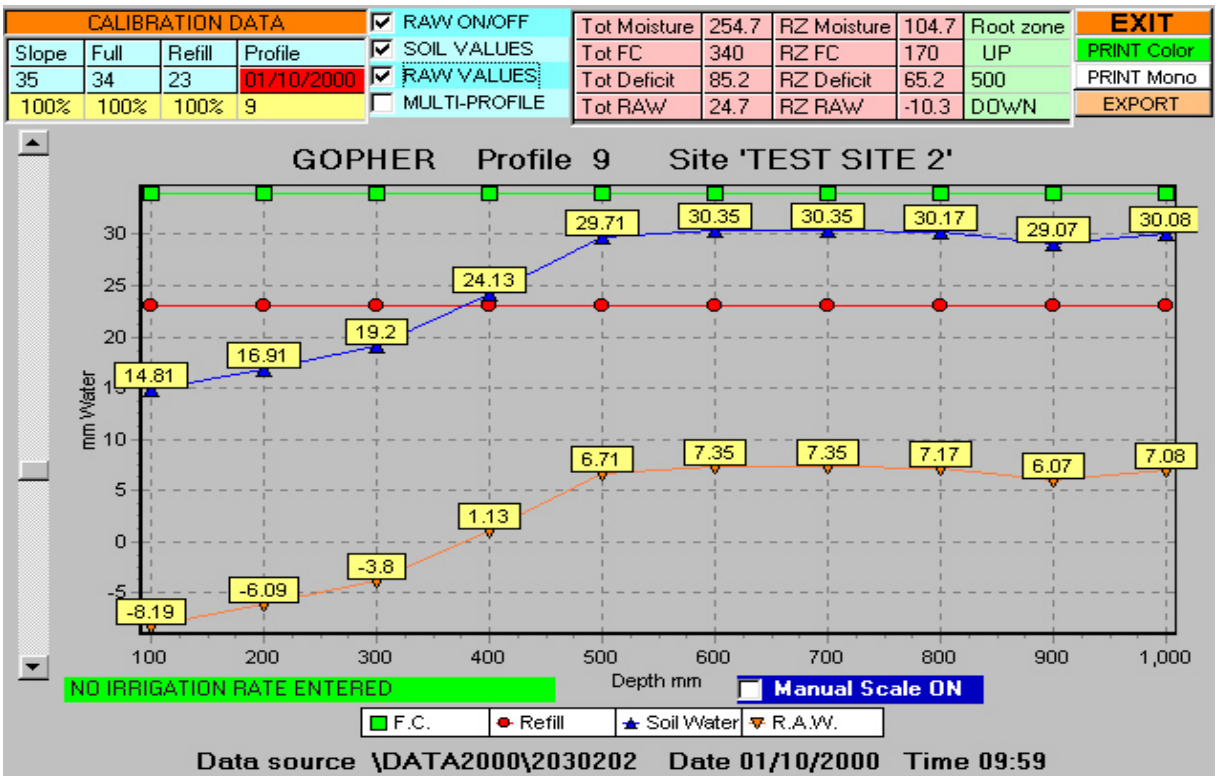
SITE PROFILE FOR A SELECTED SITE

The graph page contains the following information.
The abbreviation (RZ) used in the tables is for Root Zone.

(a) Soil moisture levels over the entire profile depth and root zone depth.
(a) Field Capacity values that were entered in the **Gopher**.
(b) Refill soil moisture values that were entered in the **Gopher**.
(c) Water Deficit. The amount of water that has been used by the plants or lost through evaporation. The deficit for the entire profile and the root zone. The root zone deficit

is the volume of water that must be added to the soil to bring the root zone profile up to field capacity.

(d) Readily Available Water (RAW) for the entire profile and also the root zone.



The calculation for the root zone soil moisture can be changed by clicking on the root zone depth UP or DOWN cells.

Four check boxes in the centre of the page allow for the following to be turned on or off.

RAW ON/OFF	This turns on or off the trace on the graph for the readily available water.
SOIL VALUES	Displays the actual water volume values for each profile point in the graph.
RAW VALUES	Displays the actual water volume values for each point in the profile.
MULTI-PROFILE	Allows selection of up to six(6) profiles to be displayed on the one graph. This gives visual comparison of profiles for WATER USE evaluation. If you click the check box it will return to the profile graph. If the wrong graph is accidentally selected, click on this graph in the list of selected graphs and it will be removed from the list.

The grid display on the left side of the screen is used to change the site calibration parameters or scroll through all the recorded profiles. The display shows the Slope, Full(Field Capacity) and Refill points. The values can be changed on the graph by clicking on the column you want to change and then drag the slider on the left of the graph to increase or decrease the value. The percentage change is shown under the actual value.

When a soil profile has different soil textures over the depth of the access tube. It is probable that the field capacity values will also be different over the depth of the access tube. If this difference is large

enough to cause errors in the recorded soil moisture data then the calibration can be edited while the PROFILE graph is displayed.

POINT EDITING

The Gopher profile graphing software in version 9.0 has a point editing program that can be used when the soil moisture PROFILE graph is displayed. The program now provides the facilities to change individual soil moisture calibration, field capacity or refill values on the graph as well as the simultaneous changing of all points for the profile that is displayed.

To change a single point on the graph, click the left mouse button while the pointer is over the marker on the graph line. The selected function will change to red on the grid at the top left of the screen an EDIT marker will also become visible at the left side of the graph displaying the edit depth of the selected point.

To change the selected point on the graph, either key the new value from the keyboard and then key <ENTER> or Click on the buttons on the slider bar at the left of the graph. The top button will increase the value and the bottom button will decrease the value. The slider can also be used to make large changes to the value by dragging the slider button with the mouse pointer while holding down the left mouse button.

When you exit the profile graph you will be prompted to save the changes. If points and overall value were changed you will be prompted twice. The first will be for the points changed and the second for the when all points in a profile were changed.

Individual calibration points can also be changed by entering the program EDIT EXISTING site header function from the main menu. Values that you wish to change are typed into the cell for that function and depth in the profile. When exiting the edit program you will be prompted to save or abandon the changes made. Any changes you have made must be transferred back to the Gopher recorder. If you do not do this the changes will be overwritten the next time you down load data to your Computer.

It is extremely important that the first soil moisture profile measured after the access tube has been installed does reflect the soil moisture and textural changes that were logged when the access tube hole was drilled. Changing the calibration to rectify a poor installation will cause serious errors with soil moisture calculations as the measurements produced will not accurately represent the actual soil moisture values.

The fourth column in this grid is the profile that is currently displayed. When the profile graph is entered the last recorded graph will be the one that is displayed. To change the profile that is displayed click on the column, then drag the slider or click on the UP DOWN arrows. The selected profile will be displayed.

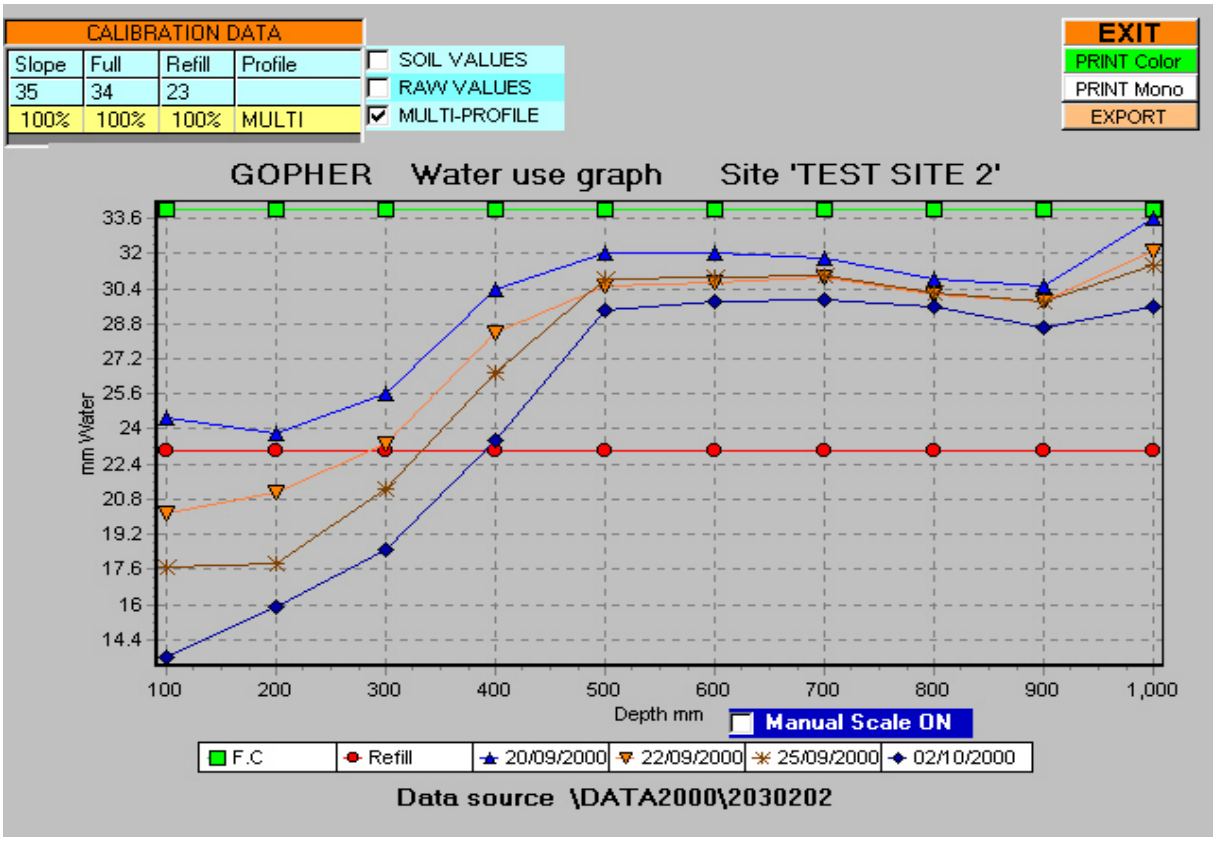
The irrigation time that has been calculated from the irrigation rate in the Irrigation data base will be displayed at the bottom left of the graph. This box also shows the total water volume that will be applied during the irrigation cycle.

To print a graph in either color or black and white click on PRINT Color or PRINT Mono. The program also allows exporting of files to disk. Click on EXPORT. The graph will be saved as a bit map (.BMP) file in the same directory as the data. The file name will have an extra digit as a suffix.

Profile graphs will have a 2 added to the file number, 3D graphs will have 3 added, Histograph slices will have 4 added, multi profile water use graphs will have a 5 added, summed Histographs will have 6 added and timed graphs will have 7 added. Site 2000309 profile graph will be saved as 20003092.BMP.

GRAPH BIT MAP FORMAT

When graphs are saved to a bit map file on disk they can now be in either color (default) or monochrome. The selection of monochrome makes the file much smaller and also prints better on

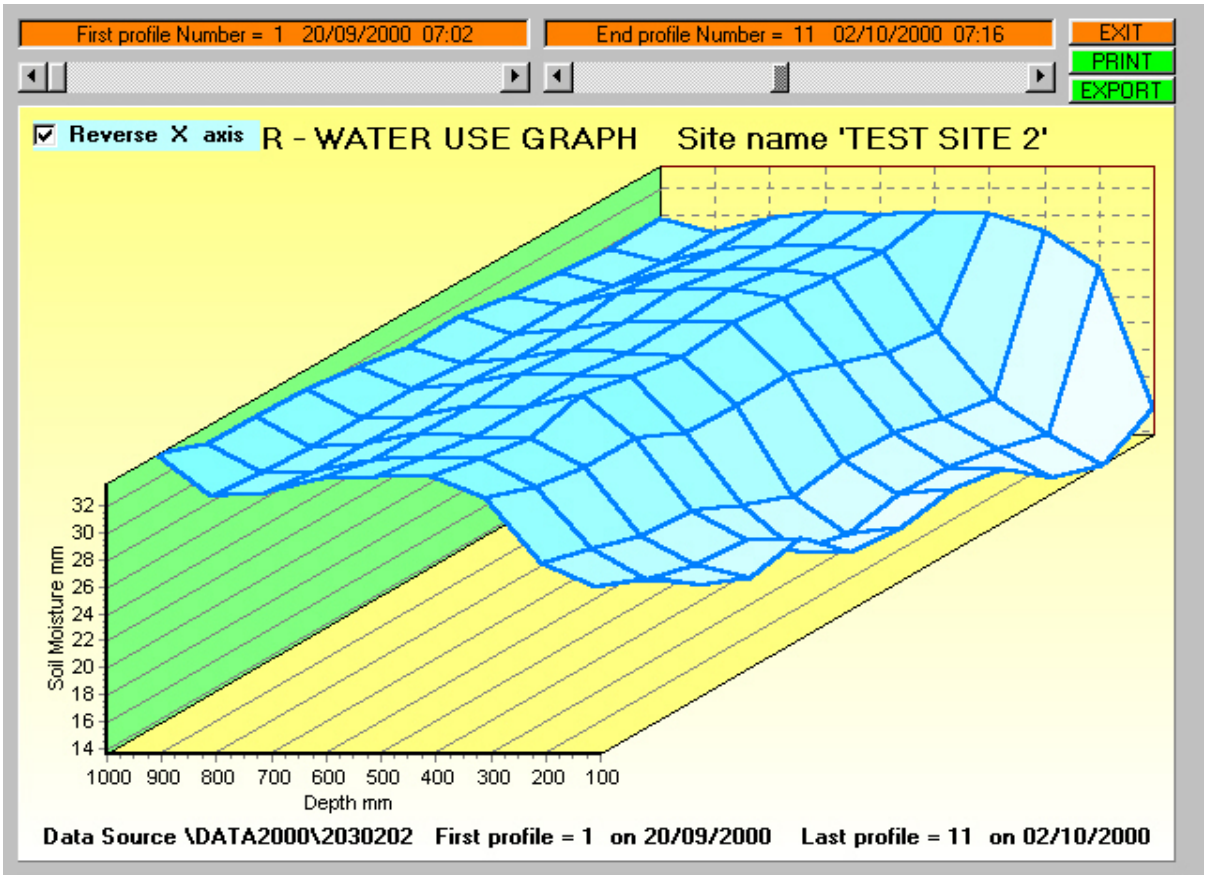


some monochrome printers.

MULTI-PROFILE WATER USE

The multi profile graph allows direct comparison of water use between different profiles for the same site. This gives a visual indication of the depth of water use and how much water is being used by your plants at each profile point.

SITE PROFILE 3D



This is a three dimensional representation of all profiles for a site, a pictorial view of the soil moisture movement in the soil.

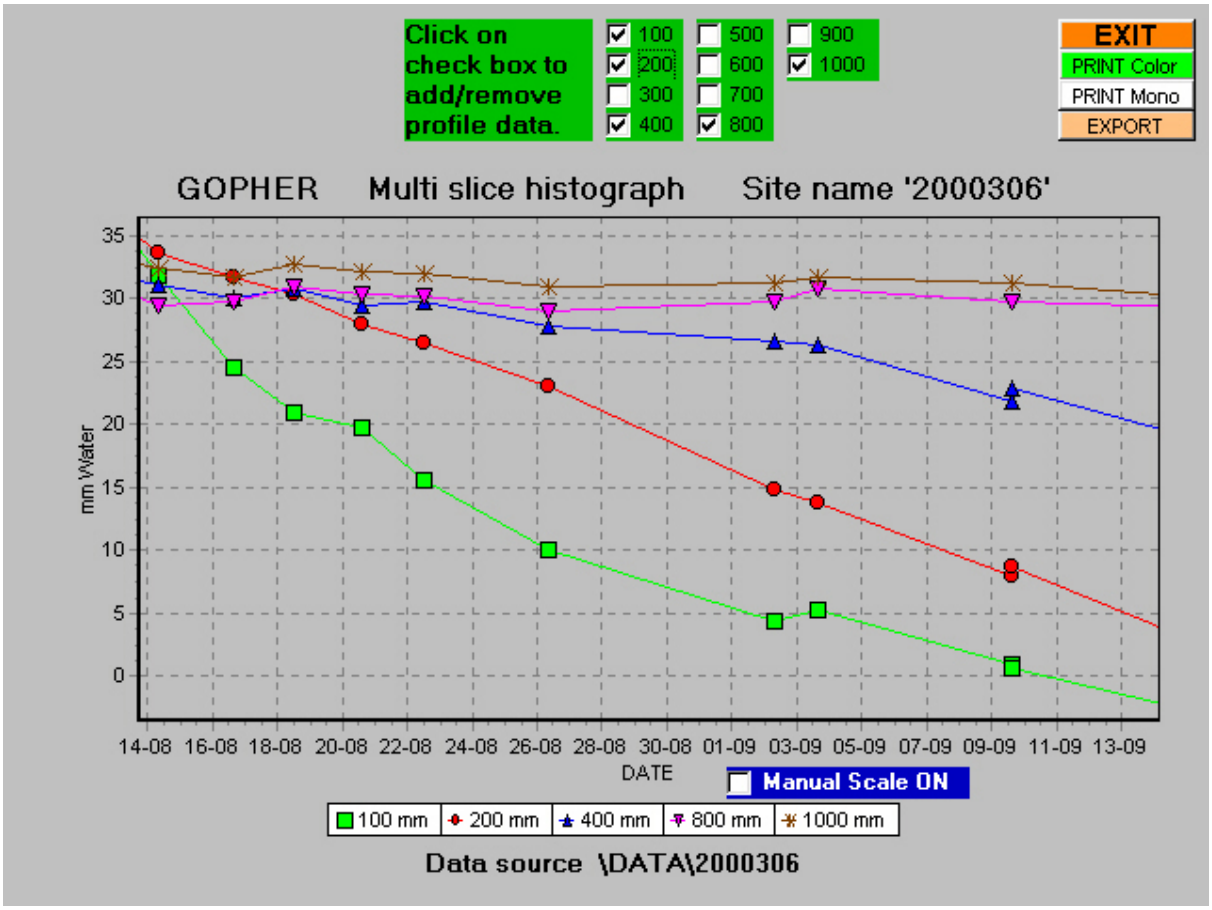
The start and end profile number can be changed by dragging the sliders at the top of the graph. The profile numbers and dates will be displayed in the text boxes above the sliders. The soil depth direction can be reversed by clicking on the check box at the top left of the graph.

The history of the dynamics of soil water movement is easy to see with this graph form. The site depth is plotted on the X-Axis, soil moisture on the Y-Axis and profile number on the Z-Axis. The Z-Axis is linear with profile number not profile date. The printing and exporting is the same as the profile graph.

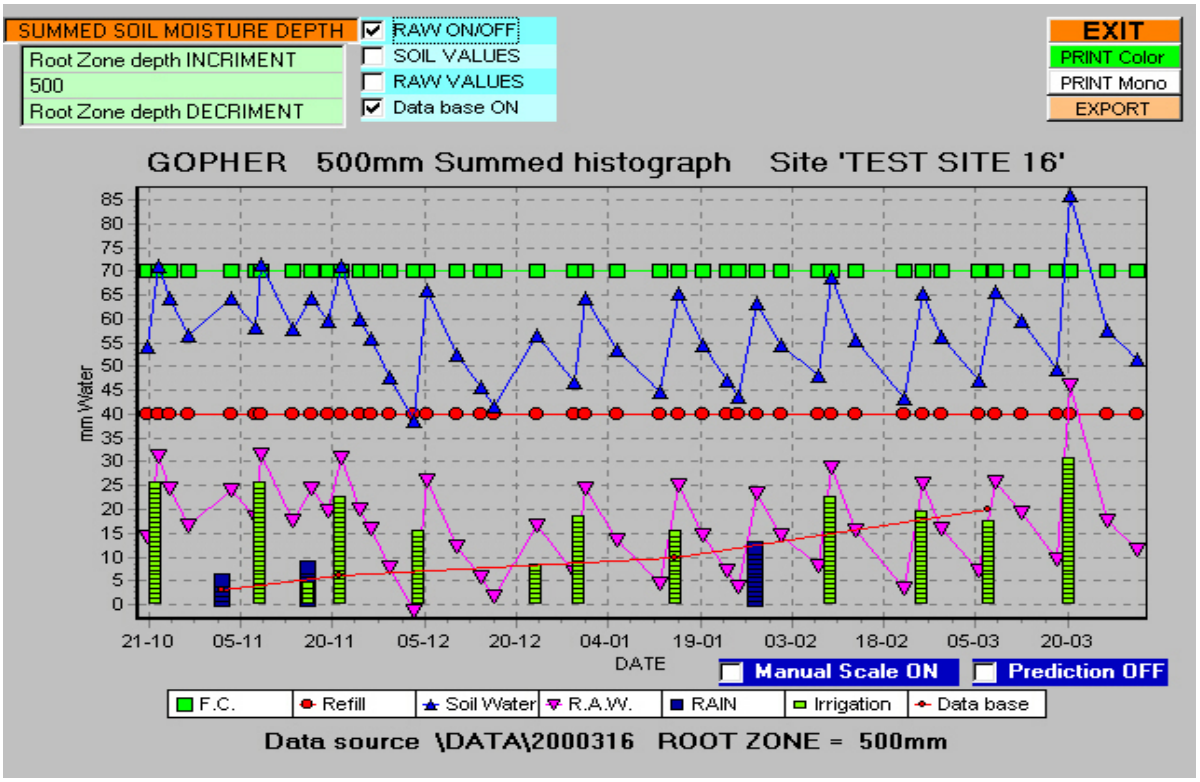
MULTI DEPTH HISTOGRAPH SLICE

This graph displays a slice at the selected depth for all the site profiles for a selected site. The graph when first displayed has the 100mm check box turned on. Other depths can be turned on or off simply by clicking on the check boxes. The last selected depths are remembered for each site, so that when the site is next selected the last combinations of slices will be displayed.

The water use and amount of water recharge at different depths in the soil profile can be seen from this graph.



SUMMED HISTOGRAPH



This graph displays the sum of the profile points down to the nominated root zone for all the profiles for a selected site. The depth of the
summed soil moisture can be changed by clicking on the 'Root Zone depth INCREMENT' or Root Zone depth DECREMENT'.

The RAW trace can be turned ON or OFF by clicking on the RAW ON/OFF check box. Actual soil moisture and RAW values can be displayed on the graph by clicking on the SOIL VALUES or RAW VALUES check boxes.

The summed Histograph can also display the data base information for irrigation, rain and size measurements that have been entered in the Precipitation file for this site. Click on the data base ON check box.

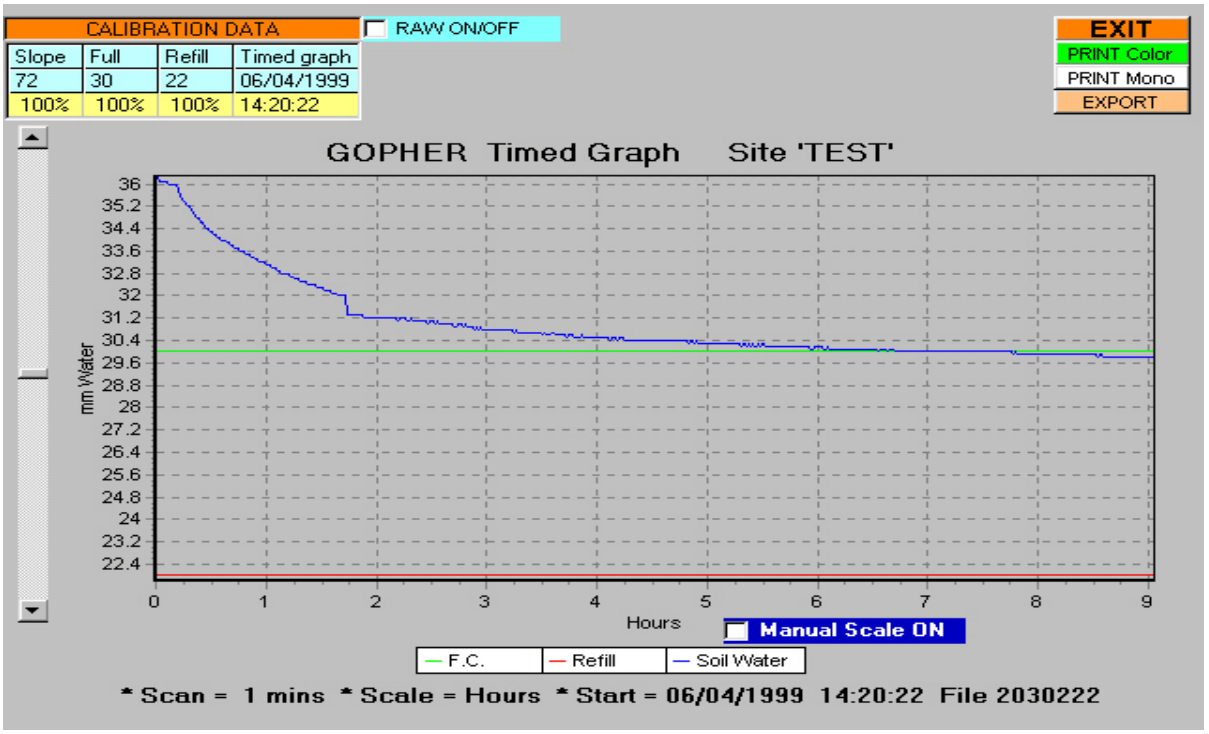
If the last recorded profiles are of decreasing value, then the program will extend the soil moisture profile line as a prediction for the next irrigation date. This line will be shown in RED on the graph.

All the graphs in version 8 also have a feature which allows the user to zoom into a specific area of the graph and then to scroll the magnified graph. To zoom into a specific area on the graph, place the mouse cursor at the **top left hand** position that is to be the start of the magnified zone. Depress the left mouse button and drag the mouse cursor until the displayed rectangle covers the area you wish to magnify. Release the mouse button. The program will now zoom into the area in the rectangle. You can also scroll through the entire magnified graph by holding down the right mouse button dragging the displayed image in the direction required. To revert to the normal graph display hold down the left mouse button and create a rectangle to the left of the starting point. The graph

will now return to the original form when the mouse button is released.

TIMED RECORDING GRAPH

Select a timed recording site and then click on Option 5 for display of the timed recording graph. Note: If a site is selected that is not a timed recording, a message box will appear to inform you that the site you have selected is not a timed recording.



Timed recording can be used to provide detailed recording of water use against time. The graph illustrated was used to measure the field capacity of the soil when drainage had ceased. Water use, recharge rates and wetting fronts can be measured and viewed with this graphing mode.

CONCATENATION

Data that has been archived at the end of an irrigation season can be retrieved and concatenated into a single file. That file will have a file name with an 8 as the most significant digit. Remember to select the files in chronological order. Each file will have the same file name but it will be located in a different directory.

First select the directory from the directory list box where the oldest data exists. Then select the site from the site file list box. Select the next directory where the current data exists. Then select the site name again from the site file list box. Click the DONE box when finished.

For example Directory DATA97, file 2000309
Directory DATA98, file 2000309
Directory DATA99, file 2000309

The concatenated file is only a temporary creation of a composite file. When the graphing program exits the file will be removed.

If the time span of the concatenated data is too great the graphs will be hard to read. If this is the case it would be better to print out each of the graphs required and paste them together.

NOTE
Sample data is included on the distribution disk. The site name is 2000316. This will be set up as the selected site when the software is run for the first time.

CALIBRATION CALCULATION

The use of this calculator is cover in a previous section of this handbook.

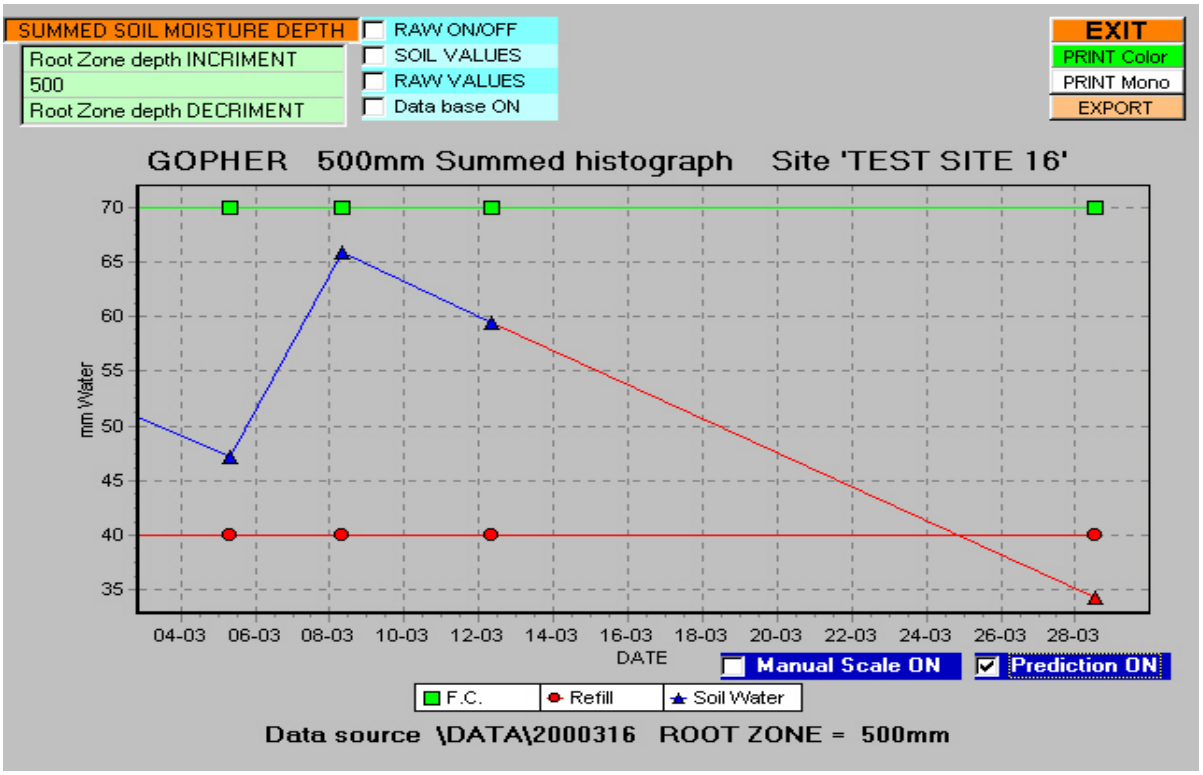
SITE ERASURE

A new method for site erasure has now been included in the program. If you want to delete a site this method ensures that all data from all site directories is removed from your hard disk.

Before deleting a site it is recommended that you back up the data on a diskette, in case some time in the future you want to re-install the data that you are going to erase from your hard drive. First select the site by positioning the mouse pointer over the site in the site file box, click the left mouse button to select the site, the selected site will now be highlighted. Now click the right mouse button while the mouse pointer is over the selected site. A message box will ask you to confirm that you wish to remove the site. If you click on the yes button in response to both prompts then the site will be completely erased.

WHEN DO WE WATER

The decision as to when to water must be based on the interpretation of the soil moisture data recorded with the **Gopher**. As described in the summed Histograph program, the PC program now extrapolates the summed data graph. If the moisture level is decreasing it will project a RED line that



will cross the Refill line at the expected irrigation date.

This date is based on the SUMMED values over the selected root zone depth. The data from the summed Histograph should never be used as the sole determining factor in setting the next irrigation date.

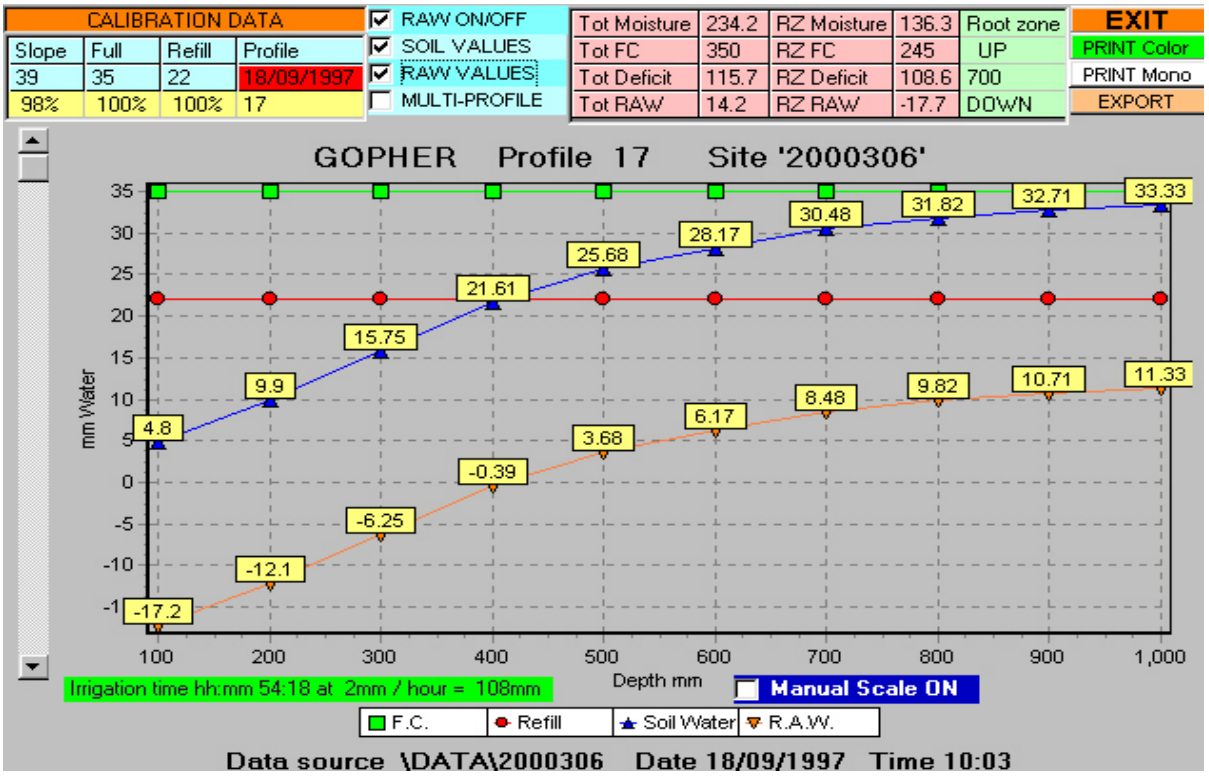
Variations of soil moisture at individual depths of the summed Histograph depth can produce a result that does not indicate the need to water. However, examination of the soil moisture profile may tell a different story.

The soil moisture values in this graph show that there is no READILY AVAILABLE WATER ABOVE 400mm, even though the available soil moisture over the entire root zone is 136.3mm.

The summed Histograph for this site predicts watering is required in two weeks. The soil moisture profile graph displayed above shows that the soil moisture values at 100, 200, 300 and 400mm are below refill. If the summed Histograph is used to predict irrigation without reference to the actual profile, serious damage could be caused to the plants - particularly young plants were the root system is predominately in the first few hundred millimetres.

By carefully observing the actual current soil moisture profile and the summed histograph, an intelligent decision can be made as to when irrigation is required by you plants.

In hot dry conditions it is often wise to irrigate for a short time, often. This ensures that the top soil always has enough water for the plants, but does not waste water as the depth of water penetration would only be in the first few 100 millimetres.



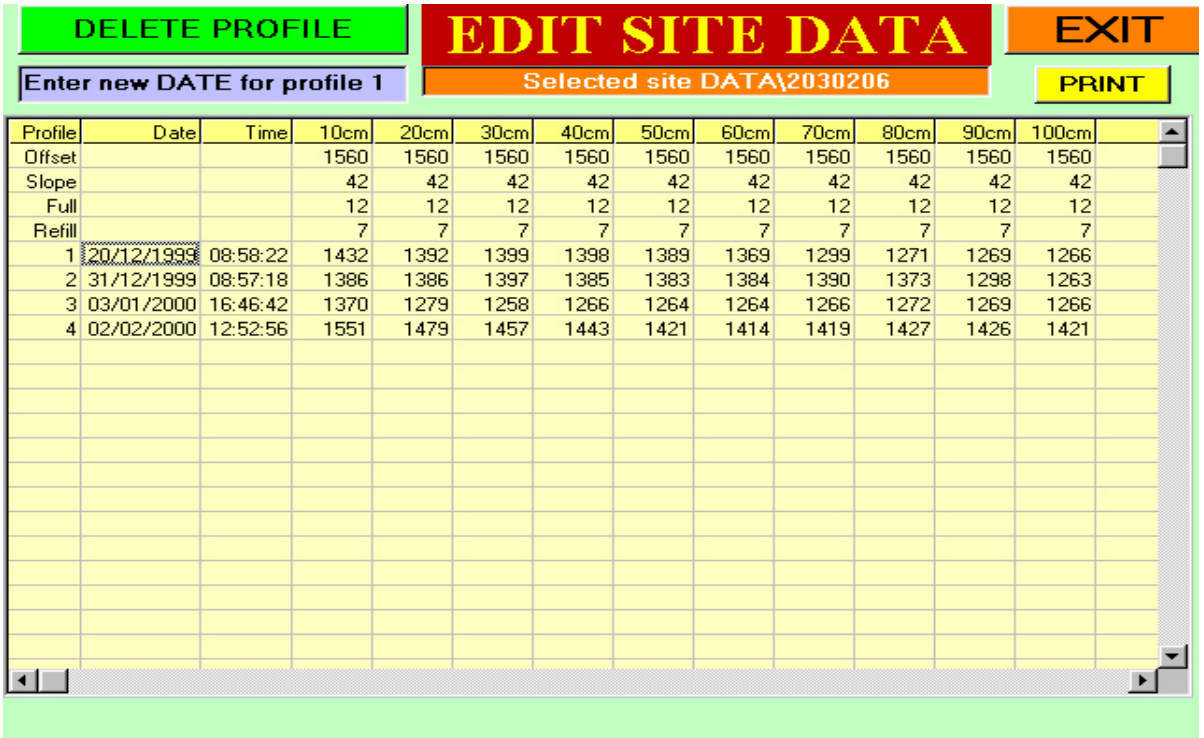
Gopher AUXILIARY PROGRAMS

Five menu items in the main menu have been separated from the normal menu items.

EDIT site DATA
RESTORE data from diskette
UPDATE site data in GOPHER
START NEW SEASON FOR SITES UPDATE GOPHER firmware

EDIT site DATA

The editing of site calibration, recording dates, times and data values has now been modified to provide a quicker and easier method of data editing. The entire site data is now displayed in a single spread sheet. Site calibration, dates, times and data points can be edited by clicking on the cell containing the data that you want to change and then typing in the new value. A message box just above the top left hand corner of the grid will display a prompt as to the cell and data type that is to be edited. The date and time format must be the same as is displayed on the screen. Each entry that is edited will change color as a visual indicator as to the entries that have been edited.



Profile	Date	Time	10cm	20cm	30cm	40cm	50cm	60cm	70cm	80cm	90cm	100cm
Offset			1560	1560	1560	1560	1560	1560	1560	1560	1560	1560
Slope			42	42	42	42	42	42	42	42	42	42
Full			12	12	12	12	12	12	12	12	12	12
Refill			7	7	7	7	7	7	7	7	7	7
1	20/12/1999	08:58:22	1432	1392	1399	1398	1389	1369	1299	1271	1269	1266
2	31/12/1999	08:57:18	1386	1386	1397	1385	1383	1384	1390	1373	1298	1263
3	03/01/2000	16:46:42	1370	1279	1258	1266	1264	1264	1266	1272	1269	1266
4	02/02/2000	12:52:56	1551	1479	1457	1443	1421	1414	1419	1427	1426	1421

A profile recording can be deleted by clicking the mouse pointer on the profile number in the left most column. A prompt will be displayed requesting that the DELETE button at the top left hand corner of the display be clicked to start the deletion process. After the DELETE button has been clicked the prompt will ask you to click it a second time. This second action will prevent accidental

erasing of a profile. The profile data will then be deleted and a red bar will appear instead of the profile data.

The data from the entire site can also be printed on your printer by clicking on the PRINT button at the top right of the desktop.

To exit the edit program and update the data file, click on the EXIT button. You will then be prompted to update the file or abort the changes. If you click YES then the changes will be written to the data file. To make the changes permanent the modified data must now be transferred back to your Gopher. If the data is not sent back to the Gopher, the next time you load data from the Gopher the edit changes you have made will be overwritten.

UPDATE GOPHER firmware

This program is used to up-Date the firmware program in your Gopher. This allow customers to keep up top date with new improvements in the Gopher program. A NEW addition to the Gopher program allows you to calibrate using a percentage calibration value for Full and Refill.

RESTORE data from diskette

This option allows backed up data to be restored back to your computer. This may be necessary if a site data file has become damaged on you computer.

The program also allows you to copy other users Gopher data on to your computer. Simply insert the disk and follow the prompts on the screen.

UPDATE site data in GOPHER

Data that has been edited in your computer must be transferred back to your Gopher. If this is not done then the next time you load data from your Gopher to your Computer the edit changes you have made will be over written. That is the data will revert back to the original values before you carried out the editing.

The site data transfer now allows for multiple site transfers at the one time. This speed up the operation of editing data and transferring the files back to your Gopher. You simply click on the site numbers that you have edited and want to transfer back to your Gopher.

START NEW SEASON ON SITES

The process of archiving the current seasons data and starting the new season in your Gopher has now been included in the Computer program. The sites to wish to re-start for the next season are simply selected from the check boxes displayed and then a new directory name is entered in each site before the sites in the Gopher are erased. A default directory name is offered, this name includes the current month and year so that the directories can be identified in the future by the date that is appended to the directory name. If you want to change the directory name simply key in a name of your choice when the directory set up is displayed.

The current calibration data is transferred back to the Gopher ready for the first recording in the new season.

REPLACEMENT SENSOR

If your sensor is damaged beyond repair, then the new sensor will have a different OFFSET. This is the value that the sensor reads in completely dry soil.

To use the NEW sensor you must start a NEW SEASON, because the new offset value cannot be changed in the same profile recordings that have been recorded with the old sensor.

Click on START NEW SEASON ON SITES. After selecting all the current sites you are using. Click on the check box ENTER NEW SENSOR OFFSET VALUE. The display will prompt you to enter the new offset value that is marked on the sensor. You will also be prompted to verify that the number you have entered is correct.

COMPUTER DATA BACKUP and RESTORE

With the increasing popularity of storage systems other than the 3.5" diskette the PC program now allows selection of a different drive for backup and restoration of data files, other than the standard default of <a:> drive. This allows the use of high density magnetic disks, external hard drives or CD's.

Each time you exit the **Gopher** program you are asked if you want to backup your data. Data backup asks for the directory that is to be backed up.

It is essential that you use a separate disk for each directory that you are backing up. This will avoid confusion in the future if the data has to be restored to your hard disk. Make sure each disk is labelled accurately. Include the date and time of backup on the label and any notations that will help to simplify the identification of the data at a later date.

Version 9.0 writes the .KEY file to the root directory of the backup disk. Data files are copied to a directory with the same name as the source. This will make it easier to copy files from one computer to another.

The precipitation data base files can also be backed up to a diskette. When the program prompts if you wish to backup these files click YES or NO if you do not want to backup at this time. If you select YES it is advisable to use a separate disk for this backup. This will avoid possible confusion and keeps all the precipitation data base files together.

To restore data back into your computer, if the data on your hard disk becomes corrupt, simply select the RESTORE option from the main menu.

To copy backup data files from another computer to you computer, simply place the back up disk in your computer and select the RESTORE option from the MAIN MENU. The program will create the directory name that was used in the original computer, if it does not exist on your computer. The program will then copy the files into this directory.

Gopher™

Soil Moisture Profiling System

Date of Purchase .....
Head Serial No .....
Gopher recorder Serial No .....

WARRANTY CONDITIONS

1. This warranty is not transferable and protects only the original purchaser of the **Gopher or Micro-Gopher** Soil Moisture Profiling System.

2. The Company shall be under no obligation in any case in which:
   (a) The defect or the condition of the **Gopher** or any part thereof is due in any way to undue wear and tear, misuse, incorrect installation or operation, neglect, accident or other similar cause including water ingress.
   (b) The **Gopher** has been altered or repaired by a person other than Soil Moisture Technology Pty Ltd.
   (c) The serial numbers or warranty void seal have been altered, defaced or removed.

3. The Company will not in any event be liable for any consequential loss or damage whatsoever, direct or indirect.

Soil Moisture Technology Pty Ltd (hereinafter called the Company) warrants this **Gopher** Soil Moisture Profiling System for one year against original factory imperfections in material and workmanship. Such service as may be necessary as a result of accident or abuse is not included. The one year warranty covers all parts and labour that may become faulty as a result of manufacturing imperfection. Casings, cables or plugs that are damaged, broken or lost as a result of mis-use, neglect, wear and tear or general usage are not covered under this warranty. The **Gopher** must be returned to Soil Moisture Technology for repair.

WARRANTY SERVICE ARRANGEMENTS

Should any defect in the **Gopher** become apparent within the period of the warranty, the purchaser should immediately contact the Company. Transportation and freight costs involved in the sending the **Gopher** to the Manufacturer is the responsibility of the purchaser. Return freight charges are the responsibility of Soil Moisture Technology Pty Ltd.

SOIL MOISTURE TECHNOLOGY Pty Ltd
PO Box 93
COOROY, Qld, AUSTRALIA, 4563

Phone 07 5442 5833 Fax 07 5442 6913
Email odysseydataflow@optusnet.com.au
Web Site www.soilmoisture.com.au