APPENDIX 2

Methods

Methods for determining climate, landscape and soil parameters are as follows.

Climate
Frost Risk
In the West Wimmera Shire, very little information has been collected with respect to frost occurrence and severity. The Bureau of Meteorology does not collect frost information at any location within the shire.

To identify frost hazard within the shire, thermal mapping information (Cawood, 1996) has been utilised in conjunction with the mapped land units. Thermal maps present spatially the relative temperature difference between areas across the landscape for one particular night (20/5/89). Although they do not show the location, severity or frequency of a frost, they do show the difference in temperature across the landscape. Based on the assumption that colder areas are more frost prone, this information was laid over the soil units to identify colder land units. Utilising three temperatures ranges from the thermal map (Class 1 >0.5^{o}C, Class 2 0.5 - $^{-}0.5^{o}$C and Class 3 <$^{-}0.5^{o}$C) three frost risk levels were determined. Frost risk is relative and is not directly linked with either severity or occurrence, however it can be assumed that Class 3 areas will have a higher frost risk than Class 1 areas. As a rule of thumb, Nhill (north east of the Shire) has frost information and experiences, on average, 35 frost days per year between April and December. Utilising the above criteria, Nhill is a Class 3 frost risk area.

Frost risk ratings are described below and presented in Table A2.1.

Class 1	Low frost risk	Frost does occur although the number and severity is less than Class 3
Class 2	Moderate frost risk	The number and severity of frosts is greater than Class 1, although less severe than class 3.
Class 3	High frost risk	The number and severity of frosts is likely to be the greatest within the shire.

Landscape
Landform
Landform elements are described using the criteria of McDonald et al. (1990).

P	Plains, Plateau
R	Rises
LH	Low Hills, Dunes
H	Hills
M	Mountains

Table A2.1. Frost classes for the land units described in the West Wimmera Shire.

Land system	Land unit description	Map unit	Frost Class
Big Desert - 1	Gently undulating plain	Pg1	3
	Gently undulating plain (closer spaced undulations)	Pu1	2
	Gently undulating rises (closer spaced undulations	Ru1	2
Big Desert transition - 2	Gently undulating plain	Pg2	2
Stranded beach ridges - 3	Undulating low hills	Lu3	3
	Undulating plain	Pu3	3
	Undulating rises	Rg3	3
Northern cracking clay plains - 4	Gently undulating plain	Pg4	1/3
	Level plain	Pl4	1

Grey and red plains and rises - 5	Gently undulating plain	Pg5	1/2
	Gently undulating plain (closer spaced undulations)	Pu5	1
	Gently undulating rises	Rg5	1
	Gently undulating rises (closer spaced undulations)	Ru5	1
Limestone rises - 6	Gently undulating plain	Pg6	2
	Undulating plain	Pu6	1
Self-mulching clay plains - 7	Gently undulating plain	Pg7	2/3
Little Desert transition - 8	Gently undulating plain	Pg8	3
	Undulating rises	Ru8	3
Little Desert - 9	Gently undulating plain	Pg9	3
	Gently undulating plain (closer spaced undulations)	Pu9	3
	Gently undulating rises (closer spaced undulations)	Ru9	3
Southern cracking clay plains - 10	Gently undulating plain	Pg10	2
Yellow Gum plains and rises - 11	Gently undulating plain	Pg11	2
	Gently undulating plain (closer spaced undulations)	Pu11	2
	Gently undulating rises (closer spaced undulations)	Ru11	2
Red Gum plains and rises - 12	Gently undulating plain	Pg12	1
	Gently undulating plain (closer spaced undulations)	Pu12	1
Sand plains and rise - 13	Gently undulating plain	Pg13	3
	Gently undulating plain (closer spaced undulations)	Pu13	3
	Undulating rises	Ru13	3
	Undulating low hills	Lu13	3
Dissected Tableland - 18	Dissected hills	Hd18	2
	Dissected low hills	Ld18	2
	Undulating low hills	Lu18	2
	Dissected rises	Rd18	2
	Undulating rises	Ru18	2
Lunette - 14	Lunette	Nu14	1
Intermittent swamps - 15	Intermittent swamp	Wg15	1
Permanent water bodies - 16	Permanent water bodies	Wg16	1
Swamp and lake complex - 17	Intermittent swamps, permanent waterbodies, lunettes, clay depressions and clay plains	Wg17	1

Water Erosion Hazard

Water erosion hazard (rill and sheet) is determined using the criteria in Table A2.2a and A2.2b.

Table A2.2a. Soil based criteria for water erosion hazard.

Soil parameters			**Soil Dispersibility**			**Hydrophobicity**	
Texture group (A1)	**Structure grade (A1)**	**Horizon depth (A1 + A2)**	**Very Low-Low E3(1), E3(2), E4, E5, E6, E7, E8**	**Medium - High E3(3), E3(4), E2**	**Very High**	**Yes**	**No**
Sand	apedal	<0.2 m o.2 - 0.4 m >0.4 m	M L L			V V V	

Sandy loam	apedal	<0.2 m	M	H		V	
		0.2 - 0.4 m	L	M		V	
		>0.4 m	L			V	
	weakly pedal	<0.2 m	H	E		V	
		0.2 - 0.4 m	M	V		V	
		>0.4 m	M			V	
Loam	apedal	<0.2 m	M	H			
		0.2 - 0.4 m	L	M			
		>0.4 m	L				
	weakly pedal	<0.2 m	H	E			
		0.2 - 0.4 m	M	V			
		>0.4 m	M				
	peds evident	<0.2 m	H	E			
		0.2 - 0.4 m	H				
		>0.4 m	H				
Clay loam	apedal	<0.2 m	M	H			
		0.2 - 0.4 m	L	M			
		>0.4 m	L				
	weakly pedal	<0.2 m	H	E			
		0.2 - 0.4 m	M	V			
		>0.4 m	M				
	peds evident	<0.2 m	H	E			
		0.2 - 0.4 m	H	E			
		>0.4 m	M				
Light clay	weakly pedal	<0.2 m	H	E	E		
		0.2 - 0.4 m	M	V	E		
		>0.4 m	M	V	E		
	peds evident	<0.2 m	M	V	E		
		0.2 - 0.4 m	M	H	E		
		>0.4 m	M	H	E		
	highly pedal	<0.2 m	H	E			
		0.2 - 0.4 m	M	V			
		>0.4 m	M	V			
Medium to heavy clay	weakly pedal	<0.2 m	H	H	E		
		0.2 - 0.4 m	M	H	V		
		>0.4 m	M	H	V		
	peds evident	<0.2 m	H	E	E		
		0.2 - 0.4 m	M	V	E		
		>0.4 m	M	V	E		
	highly pedal	<0.2 m	H	E	E		
		0.2 - 0.4 m	M	V	E		
		>0.4 m	M	V	E		

L - Low M - Moderate H - High V - Very high E - Extreme

Table A2.2b. Landscape based criteria for determining water erosion hazard classes.

Slope (%)	Topsoil erodibility (from Table A2.1a)				
	Low	**Moderate**	**High**	**Very High**	**Extreme**
<1	1	1	1	2	2
1 - 3	1	1	2	2	2
4 - 10	1	2	2	2	3
11 - 32	2	2	2	3	3
>32	2	2	3	3	3

Where 1 = Low, 2 = Medium, 3 = High

Wind Erosion Hazard

Wind erosion hazard is a function of soil erodibility, the probability of erosive winds when the soil is dry and the exposure of the land to wind (Lorimer, 1985). The inherent hazard of land to wind erosion is determined from criteria in Table A2.3.

Table A2.3. Criteria for determining wind erosion hazard classes.

	Criteria	**Class**
1	Surface soil has a strong blocky structure (aggregates >0.8 mm), or is apedal and cohesive or has a dense layer of stones, rock or gravel.	Low
	Surface soil has fine structure (aggregates <0.8 mm).	Medium
	Surface soil has a weak-moderate structure or is apedal and loose.	Go to 2
2	Surface soils with organic matter >20%	Medium
	Surface soils with organic matter 7 - 20%	Medium
	Surface soils with organic matter <7%	Go to 3
3	Surface soils with the following textures	
	Fine-medium sands	High
	Loamy sands	High
	Sandy loams, silty loams	Medium
	Loams, coarse sands	Medium
	Clay loams	Low
	Clays	Low

Gully Erosion Hazard

Gully erosion hazard is determined using the criteria in Table A2.4.

Table A2.4. Criteria for establishing gully erosion hazard classes.

Criteria	Description	Score
Slope	<1% 1 - 3% 4 - 10% 11 - 32% >32%	1 2 3 4 5
Sub-soil dispersibiltiy	E1 E2, E3(3), E3(4) E3(1), E3(2) E4, E5 E6, E7, E8	5 4 3 2 1
subsoil structure	Apedal, massive Weak fine <2 mm mod. 2 - 10 mm	1 3 2

	coarse >10 mm Moderate fine <2 mm mod. 2 - 10 mm coarse >10 mm Strong fine <2 mm mod. 2 - 10 mm coarse >10 mm Apedal, single grained	1 4 3 2 5 3 1 5
Class for rating gully erosion hazard:	**Class** **1. Low** **2. Medium** **3. High**	**Total score** 3 - 8 9 - 12 13 - 15

Rock Outcrop

Rock outcrop refers to the area of exposed rock, expressed as a percentage relative to the land surface area.

Floaters

Floaters refer to the rock within the soil profile. Floaters is expressed as the percentage volume of rock within the plant rooting depth of the profile, relative to the total volume of the plant rooting depth of the profile.

Soil

Soil physical and chemical attributes were either determined in the field or in the laboratory. Reference to either field (F) or laboratory (L) will be assigned against each attribute.

Soils for laboratory testing had the following pre-treatment. Samples collected for each soil horizon were air dried (40^0C) and ground to pass a 2 mm sieve. The gravel (<2 mm) fraction was discarded. A sub-sample of surface soils was further ground to pass a 212 micron sieve for analysis of oxidisable organic carbon. All subsequent tests were carried out on the prepared soil samples and reported in terms of air dried samples except for Moisture Retention and Wettability which were reported in terms of oven dried (105 ^{0}C). Slaking and dispersion testing had a sub-sample of small aggregates kept in their field state.

Soil Texture Groups (L)

Particle Size Analysis divides the soil sample in to the following four principal size groups:

Coarse Sand	2.0 - 0.20 mm
Fine Sand	0.20 - 0.02 mm
Silt	0.02 - 0.002 mm
Clay	< 0.002 mm

Samples are first treated with sodium hypochlorite to destroy organic matter, followed by hydrochloric acid to remove carbonates and soluble salts. Sodium hydroxide and ultrasonic bath treatment is used to disperse the clay. Gravitational sedimentation is used to separate the sand, silt and clay fraction. Measurement of silt plus clay, and later of clay alone is made using a plummet balance, after which the silt and clay fractions are removed by decantation allowing the sand fractio1` Qn to be separated in fine and coarse grades by sieving. A separate determination of the Loss by Acid Treatment is made by treating a sub-sample with hydrochloric acid. Particle size analysis provides a texture class for each soil. State Chemistry Laboratory, Method 30018 (1996).
Based on the particle size analysis results, topsoil and subsoil texture classes were grouped according to Northcote (1974).

Sand	Sand, loamy sand, clayey sand
Sandy Loam	Sandy loam, fine sandy loam, light sandy clay loam
Loam	Loam, loam fine sandy, silt loam, sandy clay loam
Clay Loam	Clay loam, silty clay loam, fine sandy clay loam
Light Clay	Sandy clay, silty clay, light clay, light medium clay
Medium Heavy Clay	Medium clay, heavy clay

Topsoil Depth (F)

Topsoil (A horizon) is defined as a surface horizon showing a texture, colour or structure difference to the soil directly below. Topsoil depth is measured in cm.

Two primary profile forms (Northcote, 1974) are used to differentiate topsoil depth:

D **Duplex** Soil profiles dominated by a significant texture contrast between the topsoil and subsoil, with clear or sharp horizon boundaries that occur over a vertical distance of less than 10 cm.

U **Uniform** Soil profiles dominated by a small, if any, texture contrast between the topsoil and subsoil, with no clearly defined horizon boundaries.

Depth to Hard Rock (F)

Depth to hard is defined as the depth (cm) to consolidated continuous rock that will impede drainage or root growth.

Organic Carbon (L)

The method used determines the oxidisable organic carbon level. In the determination the soil sample is oxidised by chromic acid in the presence of excess sulphuric acid, without the application of external heat (Walkley and Black, 1934). The colour produced is measured with a spectrophotometer. Organic carbon is expressed as a percentage (w/w). Organic matter can then be established from organic carbon. State Chemistry Laboratory, Method 058 (1987).

CEC (Cation Exchange Capacity) and Exchangeable Cations (L)

Exchangeable cations and cation exchange capacity is determined from the extractable bases, calcium, magnesium, potassium and sodium. The bases are extracted from the soil with a 1M ammonium acetate solution at pH 7, and the bases are then analysed by atomic absorption spectroscopy. Cation exchange capacity and exchangeable bases are expressed in meq/100g soil. State Chemistry Laboratory, Method 050 (1985).

Topsoil and Subsoil pH (L)

This determination is carried out on a 1:5 soil water suspension shaken for one hour, and allowed to equilibrate.

pH in H_2O at 20^oC, the pH of the above suspension is determined using a calomel electrode and digital pH meter. State Chemistry Laboratory, Method 053 (1986)

pH in $CaCl_2$ at 20^oC, this is carried out on the soil water suspension after the pH in H_2O determination. One ml of 1M calcium chloride solution is added to the soil water suspension, and the mixture stirred. The pH is then measured again. State Chemistry Laboratory, Method 053 (1986)

The pH in water is used for the suitability ratings.

Soil Salinity (L)

Soil salinity is determined from an estimate of the free salts in the soil using the Electrical Conductivity of the soil (EC). Electrical Conductivity is converted to a (Electrical Conductivity Saturated Extract) ECe value that corrects for differences in soil texture. EC is determined using a 1:5 soil water suspension shaken for one hour, and allowed to equilibrate. Measurements are made on the soil water suspension using dip cell and direct reading meter. Values are determined at 25 ^0C. Sate Chemistry Laboratory, Method 048, (1986).

Published data on the salt tolerance of agricultural crops refer to the electrical conductivity of the saturation extract (ECe). However, obtaining the saturation extract ECe in the laboratory is time consuming and hence not practical for the rapid estimation of the salinity of large numbers of samples. For this reason the EC of a 1:5 soil/water suspension is used and may be converted to an approximate ECe value by multiplying by appropriate factors for different soil textures as shown below:

Soil Texture	**Multiplication Factor**
Sands, loamy sands	13
Sandy loams, fine sandy loams	11
Loams, very fine sandy loams, silty loams, sand clay loams	10
Clay loams, silty clay loams, very fine sandy clay loams, fine sandy clay loams, sandy clays, silty clays, light clays	9
Light medium clays	8
Medium clays	7
Heavy clays	6

Values for EC and ECe are expressed in dS/m.

Internal Drainage (F and L)

Internal drainage, or the rate at which water will move through the soil profile was estimated using the criteria in Tables A2.5a and A2.5b. Land and soil criteria are used to score attributes (Table A2.5a), the sum of the score used to determine the internal drainage class (A2.5b).

Table A2.5. Criteria for scoring internal drainage

Factor	**Category**	**Score**
Primary Profile Form	Uniform	1
	Duplex	3
Bleached A_2	Nil	1
	Sporadic	2
	Conspicuous	3
Topsoil depth (if U score = 1)	>30	1
	10 - 30	2
	<10	3
Subsoil Exchangeable Sodium Percentage (ESP) or Subsoil structure	<6 (well structured blocky)	1
	>6 (large columnar or prismatic)	3
Subsoil mottle	Nil	1
	Sporadic	2
	Conspicuous	3
Landform	LH, H	1
	R	2
	P	3
Annual rainfall	<450	1
	450 - 600	2
	>600	3

Table A2.5b. The relationship between the sum of the score and internal drainage

Sum of score (from Table 4a)	Drainage category
9	Well
10 - 15	Moderately well
16 - 19	Imperfectly
20 - 21	Poor

Hydrophobicity (L)

The wettability or hydrophobicity of the soil was determined using the following method ACLEP, 1995). Soil (generally sand, loamy sand and sandy loam) was oven dried (105^{o}C) and treated with increasing concentrations of ethanol until droplets of such infiltrated the soil surface in less than 10 seconds. The molarity of ethanol required to achieve this was then rated according to the following, nil, low, moderate and severe. To determine suitability, the above ratings were sub-divided into two classes:

Class	***Rating***
No	Nil
Yes	Low, moderate and severe

Aggregate Slaking and Clay Dispersion (L)

Small soil aggregates (both air dried natural aggregates and remoulded aggregates from crushed, wetted and worked soil) were placed into deionised water and observed over time to assess their degree of stability. Observations were made after 2 hours and 20 hours for each aggregate type. Slaking (physical breakdown) was categorised into nil, slight, moderate, strong and complete descriptions.

The stability of soil aggregates in water provides an indication of the current structure of a soil or breakdown of structure that may occur if the soil is worked, particularly in a wet state. The breakdown of aggregation leads to poor structure because the sub-aggregates and individual fine particles (eg silt and clay) can clog up soil pores and thus reduce aeration and drainage. This method is a rapid way of assessing aggregate stability and although subjective, can be used in conjunction with responsiveness of organic matter and gypsum. State Chemistry Laboratory, Method 30006, (1997)

Moisture Retention and Plant Available Water Capacity(L)

Soil samples are placed on a ceramic-neoprene pressure plate and wet to saturation. The plate was placed into a pressure chamber which was then pressurised (to 1550 kPa). The sample drained to equilibrium under the applied pressure. Samples were then removed, oven dried, weighed and gravimetric moisture content calculated. State Chemistry Laboratory, Method 30032 (1996)

Calculation of PAWC (Plant Available Water Capacity) was made by using a model developed by the Department of Natural Resources, Queensland, which takes into account the particle size analysis, the moisture retention at wilting point (1550 kPa), an effective rooting depth and a model derived bulk density to convert gravimetric moisture to volumetric moisture.

Chloride (L)

This determination was carried out on a 1:5 soil water suspension shaken for one hour, and allowed to equilibrate. The soil water suspension was titrated with a silver nitrate solution, using an electrical circuit to determine the end point of the titration. Note that this determination was omitted if the EC determination was < 0.1 dS/m. State Chemistry Laboratory, Method 078 (1996)