GRDC Regional Cropping Solutions Network Final Report

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Plant Available Water (PAW) Information and Tools for better crop management decisions for Esperance Albany RCSN Zone consultants and growers

and

Understanding and managing spatial variation in stored soil moisture for better crop management decisions

Introduction

This report covers two RCSN projects: 'Plant Available Water (PAW) Information and Tools for better crop management decisions for Esperance Albany Regional Cropping Solutions Networks (RCSNs) Zone consultants and growers' and 'Understanding and managing spatial variation in stored soil moisture for better crop management decisions' covering the Kwinana West and Kwinana East RCSN zones.

The Esperance Port Zone RCSN have identified that maximum water use efficiency is not being achieved by the majority of growers within their zone. They noted that soil type variation; and their limited knowledge and ability to measure soil water correctly; were two key reasons why maximum water use efficiency is not being achieved in their farming systems. Knowing their maximum water use efficiency will enable growers in the Esperance Port zone to better manage inputs accordingly to achieve maximum yield potential.

The Albany Port Zone RCSN have also identified lack of knowledge about making the correct in-season nitrogen decisions as an issue for their zone. Growers find it difficult to access, interpret and use information from different tools and information sources, to make informed in-season tactical decisions. The improved management and efficiency of water use, and the resulting in-season management decisions made, is increasingly important for growers and industry. Growers and industry being able to understand and utilise the data from various soil water measurement tools is also important so that the practice changes outlined below can occur.

The Kwinana East and Kwinana West RCSNs identified the understanding and management of stored soil moisture and the effect of uncertain in-season rainfall variability on nitrogen management decisions as key priorities for further research.

This project aimed to meet these requirements by using a consistent process of installing soil moisture probes and running the Yield Prophet® model across the four zones.

Objectives

Understanding soil moisture dynamics is an important consideration for growers when making in-season and in some cases, pre-season management decisions. A network of soil moisture probes and Yield Prophet® sites has been established across the WA Wheatbelt to help improve the understanding of soil moisture dynamics across a range of soil types and climatic regions. This project aims to:

- Improve the understanding of how soil moisture probes and Yield Prophet® can be used to complement each other,
- Increase the range of APSoil soil type selections in Yield Prophet® by modifying existing soil types based on the probe data,
- Provide growers with access to real-time soil moisture data and periodic Yield Prophet® reports from soil types and cropping scenarios that are representative of their area, and
- Cross-validate soil moisture probe data with Yield Prophet® soil moisture modelling

Method

Four soil moisture probe and Yield Prophet® sites were established across the EPZ and Albany Port Zone in 2014 at Howick, Ravensthorpe, Jerramungup and Lake Grace. Another nine moisture probe sites were established across the Kwinana East (KE) and Kwinana West (KW) Port Zones at Beacon, Bonnie Rock, Merredin, Southern Cross, Warradarge, Coomberdale, Bindi Bindi, Yealering and Dowerin in mid-April 2014. Figure 1 shows the locations of each moisture probe site established across both the 2013 and 2014 growing seasons.

Only the data from the moisture probes installed during the 2014 growing season are reported in this paper. Results from the 2013 growing season can be provided upon request.

Moisture probe installations

Two types of soil moisture probes were installed between 3 weeks prior to sowing and immediately after sowing in 2014. Enviropro capacitance probes[1] were buried at 25cm depth, while Tekbox sensors[2] were inserted at around 10-15cm depth following sowing. Enviropro probes of either 40cm or 80cm length were used depending on soil depth. These probes have sensors spaced at 10cm intervals, providing estimates of soil water content to 65cm or 105cm depending on probe length.

A slurry of soil extracted from the soil core taken at installation was used to ensure proper contact between the soil and the probe sensors. The slurry material used at each depth is determined by the change in soil texture with depth. Initially, residual moisture from the slurry influences the soil moisture probe readings, usually until crop senescence, however the length of time that this influence occurs depends on soil type. Moisture probe readings from soils with a high clay content tend to be influenced by the slurry for a longer period than sandy soil due to the ability of clay soils to 'hang on' to soil moisture for longer.

Automatic rain gauges and temperature/humidity sensors were also installed at each site, enabling site-specific rainfall and temperature data to be fed directly into the Yield Prophet® model.

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[1] See http://www.envirotek.com.au/products/enviropro-capacitance-probe.html
[2] See http://www.tekbox.net/sensors/tbsmp02-sdi-12-soil-moisture-temperature-probe

Figure 1. Map of Southwest WA Wheatbelt indicating soil moisture probe sites.

Soil analysis

Soil cores for physical and chemical analysis were taken during probe installation, with samples generally taken at 10cm increments to a depth of 50cm, and subsoil samples taken from 50-70cm and 70-100cm or shallower depending on the soil depth. All samples were analysed for NH_4, NO_3, EC(1:5), pH($CaCl_2$), Cl and particle size (i.e. sand, silt and clay).

Sensor calibration

The data from each sensor was calibrated using soil texture-specific calibration curves provided by the manufacturer. Soil texture was determined by mid-infrared particle size analysis results from the CSBP laboratory, resulting in 104 individual sensor calibrations. The particle size analysis and soil chemistry data was then entered into CSIRO's Soil Water Express calculator (see http://www.apsim.info/swe/About.aspx) to provide an estimate of Plant Available Water (PAW), by way of subtracting the Crop Lower Limit estimate from the sum of the calibrated soil moisture sensor data.

The total PAW estimates require further calibration to account for the influence of subsoil constraints such as salinity, sodicity, acidity or other subsoil constraints. The estimated total PAW at some sites has been adjusted by not including the probe readings from deeper sensors (e.g. 85cm and 95) where subsoil constraints were assumed to be present based on the soil chemical analysis from these depths.

Moisture probe readings from soils with a high clay content will continue to be influenced by the water used during installation for a longer period than sandy soil due to the ability of clay soils to 'hang on' to soil moisture for longer.

It is anticipated that more accurate PAW Capacity (PAWC) estimates will be able to be calculated now that the Crop Lower Limit has been observed, and that the PAW estimates will be more accurate on sites where the Drained Upper Limit (DUL) has been reached.

Soil moisture, weather and yield data, Yield Prophet® reports, telemetry and hosting

Moisture probe and weather data are being logged and transmitted via the Next G Global System for Mobile Communications (GSM) network using Outpost Central telemetry. This data can be accessed via internet using the following Uniform Resource Locator (URL): https://www.outpostcentral.com/remote/loginsession.aspx?uname=RCSN, which is being monitored on a weekly basis to ensure continuity of data. The final (i.e. crop senescence) Yield Prophet® reports are also accessible from this website.

Moisture probe data and modelled ('virtual') soil moisture data from Yield Prophet® have been plotted together in new 'Probe Reports' which can be accessed from the aforementioned URL. Comparative data from four selected sites (Bindi Bindi, Beacon, Bonnie Rock and Ravensthorpe) are presented in the results. Comparative data from the remaining sites can be provided on request.

Where possible, yield mapping data provided by growers has been analysed to provide site-specific yields for the soil moisture probe locations. Hand-cuts were made at the Southern Cross site (10 x 1m cuts at the probe site), with grower feedback provided in the remaining cases.

Results

Soil physical and chemical data

The soil analysis results from each site presented in Appendix 1. The soil types as defined in Yield Prophet® through the APSoil database are shown in Table 1. Eight soil types were represented by the twelve Yield Prophet® sites registered in 2014, ranging from Yellow Sandy Earth at Yealering, to Red and Brown clays at Ravensthorpe and Southern Cross respectively. The basic starting parameters, nitrogen applications and seasonal rainfall for each site are shown in Table 1. A brief summary of the results from the Yield Prophet sites across each Port Zone is presented below.

Kwinana East

Significant early rainfall was received across the sites in the KE zone resulting in good crop establishment. Rainfall for the remainder of the season was low, with high temperatures experienced in August, resulting in low yields. The Yield Prophet® model indicated that there would be no economic response to additional nitrogen (N) applied post-seeding, with the Beacon site being the only one to received additional N (12kg/ha) in late July. Yield Prophet® estimates were generally accurate, being within 0.1t/ha (Southern Cross) and 0.5t/ha (Beacon) of the final yield (see Table 2). Further investigation is underway regarding why the Yield Prophet® estimates were below the final yield.

Two moisture probes were installed at the Southern Cross site, representing treatments where summer weeds were sprayed or unsprayed in early 2014. While the soil moisture probe data suggests that the sprayed treatment had higher soil moisture content throughout the season, EC data from the probes suggests that the bulk EC to a depth of 40cm at the sprayed treatment site is up to 2dS/m higher than at the unsprayed site, despite being closely located (approx. 20m apart). Hand-cuts from each treatment showed the grain yield from the unsprayed treatment was 0.2t/ha higher than the sprayed treatment (0.94 cf. 1.14t/ha). Further site investigations are being undertaken through soil analysis and electromagnetic surveying with respect to calibrating the probes to account for the variation in salinity and understanding soil variation across the trial site.

A similar situation exists at the Merredin site, where the two probes are locate within 450m of each other and the bulk EC to 60cm depth varies by approximately 1dS/m between the two sites. Further investigation in terms of calibrating these sites to account for significant differences in EC are also being undertaken.

Existing electromagnetic (EM) and gamma radiometric (GR) data from a previous survey was used to identify the optimal soil moisture probe location at the Beacon site.

Table 1. Basic Yield Prophet® parameters for soil moisture probe sites.

Site	Soil Type	Variety	Sowing date	Pre-seeding soil N (kg/ha)	N applied @ sowing (kg/ha)	Top up N (kg/ha)	Growing Season Rainfall (mm)
Beacon	Red Loamy Earth	Mace	11/4	72	30	12	151
Bindi Bindi	Duplex sandy gravel	Bass	11/5	57	34	80	250
Bonnie Rock	Red Brown non-cracking Clay	Mace	5/5	113[3]	8	0	163
Coomberdale	Red Brown non-cracking Clay	Mace	20/5	61	5	69	268
Dowerin	Duplex sandy gravel	Corack	24/5	46	16	23	225
Howick	Deep sandy gravelly duplex	Stingray	5/5	133	30	44	230
Jerramungup	Yellow Grey Loamy Duplex	Mace	7/5	75	32	21	292
Lake Grace	Shallow Loamy Duplex	Mace	18/5	73	9	34	530
Merredin	Red Brown non-cracking Clay	Mace	23/5	134	7	0	176
Ravensthorpe	Red Clay	Derrimut	11/5	185[4]	5	0	293
Southern Cross	Brown Clay	Cobra	1/5	195[5]	11	0	162
Warradarge	Duplex sandy gravel	Mace	24/5	67	37	75	392
Yealering	Yellow Sandy Earth	Yitpi	29/5	55	10	0	304

Kwinana West

Precision Agronomics Australia undertook EM and GR surveys of the sites at Coomberdale, Bindi Bindi and Dowerin to help identify the option locations for the soil moisture probes. This data can be provided upon request.

The sites throughout the Kwinana West zone also received significant early season rainfall, enabling good weed control and crop establishment. Yield Prophet® reports suggested that economic responses to additional post-seeding N were highly likely, with the Coomberdale GS32 (second node) report suggesting responses up to 0.5t/ha and 1.8t/ha for additional applied N in drier (Decile 2.5 rainfall) and wetter (Decile 7.5 rainfall) than average seasons respectively. Grain yield potential at Coomberdale increased between GS30 and GS32 due to the addition of 56kg/ha of N, however dry weather conditions in August reduced the yield potential later in the season. Yield Prophet® accurately predicted the final yield at this site, with yield data from N-response trial strips in this paddock currently being analysed.

[3] 24kg/ha potentially unavailable due to subsoil constraints
[4] 25kg/ha potentially unavailable due to subsoil constraints
[5] 52kg/ha potentially unavailable due to subsoil constraints

Table 2. Yield Prophet® yield estimates from automatic growth stage reports[6] and final crop yields (t/ha).

Site	Decile	GS30	GS32	GS37	GS65	GS90	Actual yield
Beacon[7]	7.5	1.8	1.6	1.3	0.8	0.8	1.3
	5	1.3	1.1	0.9	0.7		
	2.5	0.9	0.8	0.7	0.6		
Bindi Bindi[7]	7.5	3.7	N/A	3.2	3.1	3.2	3.8
	5	3.5	N/A	3.0	3.2		
	2.5	3.2	N/A	2.8	3.3		
Bonnie Rock[7]	7.5	2.9	2.1	2.0	1.1	1.1	1.2
	5	2.6	1.8	1.7	0.9		
	2.5	2.0	1.3	1.3	0.9		
Coomberdale[7]	7.5	3.4	3.6	3.2	3.2	2.9	2.8
	5	3.2	3.2	3.0	2.8		
	2.5	2.8	2.9	2.6	2.4		
Dowerin	7.5	1.9	1.9	1.6	1.3	1.4	1.6
	5	1.4	1.3	1.1	1.0		
	2.5	1.0	1.0	0.9	0.9		
Howick[8]	7.5	2.9	3.5	3.2	3.0	2.5	2.2
	5	2.8	3.4	3.0	2.9		
	2.5	2.7	3.3	2.8	2.8		
Jerramungup[7]	7.5	3.8	4.2	4.2	4.0	3.4	3.8
	5	3.5	3.9	4.0	3.7		
	2.5	3.2	3.5	3.6	3.4		
Lake Grace	7.5	1.8	2.2	2.2	2.4	2.4	N/A[9]
	5	1.7	2.0	2.0	2.2		
	2.5	1.5	1.9	1.8	2.2		
Merredin	7.5	0.9	0.8	1.0	0.9	0.6	0.94
	5	0.7	0.6	0.8	0.7		
	2.5	0.4	0.4	0.6	0.6		
Ravensthorpe[7]	7.5	4.6	4.5	4.4	4.0	3.9	4.5
	5	4.0	4.0	3.8	3.9		
	2.5	3.4	3.6	3.1	3.7		
Southern Cross[7]	7.5	3.2	3.2	2.6	1.5	1.2	1.1
	5	2.4	2.4	2.1	1.2		
	2.5	1.5	1.5	1.3	1.1		
Warradarge	7.5	3.2	3.2	4.6	3.7	3.5	2.55
	5	3.0	3.0	4.4	3.6		
	2.5	2.7	2.7	4.0	3.5		
Yealering	7.5	2.1	2.2	2.2	2.4	2.3	N/A
	5	1.8	1.8	1.9	2.1		
	2.5	1.6	1.6	1.6	1.9		

[6] Automatic growth stage reports are based on rainfall from the nearest weather station instead of the rain gauges at the moisture probe site.
[7] Site specific (i.e. derived from hand-cuts or yield map)
[8] Interpreted from equivalent canola growth stages as derived by manually generated reports
[9] N/A: Not available

Modelled N responses were also high at the Warradarge site, with the GS32 report suggesting up to 1.8t/ha and 2.1t/ha responses to unlimited N in drier and wetter than average seasons respectively. However the actual yields from this site were significantly (i.e. 1t/ha) lower than the Yield Prophet® prediction, which is most likely due to the modelled rooting depth (50cm) for this site being set deeper than the actual rooting depth (40cm). This is confirmed by the moisture probe data at mid-dough fill which showed little moisture extraction around the 50cm sensor during grain fill. Further investigations are being undertaken with regards to the rooting depth constraints at this site.

Esperance/Albany

There was a strong start to the season across the western parts of the Esperance and Albany zones, with the Jerramungup and Ravensthorpe sites receiving significant falls in April and Howick receiving 25mm to the end of May. The rainfall continued throughout the season resulting in estimated yields either increasing or staying within 0.5t/ha of the original estimates. The warm and dry conditions in August led to a slight reduction in yield potential from GS37 to GS90 (see Table 2), apart from the Lake Grace South site which had sufficient soil moisture reserves to see the crop through this period. However this episode was not nearly as severe as what was experienced in the KE and KW zones.

Modelled N responses across the Esperance/Albany sites were generally high apart from at Ravensthorpe where the initial N status was high (185kg/ha) due to a field pea crop in the previous year. Final Yield Prophet® estimates were within 0.3t/ha to 0.7t/ha of the final yields at all sites.

Capacitance probe vs virtual soil moisture data

Comparisons of estimated total soil water data as derived from capacitance probes against the modelled or ‘virtual’ soil moisture from Yield Prophet® were made for four sites (see Figure 2). The capacitance data has been scaled to match the virtual soil moisture at crop senescence (i.e. estimated Crop Lower Limit). Note that the probe vs virtual graphs in the Yield Prophet® reports available on the aforementioned website have not been scaled in this way. Figure 2 shows that the general patterns of soil moisture flux throughout the season are consistent between the probe and the virtual estimates of PAW.

The Ravensthorpe and Bindi Bindi probe data behaved as expected, with the estimated probe PAW being higher throughout the season due to the influence of the slurry used during probe installation, and the difference being greater at the Ravensthorpe site due to the heavier soil than Bindi Bindi. However the virtual PAW was generally higher than the probe PAW at the Beacon and Bonnie Rock sites throughout the start and middle of the season. Further investigation into the cause of this is required at these sites, along with others where this pattern was observed, or where the time-series patterns of the probe and virtual soil water data are significantly different.

Comparisons of moisture probe and Yield Prophet® estimates of total soil water for each site are provided in

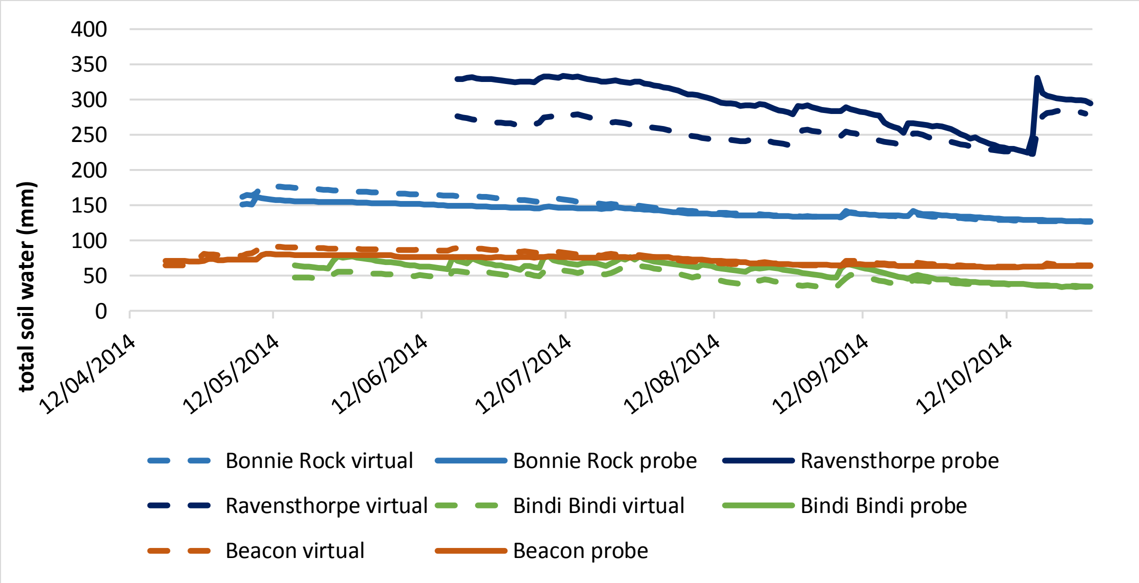

Figure 2. Comparisons of estimated total soil water (mm) between soil moisture probes and Yield Prophet® ('virtual') modelling.

Conclusion

A network of soil moisture probes and Yield Prophet® sites has been established across the Esperance, Albany, Kwinana East and Kwinana West port zones with the aim of providing public access to real-time soil moisture and weather data and periodic Yield Prophet® reports to aid in-crop decision making, with particular reference to top-up nitrogen decisions.

The effect of residual soil moisture from the slurry used at installation has influenced the first year of data from the soil moisture probes, particularly on heavier soils such as those found at Ravensthorpe, Lake Grace South, Merredin and Coomberdale.

High subsoil EC at some sites has influenced the moisture readings and further investigations are underway at those sites (i.e. Southern Cross and Merredin). The combination of capacitance and virtual soil moisture data has allowed the Yield Prophet® soil type to be more accurately characterised at the Warradarge site.

Excluding the Warradarge site (due to inaccurate soil characterisation), half of the Yield Prophet® estimates were within 300kg/ha of the final crop yield at GS30 (June/July) and 70% at GS90, with the median difference between the Yield Prophet® GS90 estimates and final yield being 0.35t/ha.

Growers and agronomists have commented that the sites provided useful supporting information when making top-up nitrogen decisions, with the soil moisture probes providing additional confidence in the model's output.

Continuation of the Yield Prophet® sites and soil moisture data recording and analysis will continue in 2015 across the Esperance/Albany and Kwinana East port zones, with the aim of further refining the sites to improve their accuracy and providing access to Yield Prophet® and soil moisture information in a more user-friendly format.

Recommendations

1. Set aside a minimum budget of $300/site/yr (total $6600 for 22 probe/weather sites) for data telemetry and webhosting services to keep data live

2. Set aside a minimum budget of $200/site/yr (total $4400 for 22 probe/weather sites) for physical site maintenance and to maintain data presentation (including updating of drained upper limit and crop lower limit levels as more data becomes available)
3. EM survey of sites prior to any further installations, especially where ‘paired’ probes are being installed to assess soil moisture differences between treatments (note aforementioned salinity differences at Southern Cross and Merredin sites)
4. Relocate the soil moisture probe at Gorya Valley (Rory Graham, North Mallee/Salmon Gums). Existing site is located in an unrepresentative soil type, with hostile saline/sodic subsoils present at 40cm. Conduct EM survey of paddock and analyse yield data to identify a more representative soil type.
5. Conduct further soil moisture calibrations for probe sites, particularly the Coomberdale, Merredin and Southern Cross sites by taking in-season gravimetric soil moisture readings at a range of soil moisture contents.
6. Maintain linkages with the CSIRO Soil Water (Oliver et. al.) and DAFWA Subsoil Constraints (Hall et. al.) projects.
7. Maintain linkages with Precision Agronomics Action on the Ground Project (Reducing N2O emissions from WA grain cropping by matching fertiliser inputs to yield potential).
8. Replace Adcon telemetry units from 2012 project with Outpost Central telemetry units to maintain consistency with data access and presentation. Estimated cost of $3200 for 8 sites (includes resale income for Adcon units). Adcon data access is difficult, slow and does not integrate seamlessly with Yield Prophet.
9. Maintain contact with the DAFWA e-Connected Wheatbelt project (contact Catherine Davies, DAFWA Northam) for enabling further expansion of soil moisture monitoring network and integration with existing sites.
10. Provide funding to Birchip Cropping Group for redevelopment of their Yield Prophet reporting interface to enable greater user flexibility, simplification and tailoring.

Acknowledgments

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Appendices

Appendix 1.1.1 Kwinana East moisture probe soil characteristics

Beacon (Sandy loam over silty loam)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	1	9	0.05	5.3	NA	12	80	8
10-20	2	18	0.07	4.4	20	17	75	8
20-30	1	5	0.04	4.3	12	22	72	6
30-40	2	3	0.04	4.7	14	20	71	9
40-50	2	2	0.03	5.2	18	15	75	10
50-70	< 1	2	0.05	5.6	19	25	69	7
70-100	< 1	1	0.04	6.7	11	9	83	8

Bonnie Rock (Sandy loam)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	22	19	0.07	4.5	NA	11	85	4
10-20	< 1	2	0.03	5.6	9	20	75	5
20-30	1	3	0.06	6.4	17	16	73	11
30-40	< 1	4	0.13	7.5	39	16	73	12
40-50	1	4	0.15	7.9	50	9	80	11
50-70	< 1	3	0.20	8.4	42	12	77	11
70-100	< 1	6	0.30	8.4	45	12	75	14

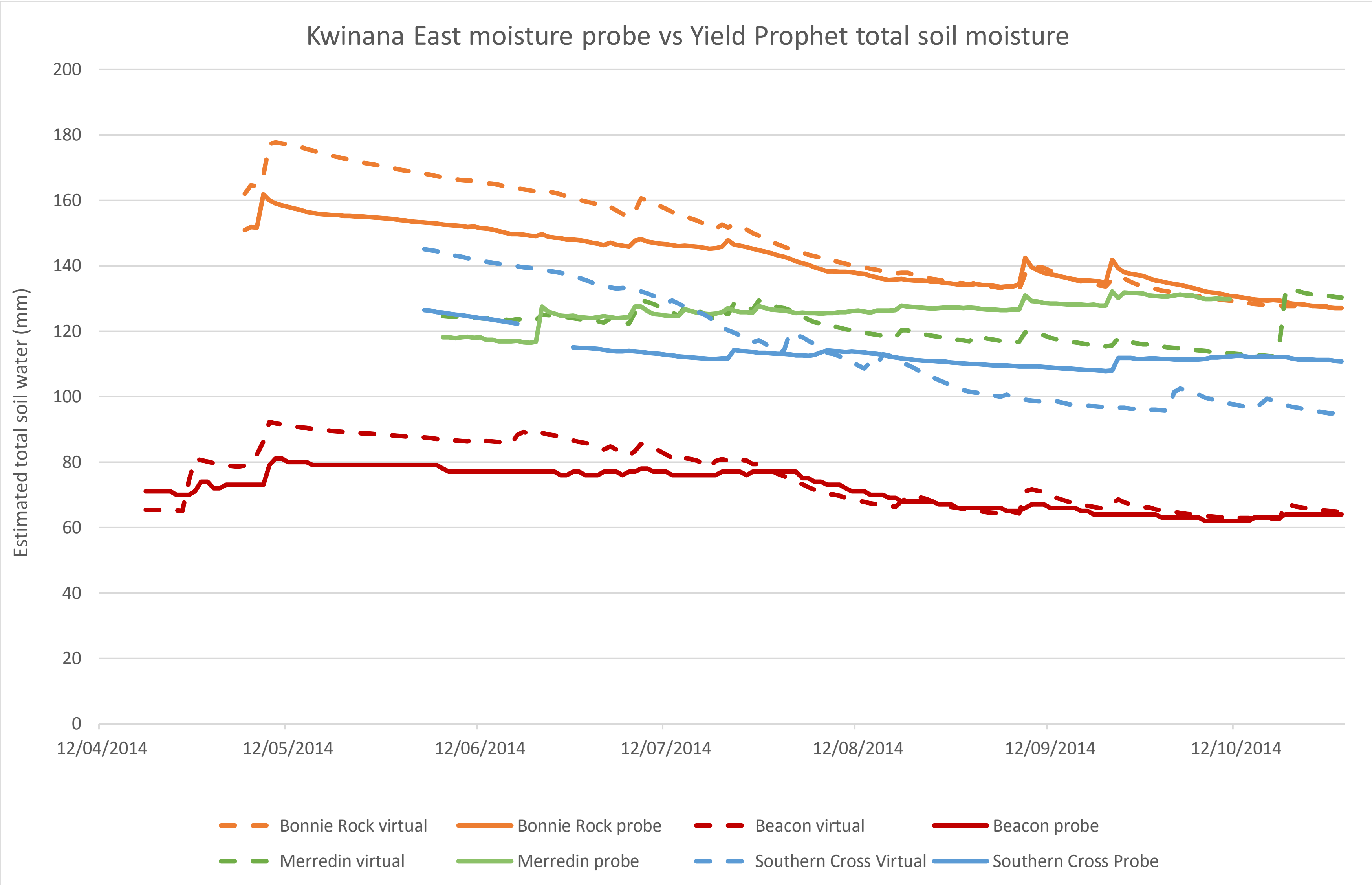
Southern Cross (Sandy clay loam)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	2	18	0.07	5.7	NA	20	76	5
10-20	< 1	13	0.10	6.5	52	17	60	23
20-30	< 1	11	0.27	7.9	91	29	65	6
30-40	< 1	10	0.27	8.1	126	30	60	10
40-50	< 1	10	0.35	8.3	166	27	60	14
50-70	< 1	10	0.40	8.4	226	28	56	17
70-100	< 1	11	0.42	8.4	240	25	59	15

Merredin (Light clay over medium clay)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
10-20	4	2	0.37	7.8	285	11	47	4
20-30	4	2	0.75	8.1	711	6	45	6
30-40	5	1	0.76	8.3	897	5	52	5
40-50	7	1	0.75	8.1	716	7	58	3
50-70	9	1	0.85	8.3	666	8	58	3
70-100	12	< 1	1.10	8.5	749	10	54	4

Appendix 1.1.2 Kwinana East moisture probe soil characteristics



Appendix 1.2.1 Kwinana West moisture probe soil characteristics

Bindi Bindi (Sand over loam)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	4	7	0.07	6.7	NA	7	87	6
10-20	3	5	0.04	4.9	14	10	85	5
20-30	2	4	0.03	5.6	8	10	84	6
30-40	1	2	0.04	5.9	9	12	79	9
40-50	< 1	2	0.08	6.2	23	19	75	6
50-60	< 1	2	0.08	6.9	17	18	77	5
60-70	1	2	0.16	7.8	34	24	69	7

Coomberdale (Sandy loam over clay loam)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	6	6	0.24	7	NA	13	75	11
10-20	1	2	0.20	7.1	154	30	59	11
20-30	1	3	0.36	8.1	267	30	62	8
30-40	< 1	1	0.69	8.3	481	32	54	14
40-50	< 1	1	0.84	8.4	580	29	60	11
50-70	< 1	2	0.87	8.2	665	22	67	11
70-100	< 1	3	1.06	8.3	880	28	60	12

Dowerin (Sand over sandy loam)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	1	4	0.03	6.1	NA	5	91	4
10-20	< 1	2	0.03	6.1	10	11	85	4
20-30	< 1	2	0.03	6.3	8	16	78	6
30-40	< 1	2	0.03	6.5	11	27	68	5
40-50	< 1	2	0.04	7.2	11	30	67	3
50-70	< 1	2	0.03	7.3	10	30	67	3
70-100	< 1	2	0.07	8.1	12	39	57	4

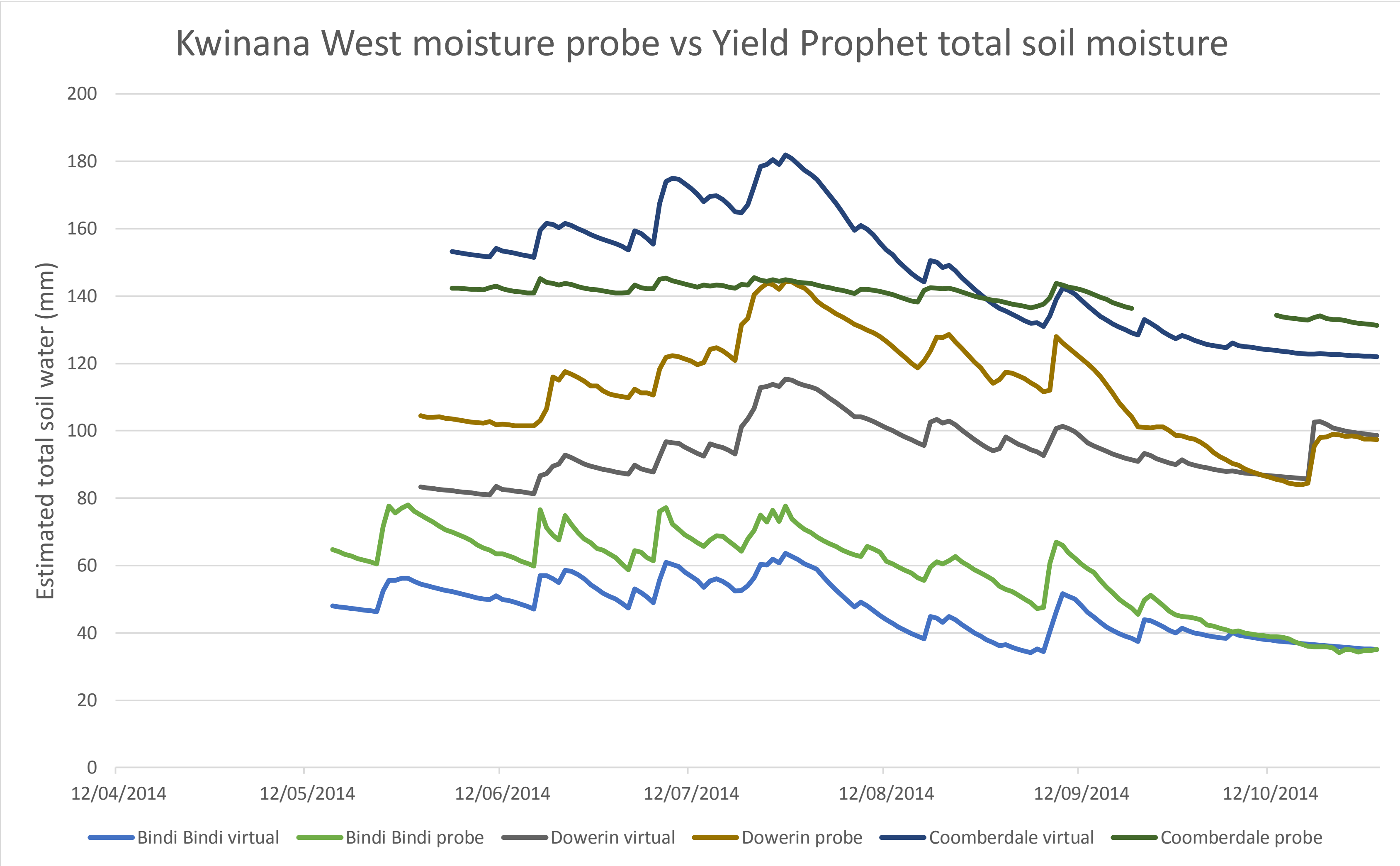
Warradarge (Sand over sandy clay)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	3	2	0.04	6.8			3	96
10-20	2	3	0.03	7	12.4	12	8	91
40-50	1	3	0.05	6.5	21.2	21	21	75
30-40	1	4	0.06	6.6	27.6	28	29	67
20-30	< 1	4	0.06	8.1	48.4	48	32	64
50-70	< 1	4	0.06	7.2	50.3	50	34	61
70-100	< 1	3	0.07	7	47.4	47	31	62

Yealering (Sand over loam over gravel/rock)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
10-20	4	2	0.06	4.8	285	11	47	4
20-30	4	2	0.02	4.4	711	6	45	6
30-40	5	1	0.01	4.5	897	5	52	5
40-50	7	1	0.01	4.4	716	7	58	3
50-60	9	1	0.02	5.1	666	8	58	3
60-70	12	< 1	0.02	6.1	749	10	54	4

Appendix 1.2.2 Kwinana West moisture probe soil characteristics



Appendix 1.3 Esperance/Albany moisture probe soil characteristics

Jerramungup (Sandy loam over sandy clay)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	1	7	0.07	4.9		10	87	3
10-20	2	5	0.09	6.2	55	44	49	8
40-50	1	3	0.10	6.2	47	33	63	4
30-40	2	30	0.08	6.8	40	25	70	5
20-30	1	2	0.10	6.5	41	19	76	5
50-60	2	3	0.10	7.1	35	12	83	5
60-70	1	3	0.07	6.5	46	12	83	6
70-100	< 1	3	0.09	6.9	64	12	82	6

Ravensthorpe (Silty clay loam over silty clay)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	3	27	0.24	7.8		30	34	36
10-20	2	18	0.41	8.3	165	42	27	31
20-30	2	16	0.64	8.5	285	52	27	21
30-40	< 1	11	0.82	8.6	447	55	26	18
40-50	1	8	0.83	8.8	723	54	27	19
50-60	< 1	9	0.89	8.7	651	54	25	21
60-70	1	6	1.00	8.6	922	42	41	18
70-80	1	5	1.09	8.6	1035	39	38	23
80-90	1	4	1.19	8.6	1033	34	45	21
90-100	2	4	1.15	8.5	1141	28	52	20

Lake Grace[10] (Medium clay)

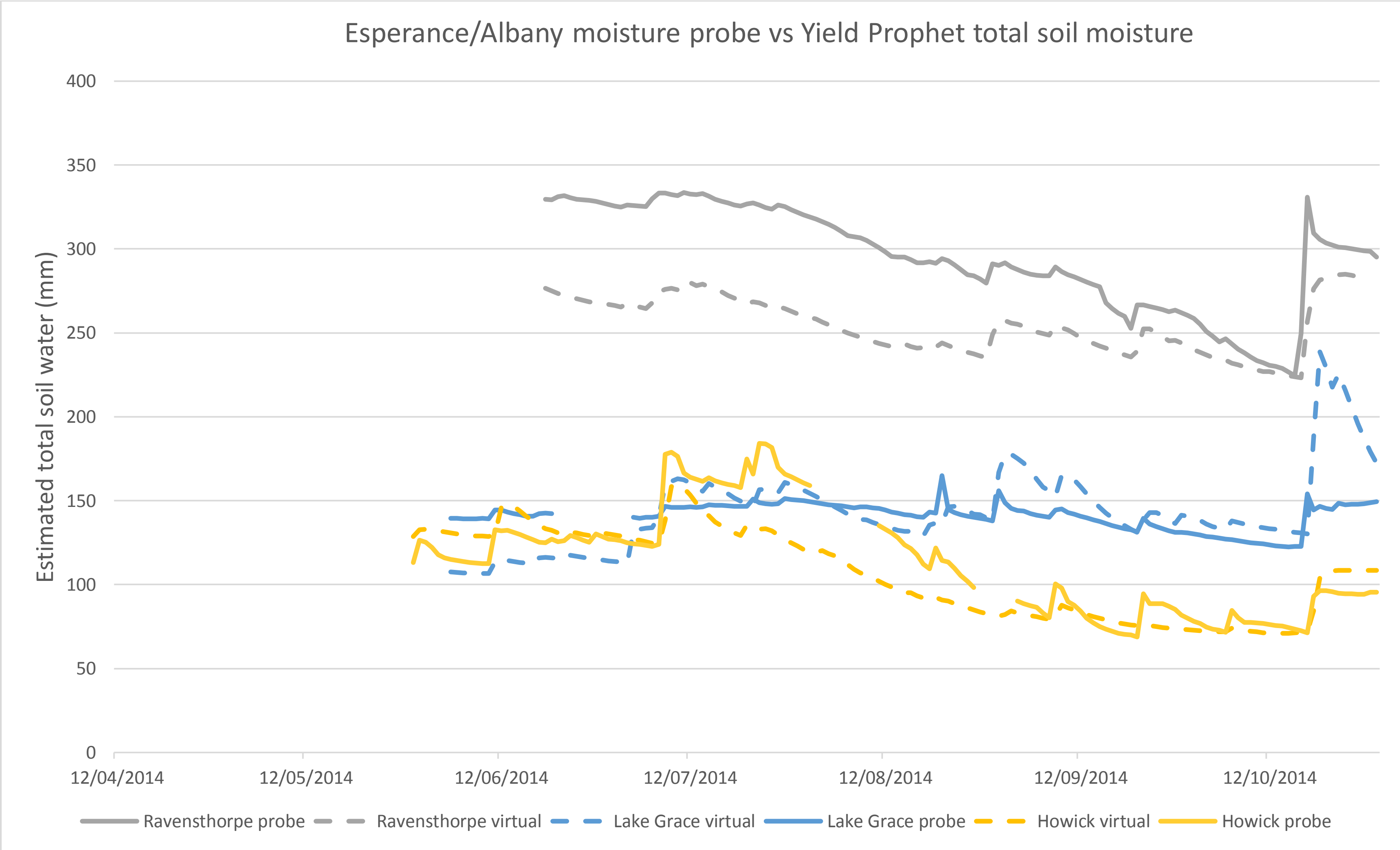
Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	4	6	0.07	5.3	32	48	41	11
10-40	1	1	0.23	8.3	30	45	45	9
40-70	2	2	0.38	8.5	49	47	46	8
70-100	<1	3	0.52	8.4	72	48	41	11

Howick (Sand over sandy clay)

Depth (cm)	Ammonium Nitrogen (mg/Kg)	Nitrate Nitrogen (mg/Kg)	Conductivity (dS/m)	pH (CaCl2)	Chloride (mg/Kg)	% Clay	% Sand	% Silt
0-10	8	29	0.08	4.3	NA	7	90	4
10-20	1	5	0.02	5.4	8	5	95	0
20-30	1	3	0.02	5.7	NA	8	90	2
30-40	2	5	0.04	5.5	10	20	77	3
40-50	1	4	0.06	5.6	12	30	60	10
50-60	< 1	3	0.05	6.0	14	35	61	5
60-70	1	4	0.04	5.9	16	NA	NA	NA
70-80	1	3	0.06	6.3	16	36	60	4
80-90	< 1	4	0.08	6.8	19	NA	NA	NA
90-100	1	4	0.13	7.5	16	42	52	6

[10] Soil chemistry undertaken as part of the DAFWA Focus Paddocks project

Appendix 1.2.2 Esperance/Albany moisture probe soil characteristics



Appendix 2 - Extension activities

Field Days

Moora-Miling Pasture Improvement Group, 10th June 2014

Location: Cranmore Downs sheds

Attendees: Approximately 13 growers, approx. 4 agribusiness/industry/extension

RCSN 'Pop-up' Field Day, Laharna Downs, 11th June 2014

Location: Andrew Todd's shed

Attendees: Approx. 8 growers, 4 agribusiness/industry/extension

DAFWA Agribusiness Breakfast, 12th June 2014

Location: Merredin DAFWA Office

Attendees: Approx. 20

RAIN Spring Field Day, 16th September 2014

Attendees: 60 growers, agribusiness, industry and extension

Location: Webster's moisture probe site

Far East Ag Research Group Spring Field Day, 23rd September 2014

Location: Moorine Rock Hall

Attendees: 22 growers, 24 agribusiness/industry/extension

Warralakin/Bonnie Rock Group post-harvest meeting, 10th December 2014

Location: Damen Maddock's house

Attendees: Approximately 6 growers

Moora-Miling Pasture Improvement Group day – Frank D'Emden (PAA) speaking at probe site

RAIN Spring Field Day – Aidan Sinnott (PAA) speaking at probe site

Media

Ground Cover

Real-time moisture tracking sharpens yield predictions - See more at: http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-113-NovDec-2014/Real-time-moisture-tracking-sharpens-yield-predictions#sthash.Bz4G6vGA.dpuf

GRDC Media Releases

New online tool offers latest soil water and crop growth data - See more at: http://www.grdc.com.au/Media-Centre/Media-News/West/2014/08/New-online-tool-offers-latest-soil-water-and-crop-growth-data#sthash.lRn8GRwI.dpuf

GRDC Harvest Radio

047: Nitrogen boost | GRDC Radio (Western Update)

http://www.grdc.com.au/CMS_Data/MediaFiles/B/3/4/B34BE91C232A4FD48D72882D4EE07022%2047%20west.mp3

Data access

Web statistics for https://www.outpostcentral.com/remote/loginsession.aspx?uname=RCSN

1045 logins

Logins from 400 unique IP addresses