# Chapter 4. Field Measurements

## 4.1 Field Measurement of Soil Hydraulic Properties

Field measurements of soil hydraulic properties were carried out for two years. During the first year (2002-03), the objective of field measurements was to measure the major soil types of the region to describe trends and variability of soil hydraulic properties in the region. The field measurements were carried out at three soil depths on 22 soil types across 50 sites (Table 4.1).

During the second year (2003-04), the objective of field measurements was to measure soil hydraulic properties of those soil types which could not be measured during the first year due to the dry season, to verify measured soil hydraulic property data of the first year for a few major soil types, and to measure variability of soil hydraulic properties within a paddock or farm. The field measurements were carried out at two soil depths across 29 sites (Table 4.1).

**Table 4.1 Sampling Sites**

| Year | Number of Sampling Sites | | | | | | Total Sampling Sites |
|---|---|---|---|---|---|---|---|
| | Soil Group | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| 2002-03 | 7 | 12 | 14 | 8 | 4 | 5 | 50 |
| 2003-04 | 4 | 7 | 10 | 3 | 2 | 3 | 29 |
| Total | 11 | 19 | 24 | 11 | 6 | 8 | 79 |

## 4.2 Field Measurement during 2002-03

Field measurements included site history (questionnaire), measurement of soil profile, measurement of saturated hydraulic conductivity at three depths, measurement of final infiltration rate and soil sampling for laboratory analysis.

### 4.2.1 Selection of Sampling Points

An initial visit was made to the property to select locations for measurement, explain to landowners about the project's aims and fieldwork to be undertaken, and obtain permission for conducting field measurement. A brief questionnaire on the history of the selected paddock was completed, and a suitable time for the field measurement was arranged based on the irrigation schedule. Two to four measurement points were identified in the paddock, soil profile was determined using a soil core tube, and GPS readings were taken to identify sampling points.

### 4.2.2 Soil Profile

The soil profile was observed from a soil core taken by a 2.5 cm diameter core tube to a depth of 60 cm (Photo 4.1). The Horizons A, B1, B2 were identified by the change in soil colour, soil texture and depths mentioned in the literature (Skene and Poutsma, 1962;

Skene, 1963; Skene and Harford, 1964; Johnston, 1952). Depth of Horizons A and B1 was measured at sampling points in a paddock.

**Photo 4.1 Identification and Measurement of Soil Horizons using Core Tube**

### 4.2.3 Saturated Hydraulic Conductivity

Field measurement of saturated hydraulic conductivity was conducted at three soil depths across 50 sites typically 4 to 5 days after irrigation. At each sampling site, field measurements were conducted at top of Horizon A (soil surface), top of Horizon B1 and top of Horizon B2, in 50 cm x 75 cm soil pit as shown in Figure 4.1.

Disc permeameters of 20 cm base diameter were used for the measurement of hydraulic conductivity. The site was levelled and cleaned of grass and debris. A ring (20 cm in diameter and 5 mm thickness) was placed on the levelled surface, and the area within the ring was filled with fine sifted sand to prepare a 5 mm thick leveled sand bed. The sand layer was to ensure good contact between the base of the disc permeameter and the soil below.

A permeameter filled with water was placed on the sand bed and small soil water potential of -30 mm was applied (Photo 4.2). After four consecutive readings of steady infiltrate rate, water pressure was changed to -20 mm. Similar processes were followed for -10 and 0 mm.

**Photo 4.2 Field Measurement of Hydraulic Conductivity**

Hydraulic conductivity measurements were taken at small negative soil water potentials (0 mm to -30 mm soil water potential) to avoid crack flow through preferential pathways. This makes it possible to compare different soil types as the impact of the sorptivity component (closely related to the antecedent soil water content) on the measurement is minimised. Moreover, hydraulic conductivity near saturation changes very rapidly with small variations in soil water potential, and 5 mm depth of contact material (sand bed) can have a large influence on the soil hydraulic conductivity. The soil water potential at the soil surface was approximately represented by adding the depth of sand bed into the applied soil water potential at the disc permeameter membrane (Reynolds et al, 1996).

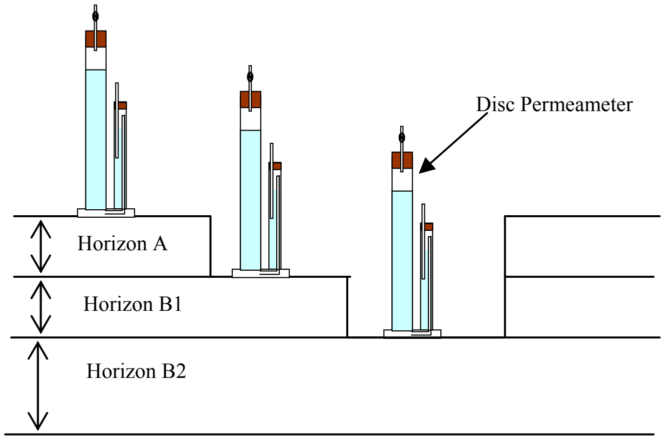


**Figure 4.1 Measurement of Hydraulic Conductivity at Three Depths**

### 4.2.4 Final Infiltration Rate

A ring infiltrometer of 35 cm diameter was used to measure final infiltration rate. A soil pit to the top of Horizon B1 was dug adjacent to the location of hydraulic conductivity measurement. The infiltration ring was inserted to a depth of 15 cm with care being taken to minimise disturbance of the soil surface and the soil structure. The ring was filled with water to a depth of about 10 cm and the water level in the ring was measured manually for 4 hours using a T-ruler. The length of time required to achieve steady infiltration rate ranged from 1 to 4 hours depending upon soil type, texture, and antecedent soil moisture conditions.

**Photo 4.3 Measurement of Infiltration**

### 4.2.5 Soil EC and pH

A soil sample of 20 g was taken from the middle of Horizon A and Horizon B1. Distilled water of 100 ml was added to prepare 1:5 soil water suspension. It was kept aside for a minimum of one hour and mixed thoroughly by shaking. EC and pH readings were taken using TD Scan 20 and pH Scan 3 meters from Eutech Instrument.

### 4.2.6 Soil Sampling

Two undisturbed cores of 73 mm diameter and 64 mm height and one undisturbed core of 73 mm diameter and 31 mm height were taken from the middle of both Horizons A and B1 at all sampling locations on 50 sites. These samples were used for determination of bulk density, water holding capacity, and soil texture in the laboratory.

In addition, one bulk sample of 500 g was taken from one point from both Horizons A and B1 at all sampling sites. These samples were used for chemical analysis in the laboratory for determination of exchangeable cations, organic matter, EC and pH of soil.

**Photo 4.4 Soil Sampling**

### 4.3 Field Measurement during 2003-2004

During 2003-04, field measurements included farm history questionnaire, EM survey for selection of points for the measurement of hydraulic properties, measurement of soil profile, measurement of saturated hydraulic conductivity, measurement of final infiltration rate and soil sampling for laboratory analysis. An initial EM survey was carried out at the selected paddock, and the EM data were used for the selection of measurement points. Field measurement of saturated hydraulic conductivity was carried out at only two soil depths. Three types of field experiments were carried out at a total of 29 sites as shown in Table 4.2.

**Table 4.2 Field Experiments during 2003-04**

| Experiment | Purpose | Number of Sites | Number of Points per Site | Soil Types Measured |
|---|---|---|---|---|
| 4 point trial | - Measurement of soil hydraulic properties of those soils which could not be measured during the first year<br>- Verify measured soil hydraulic properties of the first year of a few major soils | 21 | 4 | Ss, Ssp, Kl, Cl, Wlp, Mlfp, Sfsl, Llfp, Llsfp, Ll, Wl, Gl, Gcl, Glfp, Acl, Ccl, Blfp, Crc, Cc |
| 8 point trial | - Determine variability in hydraulic properties within a paddock or a farm<br>- Explore relationship between soil hydraulic properties and EM data and other soil properties | 6 | 8 | ESfsl, Tl, Ll, Wl, Gl, mixture of soil types of Csl, Mlfp, Nl,Wal |
| 40 point trial | - Determine variability in hydraulic properties within a paddock<br>- Explore relationship between soil hydraulic properties and EM data and other soil properties | 2 | 40 | Nfsl, Sfsl |

#### 4.3.1 Selection of Paddocks

An initial visit was made to the property to select locations for measurement, explain about the project's aims and fieldwork to landowners to be undertaken, and obtain permission for conducting field measurement. A brief questionnaire on the history of the selected paddock was also completed. An Electromagnetic Induction (EM) survey was carried out on the selected paddock using an EM38 instrument, and a suitable time for the field measurement was arranged based on the irrigation schedule. The EM measurement methodology is described in the following section.

#### 4.3.2 EM Measurement

Electromagnetic Induction (EM) is a non-invasive, non-destructive, quick and inexpensive sampling method of measuring electrical conductivity (EC) of soil. Soil EC is a function of soil salinity, clay content and water content. Therefore, soil EM measurements have potential for providing an estimate of within field variation of these properties. In areas of low soil salinity, spatial variation in soil water content is often a major factor in contributing variations in bulk soil EC. In addition to soil salinity and soil moisture, soil EC can provide information on soil texture. William and Hoey (1997) used EM measurements of EC to estimate within field variations in clay content. Soil hydraulic properties are generally correlated with soil texture. Therefore, EM survey method was selected to identify extreme texture variability within a paddock.

A regular grid of a minimum 10 m x 10 m to a maximum of 20 m x 20 m was selected depending upon the size of the paddock (Figure 4.2). Flags or farm fence points were used as a reference for grid lines. EM measurement was carried out using an EM38 instrument manufactured by Geonics Limited, Canada (Photo 4.5). The EM38 instrument was selected as it is most suited for EM measurement of shallow soil depths. The EM38 was operated manually in both horizontal and vertical dipole modes. EM38 response to soil conductivity varies as a nonlinear function of depth. Sensitivity in the vertical dipole mode is highest at about 0.4 m from the instrument while sensitivity in the horizontal dipole mode is highest near the soil surface. Operation in the vertical dipole mode provides an effective measurement depth of approximately 1.5 m and in the horizontal dipole mode provides an effective measurement depth of approximately 0.75 m. The coordinates of the grid were recorded by a GPS instrument manufactured by Thales. The EM data were analysed to determine minimum, maximum, 25, 50 and 75 percentile values in both horizontal ($EM_h$) and vertical ($EM_v$) modes. These data were used to select 4 or 8 field sampling points in a paddock depending upon the type of experiment.

**Photo 4.5 EM Measurement using EM38 Instrument**

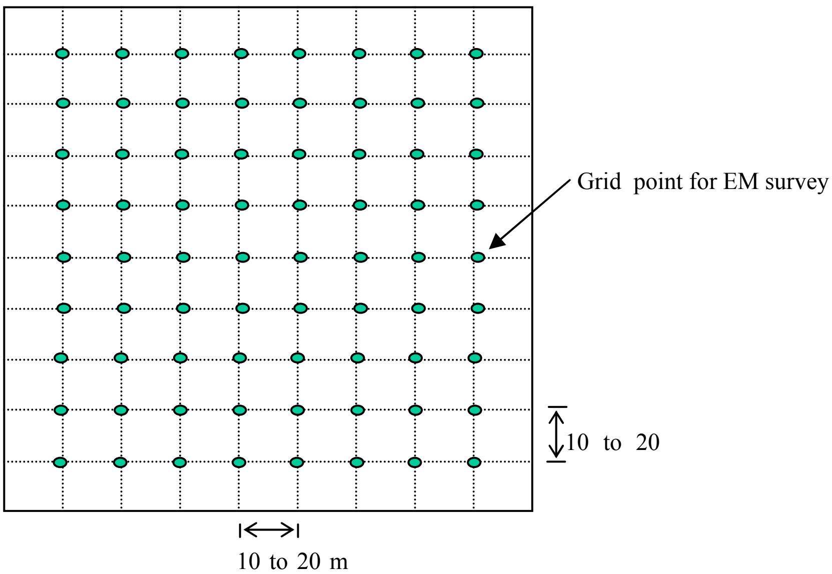


**Figure 4.2 Grid for EM Measurement**

### 4.3.3 Measurement of Soil Hydraulic Properties

Field measurement was conducted typically 4 days after irrigation. The selected points were located in the paddock using GPS. The soil profile was observed from a soil core taken by a 2.5 cm diameter core tube. Depth of Horizon A was measured.

Field measurement of hydraulic conductivity was conducted at two soil depths. At each sampling site, field measurements were conducted at top of Horizon A (soil surface) and top of Horizon B1 in a 50 cm x 75 cm soil pit as shown in Figure 4.3. Disc permeameters of 20 cm base diameter were used for the measurement of hydraulic conductivity. The methodology for the measurement of hydraulic conductivity using disc permeameters was described earlier in Section 4.2.3.

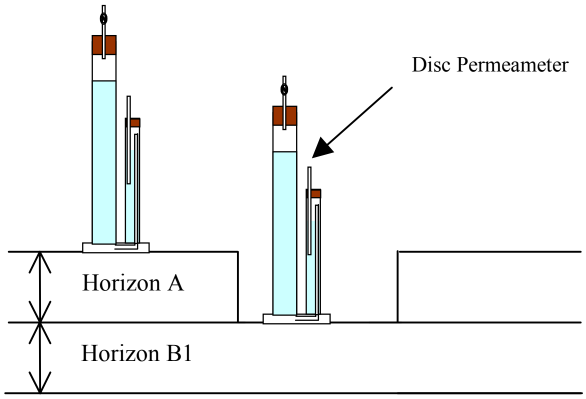


**Figure 4.3 Measurement of Hydraulic Conductivity at Two Depths**

Infiltration rate was also measured using a ring infiltrometer of 35 cm diameter at the top of Horizon B1. A soil pit to the top of Horizon B1 was dug adjacent to the location of the hydraulic conductivity measurement. The infiltration ring was inserted to a depth of 15 cm with care being taken to minimize disturbance of the soil surface and the soil structure during installation. The ring was filled with water to a depth of about 10 cm and the top of the ring was covered with a lid to stop evaporation. The water level in the ring was measured manually using a T-ruler as well as an oblique ruler for 24 hours. The oblique ruler could measure up to a resolution of 0.1 mm and its readings were useful when infiltration rates were very low. Steady state or final infiltration rate was determined using measured infiltration rate data.

40 Point Trials

40 point trials were conducted at two sites to measure the variability in soil hydraulic properties within a paddock. On both sites, field measurement of hydraulic conductivity was conducted on 40 points in a paddock. One site was Shepparton fine sandy loam (Sfsl) soil type and the other was Nanneella fine sandy loam (Nfsl) soil type. Figure 4.4 shows the grid of measurement points for the Nfsl site. Field measurement commenced 2 days after irrigation. An initial EM survey was conducted using EM38 on 10 m x 20 m grid as shown in Figure 4.4. Subsequently at each point, hydraulic conductivity was measured at the top of the Horizon A, and infiltration rate was measured at the top of Horizon B1 in a

50 cm x 75 cm soil pit as shown in Figure 4.5. The field measurements at each site were completed within 2 days.

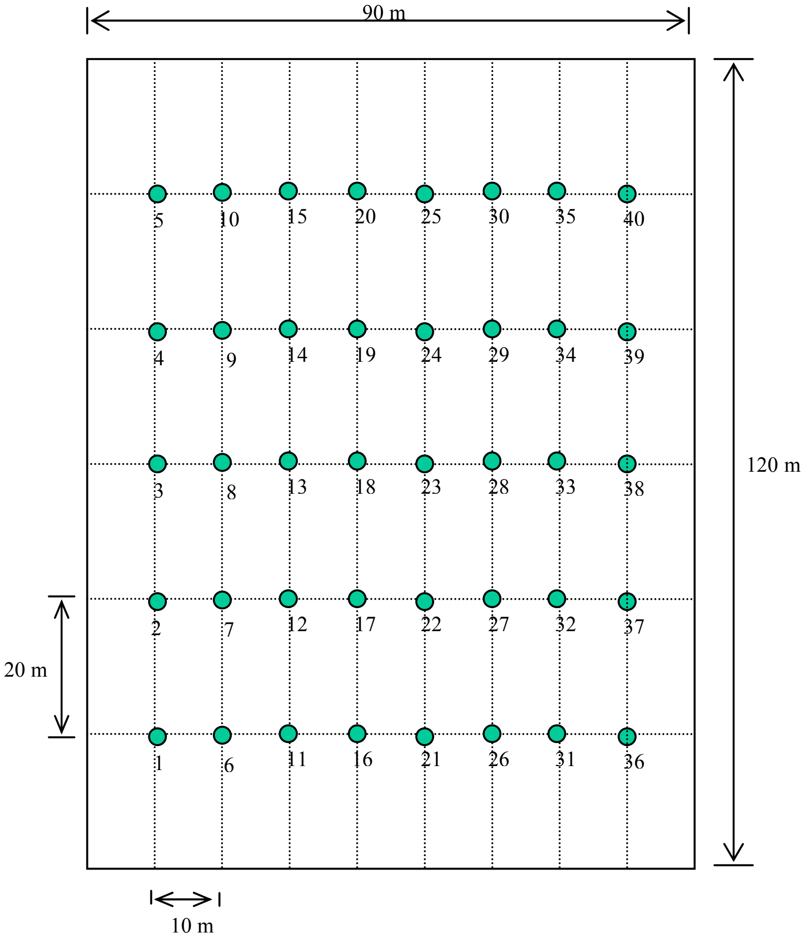


**Figure 4.4 Measurement Points for 40 Point Trial for the Nfsl Soil Type**

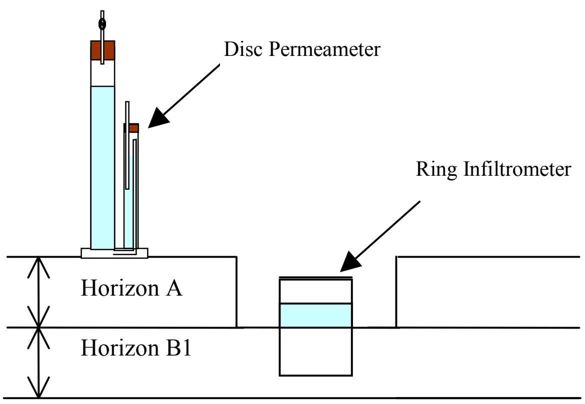


**Figure 4.5 Field Measurement at Two Depths**

**Photo 4.6 Field Measurement of Hydraulic Conductivity in Grid Row**

### 4.3.4 Soil Sampling

One undisturbed core of 73 mm diameter and 64 mm height and one undisturbed core of 73 mm diameter and 31 mm height were taken from Horizons A and B1 at each sampling location. These samples were used for determination of bulk density and soil texture in the laboratory.

In addition, one bulk sample of 500 g was taken from both Horizons A and B1 at all sampling points. These bulk soil samples were used for chemical analysis in the laboratory for determination of exchangeable cations, organic matter, EC and pH of soil.