Monitoring Mallee Seeps

Project 1498C for the

South Australian Murray-Darling Basin

Natural Resources Management Board

Progress Report July-Dec 2016

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This project is funded through the South Australian Murray-Darling Basin Natural Resources Management Board and the Australian Government's National Landcare Program

Australian Government | National Landcare Programme

Government of South Australia
South Australian Murray-Darling Basin Natural Resources Management Board

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The author acknowledges the assistance of farmers Stuart Pope, Peter Rose, Andrew Thomas, Kevin, Geoff and Rodney Bond and David Arbon, as well as Scott Gillett of Wisdom Data and various staff from NR SAMDB in the compilation of this document. Thanks also goes to Nigel Wilhelm and Peter Telfer of SARDI for harvesting the Pope trial and for Viterra Loxton for assistance in measuring grain quality.

Contents

1 Project Summary

This project has given valuable insight into the dynamics of mallee seeps that compliments the in-depth catchment reports that have recently been commissioned by NR SAMDB.

Piezometers established at 3 of the sites show sharp rise in water tables close to the seep areas after high rainfall events (25mm plus) in March, or after smaller rains (10-15mm) when the soil profile was nearing field capacity following previous rains later in the season.

The midslope piezometers essentially showed a gradual increase in water levels throughout the above average rainfall growing season. However, it is still unclear whether this rise is due many rainfall events or a few large rainfall events at critical times. At 3 sites the soil moisture probes only show spikes in the deep moisture sensors (70cm and 90cm depth) on very few occasions is expected that these are what most contribute to recharge in the upper sandy catchment areas, leading to lateral flow across the top of the impermeable Blanchetown clay layers and to discharge areas lower in the landscape.

However, the midslope piezometer at one site shows at least 6 distinct rises in water table that are in direct response to rainfall events as it rises over the growing season. This gives clear indication that significant recharge can be caused by events while crops are growing, and are not just due to large summer rainfall onto sands with summer weed control.

It is likely that sites may react differently depending on specific sand properties, landscape variations and catchment management. More specific soil testing as to the water holding and infiltration properties of the sands at the sites may be advantageous in understanding these dynamics. Some sites have only recently data loggers, and will help inform these questions about the main contributors to recharge in the coming seasons.

Farmer management options being tested to try and improve water use in the catchment areas have shown positive results:

- Established lucerne has grown well even on the non-wetting sand and has been cut for hay on numerous occasions. Soil moisture use of the perennial deep rooted lucerne has been measured (using soil moisture probes) at over 50mm per annum more than the cereal hay grown alongside. The corresponding piezometer at this site showed a 20cm drop between March and Sept 2016, where other sites had an increase of between 70cm and 150cm.
- The effects of spading chicken manure in April 2016 have definitively continued into the second season, with 9t/ha reaping 1.9t/ha more wheat than the control area, with 2 year gross margins for the cost of the soil amelioration being in excess of $400/ha.

However, the area that was only spaded without chicken manure produced a poorer crop than the control in some areas. This is because the increased yield last season depleted the soil nutrition, with no manure to supply critical nitrogen, phosphorus and trace elements. This emphasizes that the benefits of spading chicken manure is in both breaking compaction as well as boosting soil nutrition and water holding capacity.

- Saltbush for grazing has grown well in seep areas, but all vegetation areas need some replanting due to establishment issues such as rabbits and hares that must be addressed.
- One farmer has successfully established a sunflower summer crop in an areas well away from the seep areas. Summer crops are sometimes opportunistically grown in the mallee, and are generally only successful with strong spring and summer rainfall, which is usually difficult to rely on.

These sites are also indicating various stages of seep formation through crop and vegetation changes that could assist farmers to identify emerging threats of seeps within currently productive farming land. Distinct colour differences towards the end of crop senescence in the October period appears to be a key indicator of paddock areas that are accessing late season moisture and are potential danger areas for seep formation.   Areas subject to long periods of moist soil soon become thick with ryegrass, out competing crops and persisting with growth much longer into the spring and summer months.

2 Introduction

This is the fourth report associated with monitoring 4 seep sites between Mannum and Karoonda that were originally established under the “On-Farm Trials and Demonstrations to Address Seeps in the Murray Mallee” project funded through the NR SAMDB.

Background to each site, EM38 mapping, soil tests and initial monitoring are contained in an earlier report entitled “On-Farm Trials and Demonstrations to Address Seeps in the Murray Mallee”, by Chris McDonough, Rural Solutions SA in July 2015. The second and third reports, “Monitoring Mallee Seeps Progress Report”, July-Dec 2015 and Jan-June 2016 are a continuation of monitoring of soil moisture readings, water table levels and the progress of various treatments at these 4 established sites. The reports also provide some recommendations for future seep management.

The findings from these four sites are providing valuable information for seep management across the Mallee and are often referred to at various farmer meetings, field days and site visits about soaks, their causes and management strategies that may be employed that fit in with different farming systems and needs.

3 Site Monitoring

3.1 Pope Site, Karoonda

Seep site at Popes, south west of Karoonda, has 2 main areas of focus. The first being the network of piezometers and moisture probes that allow assessment of groundwater levels in response to landscape, rainfall and farming systems influences, particularly after the high rainfall through Spring.

The second area of interest has been the crop results from the spading trial established in 2015. The treatment affects in the second year will help define the longer term value of each treatment, as well as their influence on soil water use that may impact on seep developments.

Table 1 shows that the 2016 rainfall received at Karoonda was well above the district average by nearly 240mm, with very high monthly totals in January, March, May, July, August, September and December. This has therefore been a good year to assess the impact of this rainfall on the catchment, water tables and seep areas.

Fig 1. Pope soak site with monitoring equipment approx. locations

Table 1. Karoonda 2016 and average annual rainfall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Karoonda 2016 Rainfall (mm)	35.2	6.8	53	8.8	54.2	31.2	57	70.4	119.3	34	28.2	83.8	581.9
Karoonda ave Rainfall (mm)	18.1	19.8	17.7	24.5	35.5	35.1	35.2	38.3	35.6	31.9	23.9	25.1	343.2

3.1.1 Pope Moisture Probe and Piezometer Results

There are 3 soil moisture probes at this site, each containing sensors at 20cm intervals, down to 90cm, as well as 5 piezometers within the immediate catchment (see Fig 1.).

The first moisture probe is placed on the top of the non-wetting sandhill at the southern end of the catchment (Photo 1). This paddock was sown to lupins in 2016, but did not have crop planted specifically around the probe, meaning that this graph does not directly reflect crop moisture use. It does, however, indicate which rainfall events have potentially contributed toward recharge. There are 2 rainfall events that show a sharp rise or spike in the 90cm probe sensor, suggesting that moisture may have leached beyond the rootzone. Figures 2, 3 and 4 show that on March 11th a 31mm rainfall that fell into a fairly dry soil profile caused recharge, while Sept 28-30 saw approx. 24mm over 2 days that also caused recharge into an already wet profile, close to its drained upper limit (see Fig 3.).

At this site piezometer PO8 has only recently had a data logger attached to it (see Fig 5.). The water table is approximately 7.5m below the surface. While there has been a slight change in the water level (within 10cm) it is too soon to assess any clear moisture responses.

Piezometer PO9 is situated at a nearby seep area that this sandhill appears to feed into. This seep is high in the catchment and overflowed after the March rainfall. Fig 6. shows a spike in the piezometer readings after the March rainfall event, then gradually lowering to a level in June that remained fairly constant through to September. *Unfortunately when the data logger was recalibrated in October there is a period of missing data (mid-Sept-Oct) and it is apparent from photos that the seep water level rose through this high rainfall period.* Fig 7. shows the decline of 85cm through November and December, also visible in Photos 2 & 3.

Figure 3 reveals that the soil moisture levels in the rootzone were consistently higher than at the end of the growing season in the 2 previous years, and there is far higher moisture through the profile going into 2017. While this is partially due to the lack of crop growing right next to the probe (see Photo 1), it is consistent with other nearby probe sites that did have surrounding crop growth (Figs 8 & 11), and equates to 30-50mm more soil moisture remaining in this sandy soil profile than at the end of 2014. Soil moisture levels prior to any summer rainfall are already similar to those of early March 2016, meaning that any rain event of 30mm or more is likely to lead to recharge. This suggests that these soils are more vulnerable to recharge, and seeps areas are more likely to fill up and grow with lower levels of rainfall in 2017, since the soil profiles are already moist.

Fig 2. Soil moisture probe readings for non-wetting sandhill site, May 2014-Dec 2016

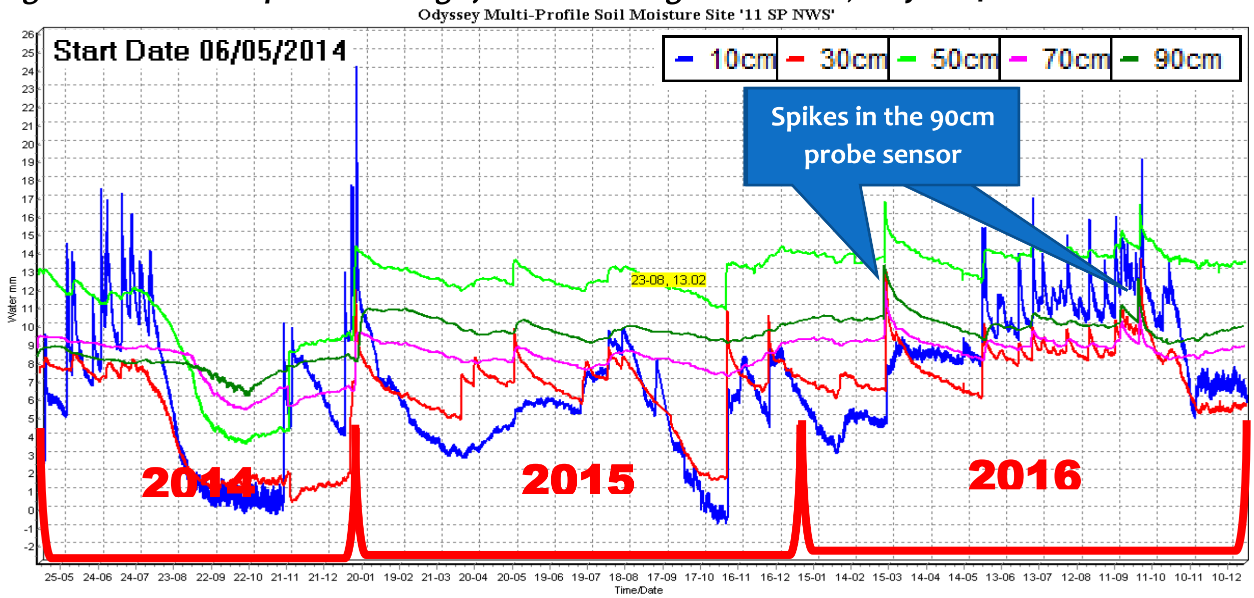


Fig 3. Summed soil moisture probe readings for non-wetting sandhill, May 2014-Dec 2016

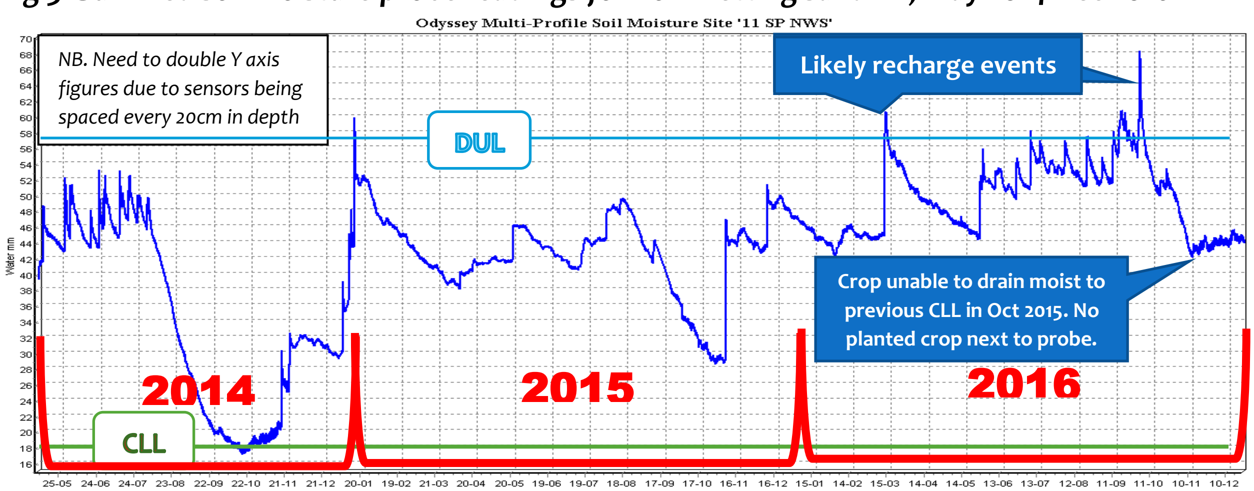


Fig 4. Matching rainfall, May 2014-Dec 2016

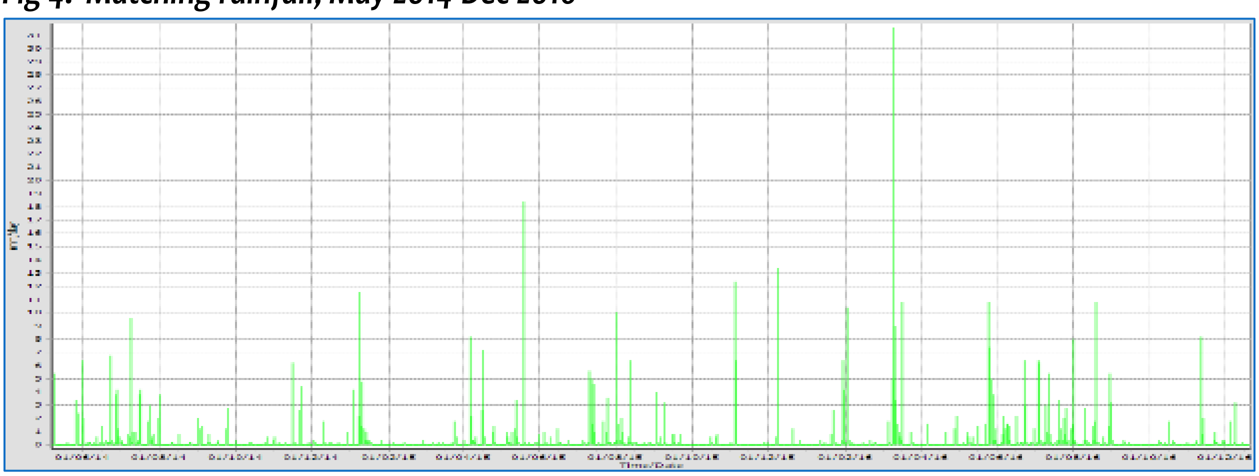


Fig 5. Piezometer 8, groundwater level for southern sand hill, Nov - Dec 2016

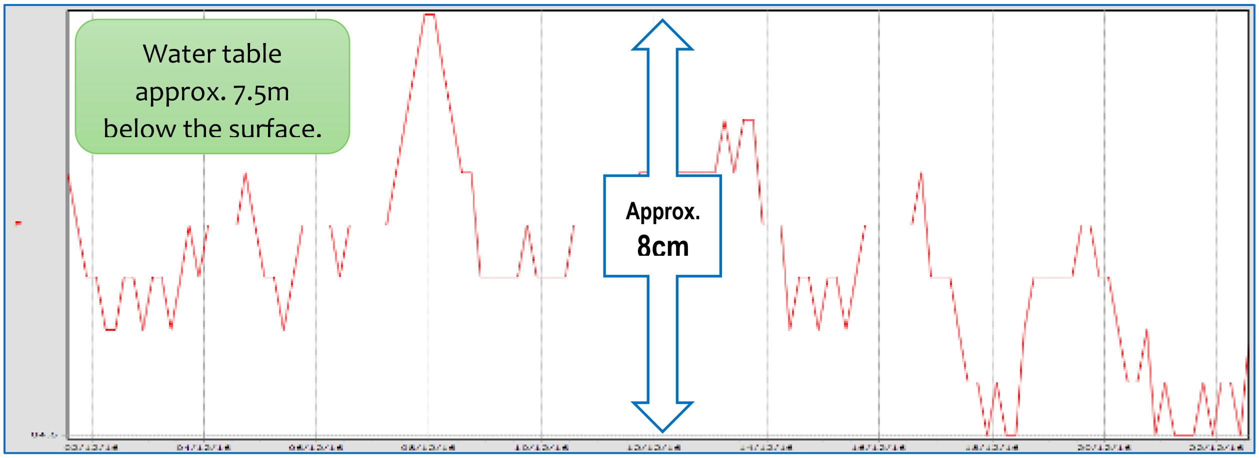


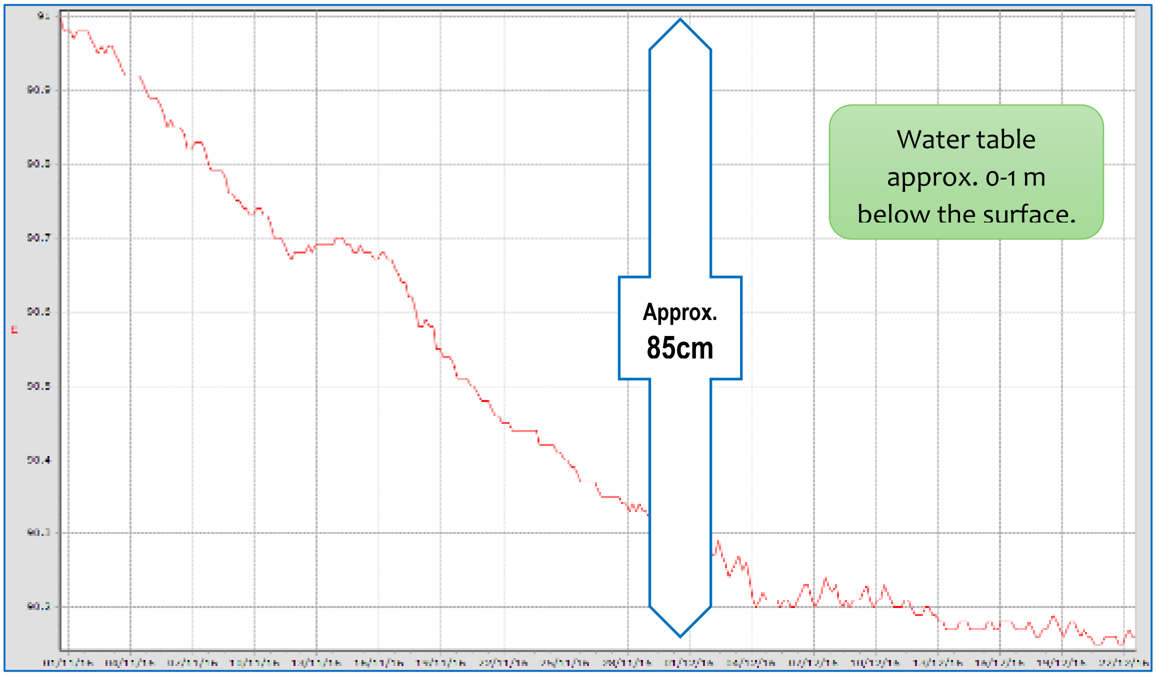
Photo 1. Non-wetting Sandhill moisture probe & Piezometer 8 with upper seep in background

Photo 2. Piezometer 9 at upper catchment seep which was full on Oct 31st 2016.

Photo 3. Piezometer 9 at upper catchment seep which was receding on Dec 22nd 2016.

Fig 6. Groundwater level for Piezo 9, high southern seep, Feb - Sept 2016

Fig 7. Groundwater level for Piezometer 9, high southern seep, Nov - Dec 2016



The second and third soil moisture probes are located within the spading trial just south of the main soak in deep sand with a clay layer at approximately 90cm depth. *It is worth noting that not all of the Sept rain events appear on the rain gauge graph (Figs 8 and 10) which are clearly visible in the topsoil moisture readings. This may be due to the storm clouds missing the gauge or more likely a blockage in the gauge funnel caused by bird droppings (which has since been rectified). The Karoonda rainfall data shows rainfall events.*

Figures 8, 9 and 10 show the soil moisture at the control treatment area matched against the site rainfall. The 90cm sensor shows higher soil moisture because it sits within the top of the clay. At this site it would appear that the only rainfall event clearly contributing to recharge is the 31mm in March. However, if the clay at 90cm is already at a field capacity to saturated level, then it is possible that spikes at the 70cm sensor may be more indicative of recharge events, contributing to mainly lateral moisture movement at 90cm. It is therefore possible that the September rainfall did contribute to recharge. Photos 4, 5 & 6 show that moisture has been consistently seeping throughout the season from the paddock sand into the seep area from the south where the probes are located.

The probe sensors within the spaded chicken manure treatment generally shows similar impacts to the control probe, in regard to rainfall events that most likely contributed to recharge (Figs. 11-13). There is, however, clearly less soil moisture at the start and end of the season at this site, due to the deep root penetration higher crop water use (25-30mm difference each year). This is a positive indication that the soil amelioration has the potential to reduce the groundwater pressure on the growing seep area.

Fig 8. Soil moisture probe readings for control site, July 2015 - Oct 2016

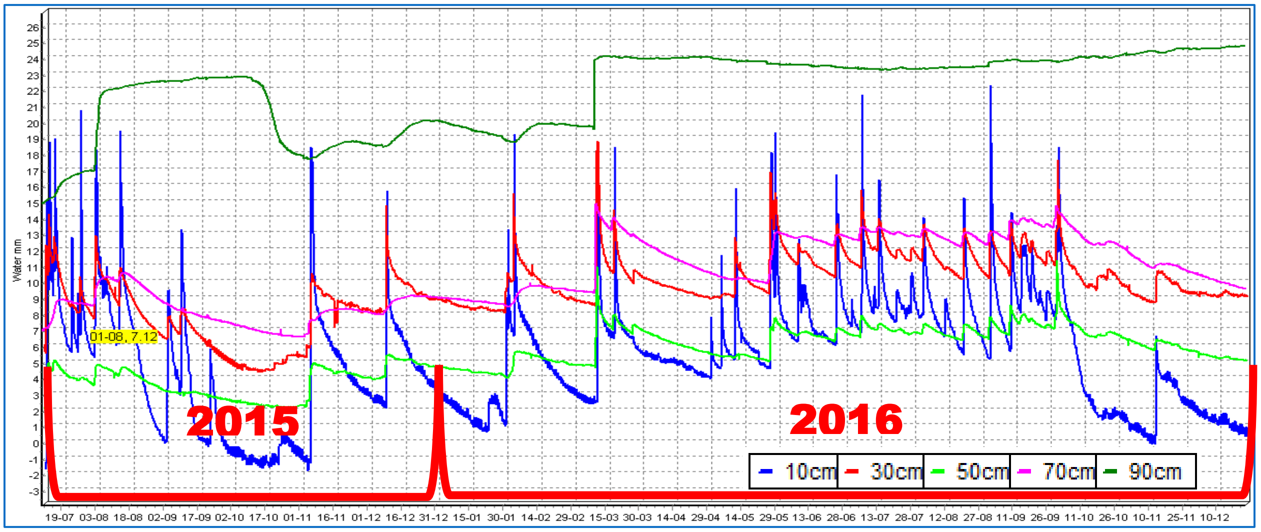


Fig 9. Summed soil moisture readings for control site, July 2015 - Oct 2016

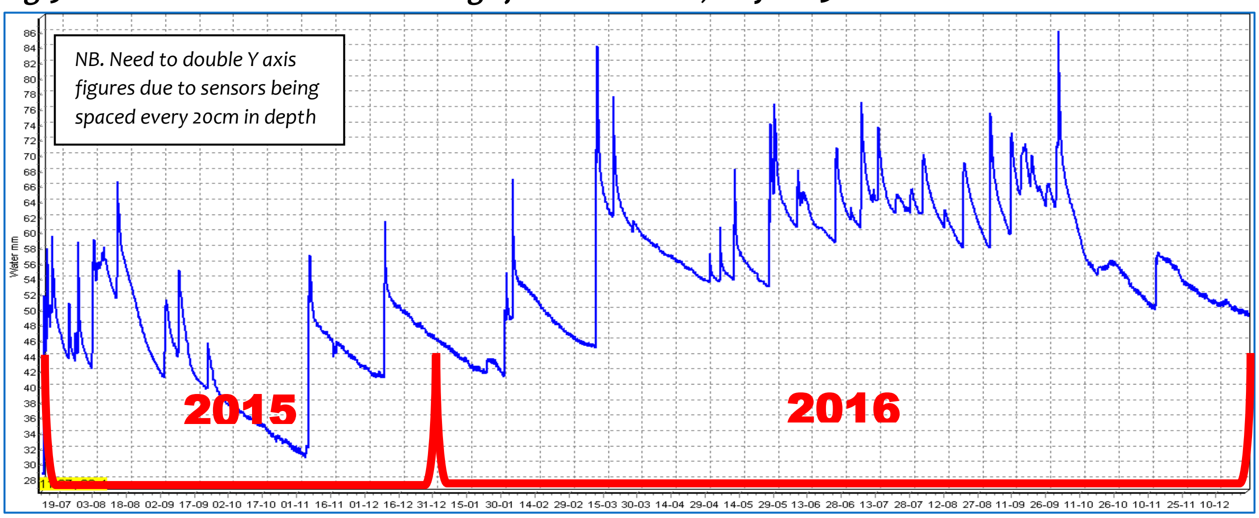


Fig 10. Matching site rainfall, July 2015-Dec 2016

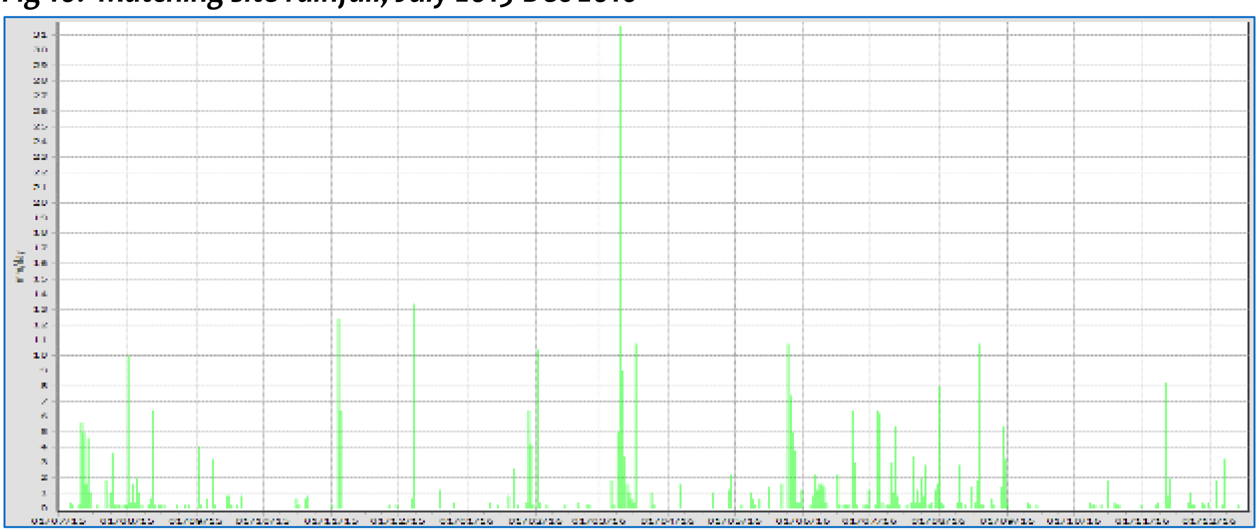


Photo 4. Moisture still seeping out of the sand into main the seep on Oct 31

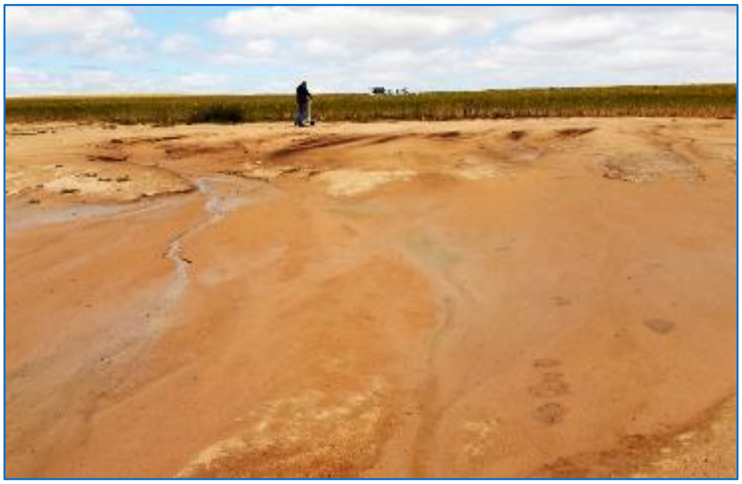


Photo 5. Moisture still seeping to the surface at the main soak, Dec 1.

Photo 6. Moisture still seeping to the surface at the main soak, Dec 22.

Fig 11. Soil moisture probe readings for spaded chicken manure, July 2015 –Dec 2016

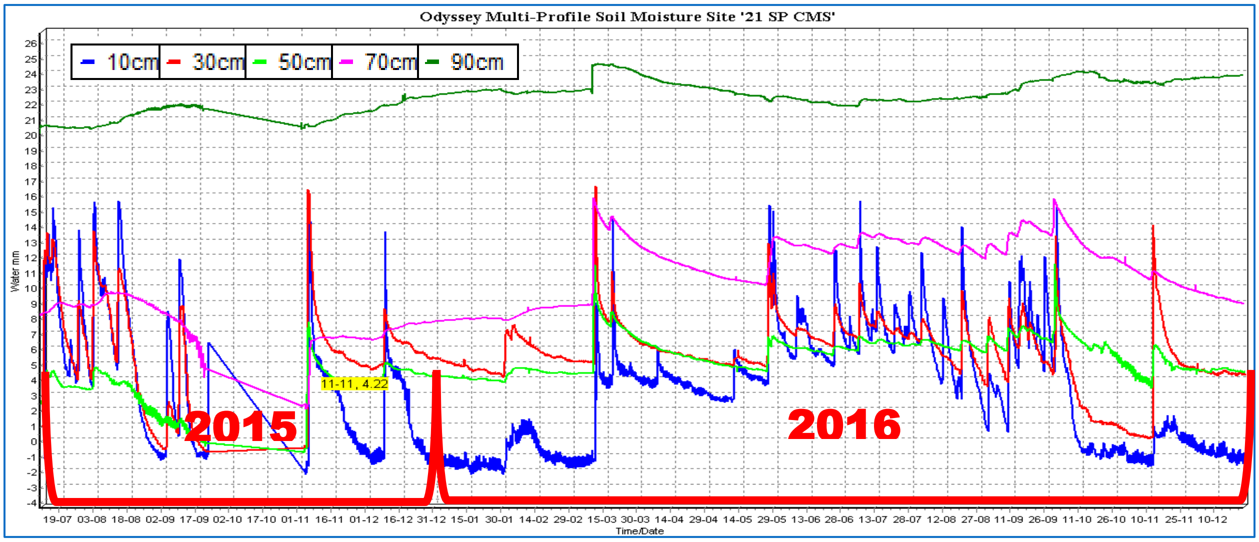


Fig 12. Summed soil moisture readings for spaded chicken manure site, Oct 2015-May 2016

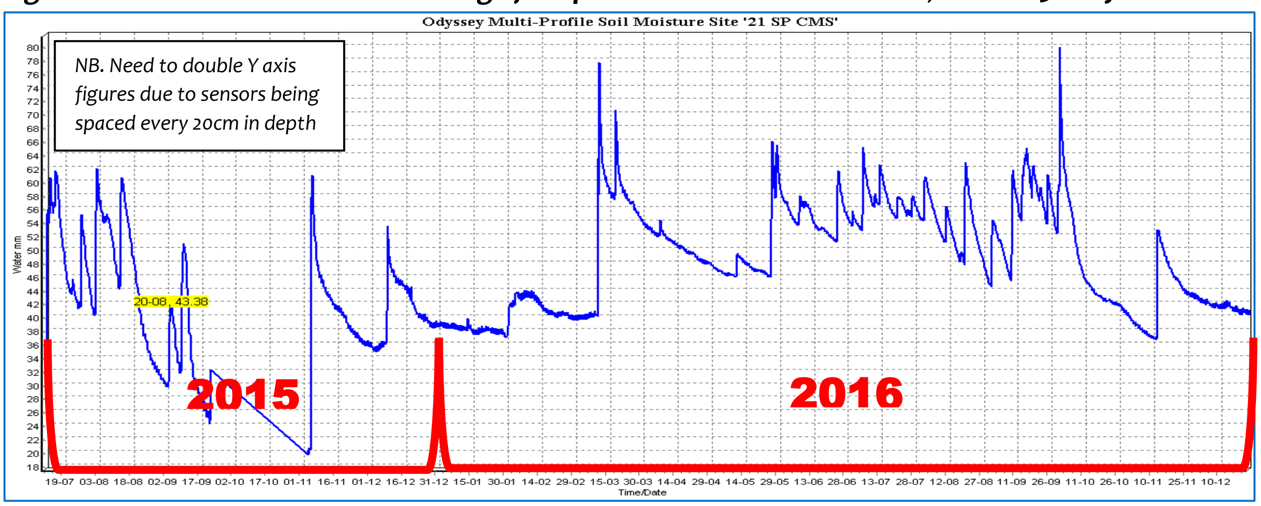
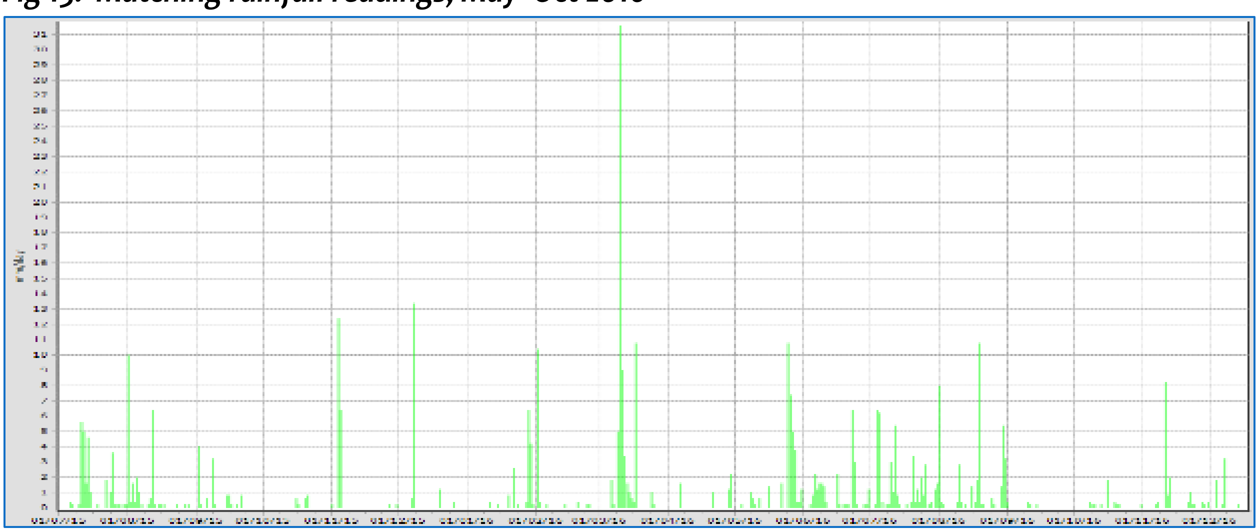


Fig 13. Matching rainfall readings, May- Oct 2016



Piezometer 7 is located on the southern side of the main soak area. The initial water level was recorded at 3.5m at installation in Feb 2016, which would have risen after the March rainfall similar to PO9. A data logger was installed in on Oct 31 which has only shown a slight downward trend in the 7 weeks of recording. The impacts of rainfall events at this site may be both immediate as well as longer term as this seep is at the bottom of a large catchment. The piezometer data will provide useful information into the future.

Piezometer PO6 had a re-used data logger attached when established in Feb 2016. The sensor strip on this older logger only had a range of about 1.5m length, which was already partially in the water as expected. This site, however, experienced an unusually high rise in the water table for a mid-slope area well away from the seep scald, as shown in Fig 14. This rise of approximately 75cm engulfed the data logger on Aug 16 when it ceased to record. While the water level at this site would have continued to rise after this, it was not able to be rectified until Oct 31 with a new data logger with a 4m sensor strip. Fig 15 shows the new set of recording from this time begin at a level 25cm higher when the original data logger stopped. The high rainfall in September, as well as the slope of the graph when it resumed in November suggests that the water level rose by well over a meter overall, but the peak of the rise is unknown.

This large groundwater rise in this mid-slope suggests a strong lateral movement of water through this area towards the main seep. There is a large area of poor crop growth developing on this side of the main seep toward this probe site (see Fig 17 & Photo 13).

Piezometer 5 is in the midslope fence line well south of the main seep area. Figure 16 shows a 30cm drop in the water level in the 7 weeks after it was put in on Oct 31.

Fig 13. Piezometer 7, groundwater level for main seep, Nov - Dec 2016

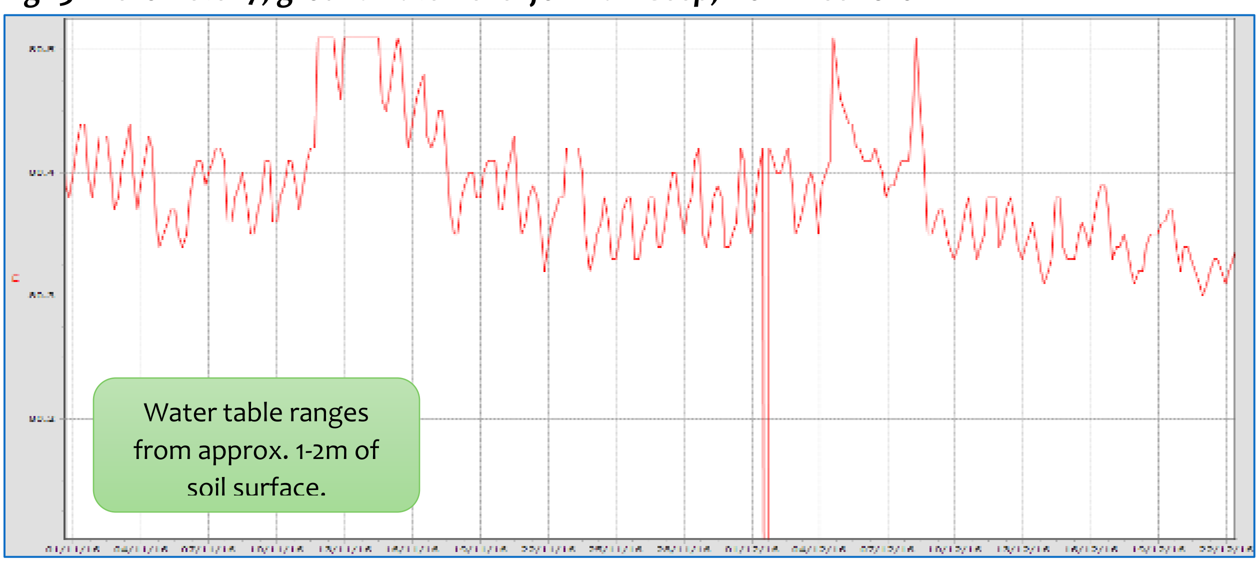


Fig 14. Piezometer 6, groundwater level for eastern fenceline, March - Aug 2016

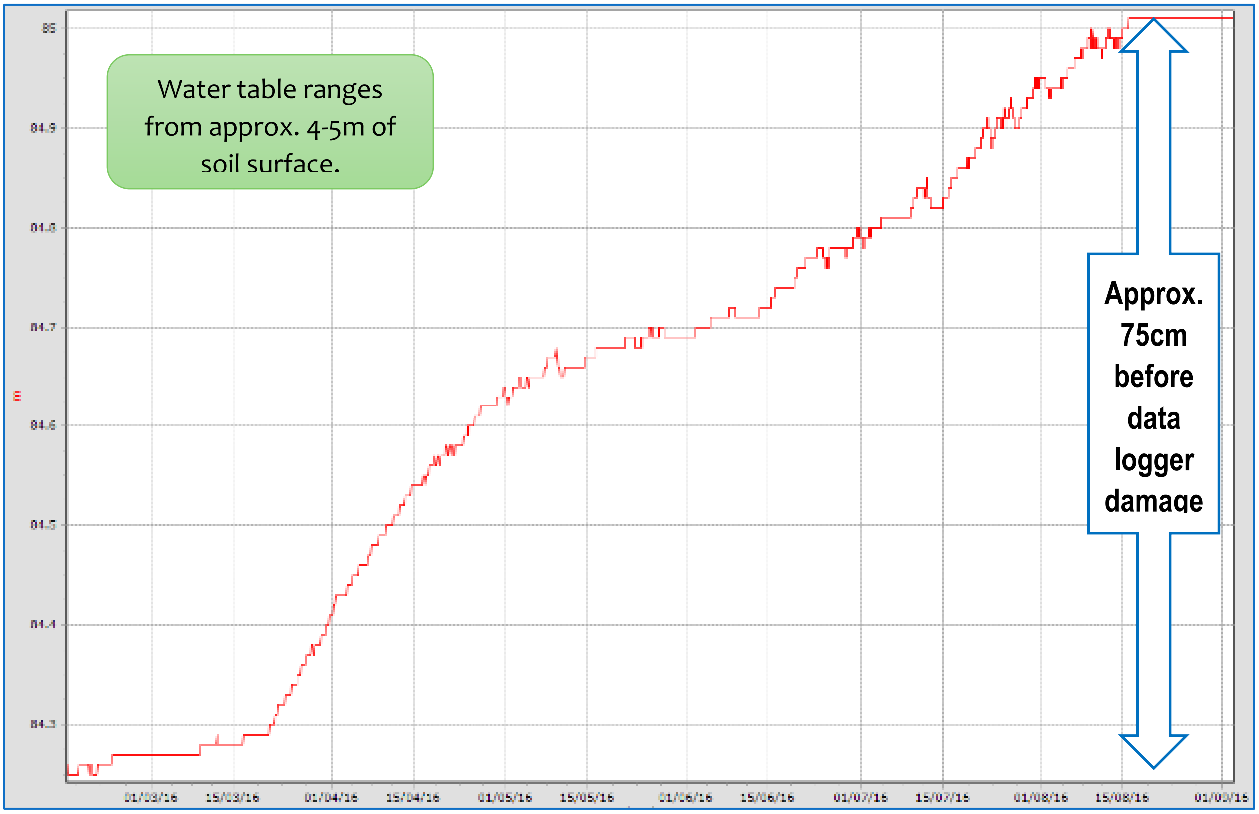


Fig 15. Piezometer 6, groundwater level for eastern fenceline, Nov - Dec 2016

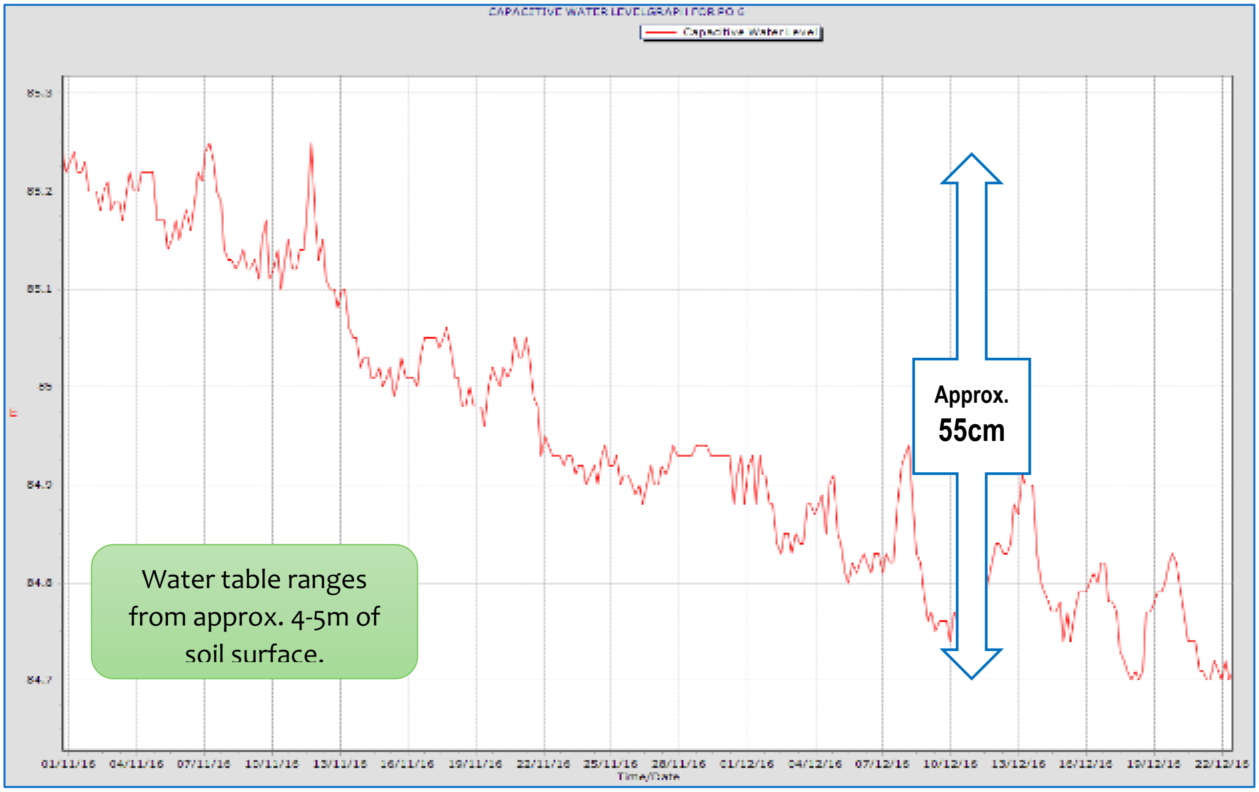
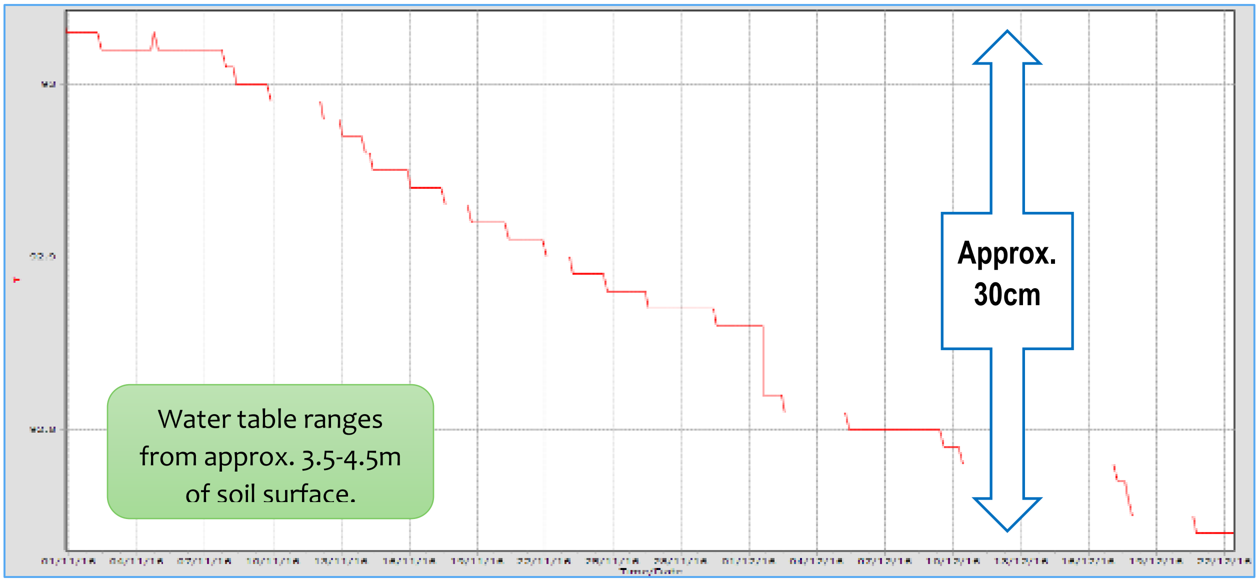


Fig 16. Piezometer 5, moisture readings for southern fence line, Nov - Dec 2016



Soil moisture data from this catchment shows that there have been 2 specific times that rainfall events (in both March and September) appear to have directly led to moisture passing beyond the crop root zone to potentially contribute to ground water recharge. The 2 piezometer sites which have collected data since Feb 2016 both show an initial sharp rise in groundwater after the heavy March rainfall. This level continued to rise in the lower end of the catchment through September. As the heavy crops were at their highest water use through spring, it is unclear how significant the high spring rainfall contributed to the groundwater recharge, as all piezometers levels were found to be receding at various levels in November and December.

Now that all of the piezometers have data loggers, it is expected that they will be extremely informative as to the catchment moisture dynamics in the coming years.

3.1.2 Pope Spading Trial 2nd Year Results

Figure 17 shows the 2016 Google earth map of the trial site taken in October while the crop was still ripening. While it shows there are some inherent natural soil differences across the main site, it clearly shows a darker green crop where the chicken manure was spaded in 2015, which is also very clear on the northern trial site area, where the 12t/ha spaded chicken manure area is outstanding. Unfortunately this northern trial is too steep and sandy for the plot harvester traverse and gather yield data.

There is also evidence of where the farmer spread his left over urea for the paddock which included a small corner of the original trial. This has been accounted for in the trial analysis. While this is a farmer scale trial covering 3.7ha, the plots were harvested using the SARDI plot harvester and samples taken for yield and quality analysis. Each treatment was divided into 3 sections to help make more direct comparisons between the similar sand zones, as shown in Fig 17. Section 2 generally was the worst sand, followed by Section 1, while Section 3 is inherently slightly more productive sand. 2 reaping passes were made through each treatment, meaning a total of 6 plot samples were taken from each treatment. The complete results data is shown in Table 3, with treatment averages shown in Table 2.

Fig 17. Trial site map around main seep area (Google Earth Oct 2016)

Table 2 shows a summary averaging all treatment plots, and clearly indicates that the spaded chicken manure treatments have continued to significant yield advantages over the control areas of 1.9t/ha for the 9t/ha spaded chicken manure, and 1.4t/ha for the 6t/ha spaded chicken manure. The 2 year gross margin which takes into account the high initial cost of these soil amelioration treatment, show that the benefits have already outweighed the costs by over $400/ha where chicken manure was spaded, while the ongoing value of spading only has been diminished.

Table 3. 2016 Trial Treatment Results averaging all plot sections.

Treatment	Ave Treatment Yield (t/ha)	Ave Treatment Protein (%)	Ave Yield above Control (t/ha)	Ave N Export in Grain (kg/ha)	Ave Treat. 2 Year GM over Control ($/ha)
Control West	2.3	8.2		85	
Spaded Only	2.2	7.9	-0.14	77	$41
Sp Chicken Man 9t/ha	4.2	8.9	1.87	169	$416
Sp Chicken Man 6t/ha	3.7	8.7	1.44	148	$425
Control East	2.3	7.8		81	

The Spaded Only area yielded poorer than the control and exported less N. This is because the higher yields from Spaded Only in 2015 exported more N, leaving 27kg/ha less N in the soil profile according to deep soil test taken in June 2016 (see Table 5). This clearly shows the importance of supplying extra nutrition with the spading, if longer term yield benefits are to be experienced. While spading can loosen compacted sand and allow roots to access deep soil moisture, these sands are still naturally extremely infertile and cannot reach yield potential without significantly higher nutrition.

These soil test results also show that the N levels from the spaded chicken manure areas were similar to the control areas in June 2016 after exporting significantly higher N in the 2015 yields. The fact that the higher yields and proteins in 2016 led to 84kg/ha more N exported from the 9t/ha area than the control area, and 63kg/ha from the 6t/ha area, show that the chicken manure is continuing to contribute significant amounts of N into soil throughout the growing season.

Table 2. Complete plot harvest details by treatments and plot sections, including grain quality

Treatment	Section Area	Rep	1. Yield (t/ha)	2. Protein (%)	3. Screenings (%)	4. N exported in grain (kg/ha)	5. Diff in N export over control (kg/ha) ave.	6. Ave yield (t/ha)	7. Ave Protein (%)	8. Yld Above Control (t/ha)	9. % Yld Increase
Control West	1	a	2.59	8.3	1%	98	Ave N export				
Control West	1	b	1.73	8.2	1.8%	64	86	2.16	8.3		
Control West	2	a	2.54	8	1.3%	92					
Control West	2	b	1.67	7.8	2.5%	59		2.10	7.9		
Control West	3	a	2.59	8.3	1.5%	98	Soil Test N				
Control West	3	b	2.64	8.6	1.4%	103	60kg/ha	2.61	8.5		
Spaded Only	1	a	1.80	8.2	1.6%	67	Ave N export				
Spaded Only	1	b	1.75	7.6	1.5%	60	79	1.77	7.9	-0.38	-18%
Spaded Only	2	a	1.43	7.3	2.1%	47	- Control				
Spaded Only	2	b	1.65	6.9	2.1%	52	-6	1.54	7.1	-0.56	-27%
Spaded Only	3	a	3.13	8.4	1.5%	119	Soil Test N				
Spaded Only	3	b	3.17	9	1.4%	130	33kg/ha	3.15	8.7	0.53	20%
Sp Chicken Man 9t/ha	1	a	4.23	8.4	1.7%	162	Ave N export				
Sp Chicken Man 9t/ha	1	b	3.37	8.6	1.5%	132	174	3.80	8.5	1.64	76%
Sp Chicken Man 9t/ha	2	a	4.97	8.1	0.9%	183	- Control				
Sp Chicken Man 9t/ha	2	b	3.18	9.8	1.4%	142	89	4.07	9.0	1.97	94%
Sp Chicken Man 9t/ha	3	a	4.38	9.2	1.2%	183	Soil Test N				
Sp Chicken Man 9t/ha	3	b	4.87	9.3	1.0%	206	58kg/ha	4.62	9.3	2.01	77%
Sp Chicken Man 6t/ha	1	a	3.84	8.3	1.4%	145	Ave N export				
Sp Chicken Man 6t/ha	1	b	4.31	9.6	1.7%	188	149	4.07	9.0	1.92	89%
Sp Chicken Man 6t/ha	2	a	3.07	8.2	1.5%	114	- Control				
Sp Chicken Man 6t/ha	2	b	3.07	8.3	1.4%	116	64	3.07	8.3	0.96	46%
Sp Chicken Man 6t/ha	3	a	4.41	9.2	1.6%	184	Soil Test N				
Sp Chicken Man 6t/ha	3	b	3.70	8.8	1.4%	148	69kg/ha	4.06	9.0	1.44	55%
Control East +N*	1	a	2.79	9.7	3.9%	123					
Control East +N*	1	b	2.69	10.1	4.0%	123		2.74	9.9		
Control East	2	a	1.92	7.6	1.4%	66	Ave N export				
Control East	2	b	1.99	7.2	2.2%	65	82	1.95	7.4		
Control East	3	a	2.54	8.7	1.6%	100	Soil Test N				
Control East	3	b	2.72	7.8	2.5%	96	60kg/ha	2.63	8.3		

*Farmer spread leftover urea at very high rate (100-150kg/ha) on this area, so has not been included in treatment averages

Table 3 shows the harvest results of all the trial plots. Column 2 shows that all plots had protein levels below what is required to achieve APW quality. While the nitrogen supplied by the 6 and 9t/ha of chicken manure treatment areas has generally resulted in higher protein levels, the yields of these plots averaging between 1.4-1.9 higher than control was where the majority of extra available N was utilized. This is clearly evidenced in column 4 highlighting the N export in the grain based on yield and protein, where the 9t/ha chicken manure spaded plots found and exported 89kg/ha N more than the control, while the 6t/ha chicken manure spaded area exported 64kg/ha more N.

Columns 6-9 of Table 3 are colour coded so that direct comparisons can be made between the different sand zones within the trial area. Table 4 provides a comparative gross margin assessment of the cost of the various treatments over the control plots. Because all the extra cost occurs in the first year, the 2 year gross margin of the 9t/ha treatment is now very similar to the 6t/ha treatment (as the higher cost of the 9t/ha site was still slightly negative after year 1). The higher rate has resulted in the highest yield in 2016 and a 2 year gross margin of $416/ha, with the 6t/ha plot (although yielding slightly lower) showing a 2 year gross margin above the control area of $425/ha.

An average grain price of $220/t was used in gross margin calculations for both years. While this is slightly higher than the present grain prices, it does reflect a more average grain price for the region. It is interesting to note that the spading chicken manure treatments have consistently shown the highest gross margin advantage over the control in section 2, the poorest sand area, as can be seen in Tables 2 and 4.

Table 4. Gross Margin analysis for treatment costs above control areas.

Treatment	Original Treatment cost $/ha	YR 1 (2015) GM over control @ $220/t	YR 2 (2016) GM over control @ $220/t	2 Year GM over control ($/ha)	Ave Treat. 2 Year GM over control ($/ha)
Spaded Only	$100	$31	-$84	-$53	
Spaded Only	$100	$21	-$124	-$104	$41
Spaded Only	$100	$162	$118	$280	
Sp Chicken Man 9t/ha	$415	-$125	$361	$236	
Sp Chicken Man 9t/ha	$415	$164	$434	$598	$416
Sp Chicken Man 9t/ha	$415	-$28	$442	$415	
Sp Chicken Man 6t/ha	$310	$3	$421	$424	
Sp Chicken Man 6t/ha	$310	$265	$212	$477	$425
Sp Chicken Man 6t/ha	$310	$55	$318	$373	

Table 5. Second year soil testing at spading site for changes & carry over nutrition, June 2016

Apal	Mg	Na	Nitrate NO3	Ammonium	Avail N	Colwell K	Organic Carbon	Colwell P	PBI	CL Sulfu	Exch K	Exch Ca	Exch Mg	Exch Na	ECEC	Exch K	Exch Ca	Exch Mg	Exch Na	Ca:Mg
	mg/kg	mg/kg	mg/kg	mg/kg	kg/ha	mg/kg	%	mg/kg		mg/kg	c.mol/kg	c.mol/kg	c.mol/kg	c.mol/kg	c.mol/kg	%	%	%	%	ratio
POPE CONTROL 0-10	43.9	8	7.5	8	26	72	0.48	30	13.3	5.2	0.144	1.372	0.361	0.035	1.93	7.47	71.00	18.70	1.80	3.80
POPE CONTROL 10-40	38.1	24.2	2.2	3.7	30	48	0.11	17	12.8	4.3	0.103	1.747	0.314	0.105	2.27	4.52	77.01	13.83	4.64	5.57
POPE CONTROL 40-60			0.5	0.5	3															
				Total	60															
POPE 6TCM 0-10	39.3	8	5.5	5	18	81	0.31	25	10.8	9.2	0.166	1.072	0.323	0.035	1.61	10.32	66.76	20.14	2.17	3.32
POPE 6TCM 10-40	30.4	8	2	5.3	37	72	0.11	15	11.5	3	0.174	1.022	0.250	0.035	1.49	11.65	68.57	16.78	2.33	4.09
POPE 6TCM 40-60			0.5	0.5	3															
				Total	58															
POPE 9TCM 0-10			17.1	4.9	37															
POPE 9TCM 10-40			3.8	0.5	22															
POPE 9TCM 40-60			1.6	1.1	9															
				Total	69															
POPE SPADED 0-10			3.8	2.3	10															
POPE SPADED 10-40			3.3	0.5	19															
POPE SPADED 40-60			0.5	0.5	3															
				Total	33															

3.1.3 Further Trial and Catchment snapshots

Photo 7. Thick wheat crop heads evident on Dec 1, from Spaded Chicken manure 9t/ha area

Photo 8. Poorer wheat crop growth evident at harvest, from Spaded Only area

Photo 9. Control area wheat crop looking slightly improved over Spaded Only area

Photo 10. Soil pit near main seep area showing water table at about 1m depth

Photo 11. Recording data from Piezometer 5 at top of main seep scald

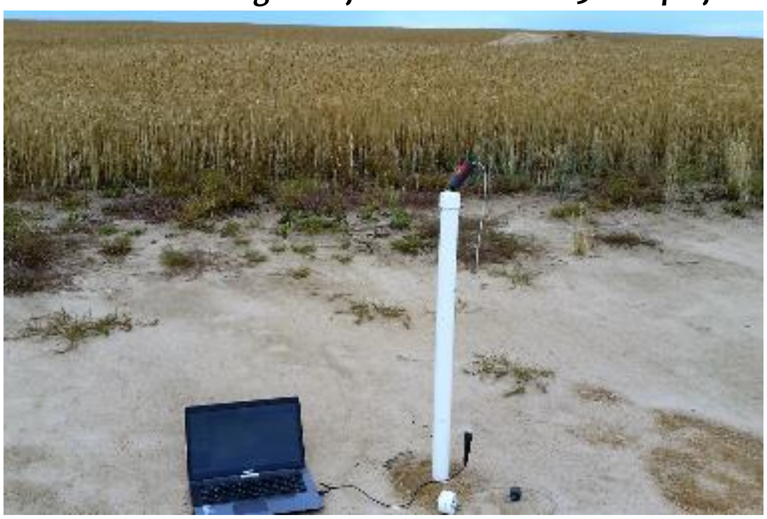


Photo 12. Growing areas of poor crop growth with soak extending on western side.

Photo 13. Areas of ryegrass and poor crop growth forming on east side of main soak

Photo 14. Midslope fence line Piezometer 6 east of main seep scald

Photo 15. Piezometer 8 and soil moisture probe at top of non-wetting sand hill

Photo 16. Receding water table at top seep area, near Piezometer 9 on Dec 22.

Photo 17. Overflow area from top soak area that has prevented any lupin crop growth.

Photo 18. Growing seep areas on western area of wider catchment

3.2 Rose / Thomas Site, Wynarka

2016 was a very wet year at Wynanka, with annual rainfall similar to the Karoonda monthly records shown in Table 1. This appears to have contributerd to an expansion of both the established and newly forming seep areas, indicated in Fig 18. This is of great concern to the farmers involved as they experience valuable farming land become unproductive.

Monitoring shows that rainfall events directly contributing to water level recharge within this catchment may need to be as high as 40-50mm at some times of year, but can be as low as 10-12mm at other times, depending of the level of soil moisture at the time as well as the level of vegetative water use (crop, pasture, trees etc) at the time of that event.

Fig 18. Site map showing seeps and monitoring equipment locations (Google Earth Oct 2016)

3.2.1 Seep area

The piezometer RO3 readings from the edge of the main soak has been most responsive to rainfall events, with surface water evident for much of the growing season. Fig 20 shows the main initial filling (water level rise of 55cm) after the March rainfall event of over 50mm within a few days (Figs 19 & 20), but this reduced greatly over the following month. This March rainfall happened when most of the rootzone in the catchment was dry, and therefore had the capacity to absorb much of this rainfall without contributing to recharge. However, the size of this event must have exceded this capacity and therefore led to water accumulation at the main seep.

Figs 19 and 20 show the next sharp rise in water levels come after much smaller rain events of 10-12mm over a few days in mid May. This was then followed a very significant filling and overflow of the seep area (apparent from the flattenting of the red graph line at the top) after rainfall of approximately 15mm over 2 days in late May.

The rest of this above average rainfall growing season sees RO3 rise and fall by 5-10cm, before it begins a steady decline in October, when the crop water use in surrounding paddocks is at its highest, temprature levels and evapotation are increasing, and there is a breif period of very little significant rainfall.

Fig 19. Rainfall records from site Nov 2015 -- May 2016.

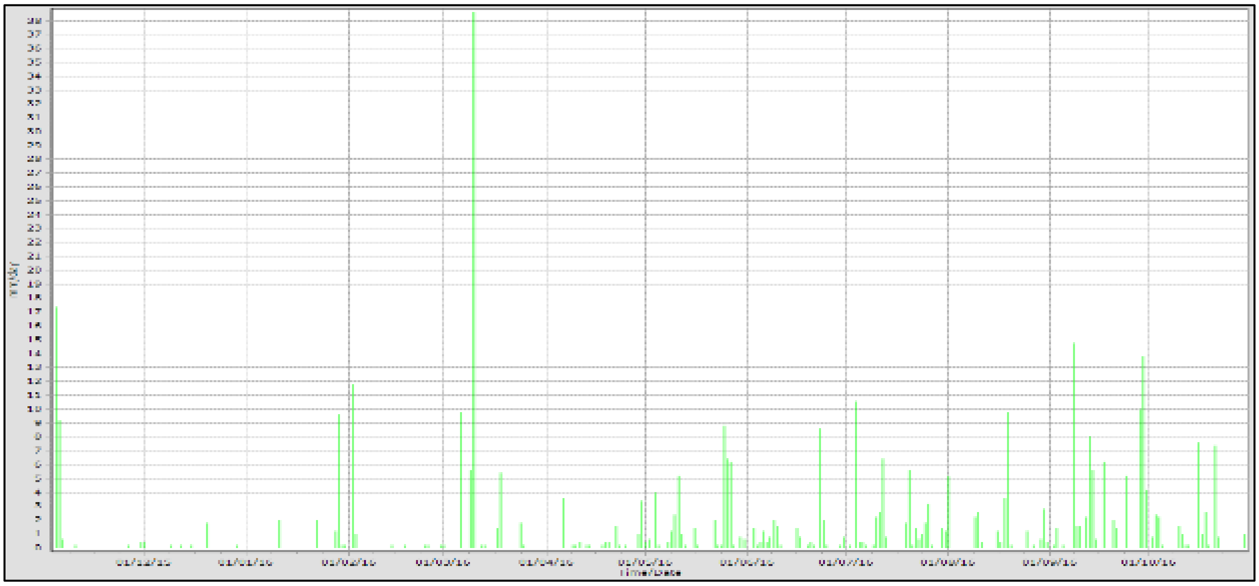
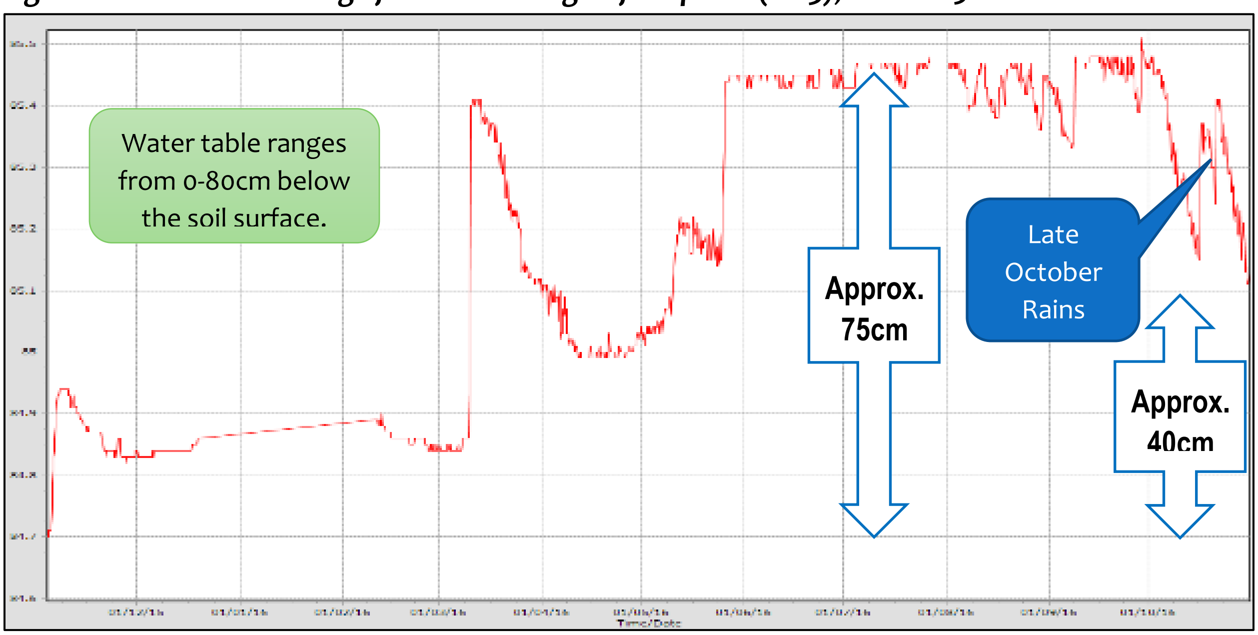


Fig 20. Piezometer readings for Bottom edge of seep site (RO3), Nov 2015 - Oct 2016

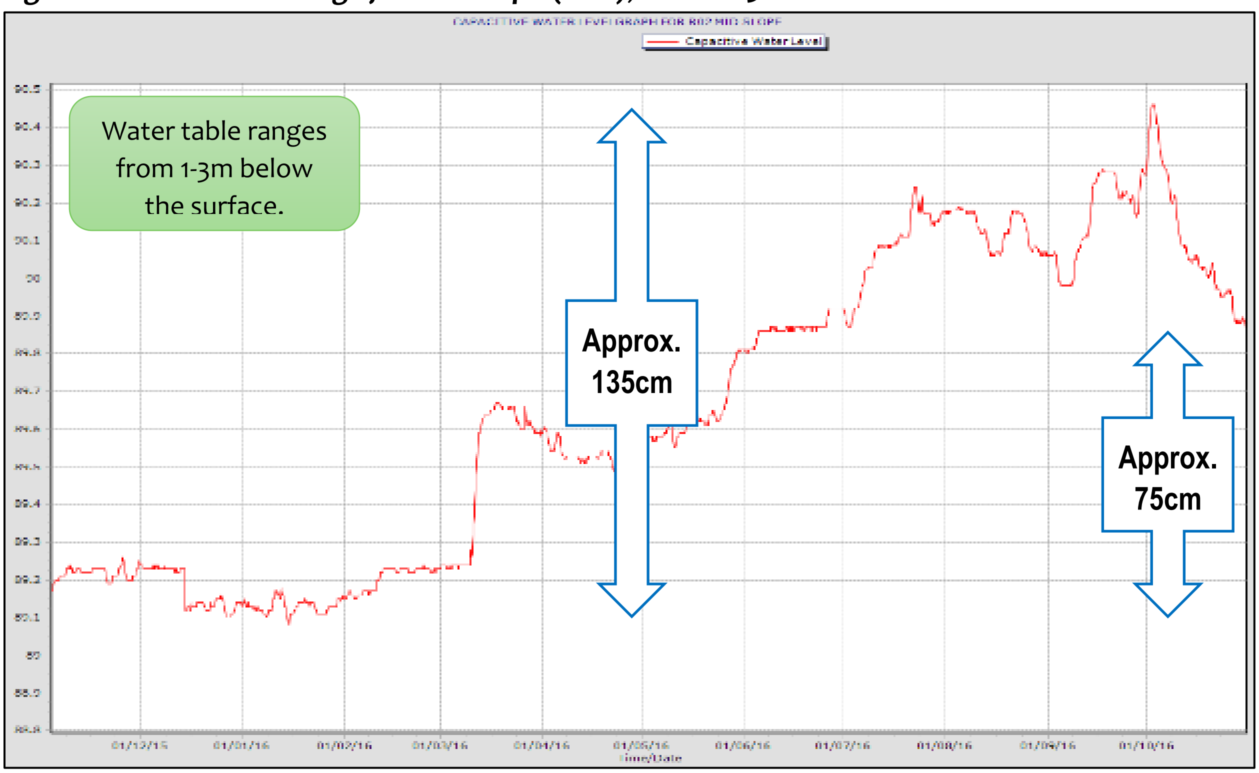


3.2.2 Midslope area

The Piezometer RO2 in the midslope above the seep (Fig 21) shows an initial rise in water level of about 40cm after the March rainfall event, with a less dramtic fall over the following month than RO3, due to the more gradual infiltration of water through the soil profile to the deeper perched water table at initially around 2m. The water level then continues a steady rise of about 80cm over the winter months, with specific rises attributable to rainfall events. **This is a significant finding, showing that multiple seasonal rainfall events are contribtuing to reacharge, even through the growing season of an above average rainfall year when there is a crop growing. It shows that these non-wetting sands are not just contributing to reacharge after summer rainfall events when summer weeds are controlled.**

There is a sharp decline in water table from the start of October, which suggests that this period of high crop water use has decreased the pressure of the immediate surrounding catchment contributing water into the seep area. It may also suggest that some of the saturated soil in this profile still sits within the rootzone of the cereal crop.

Fig 21. Piezometer readings for Mid-slope (RO2), Nov 2015 - Oct 2016



The moisture probe in the midslope an the northern side of the same sandhill (Fig 22) shows clear responses to rainfall events in the top 40cm ver the las 3 seasons. It also appears that 50, 70 and 90cm sensors are in soil that may well be close to saturation, but it would be good to confirm this with some targeted soil testing and texturing. It may be the case that the sharp spikes in the light green 50cm sensor line may be indicators of direct rainfall reacharge at this site clearly indicated in both Marcha and Sept 2016.

It is interesting that there were two 7mm rainfall events in late October that both cause brief spikes in the water level of 20cm at the seep area (RO3). This, however, is not registered as affecting the water level at the midslope (RO2), and the soil moisture probe only registers spikes at the 10cm sensor. It is therefore likely that this rise at the seep was from a direct water accumualtion from the immediate scald catchment area, which then quickly evaporated or settled out over the following 2 weeks, rather than from a significant contribution from even the slightly the wider catchment area.

Fig 22. Soil moisture data from midslope probe above northern seep (May 2014 – Nov 2016)

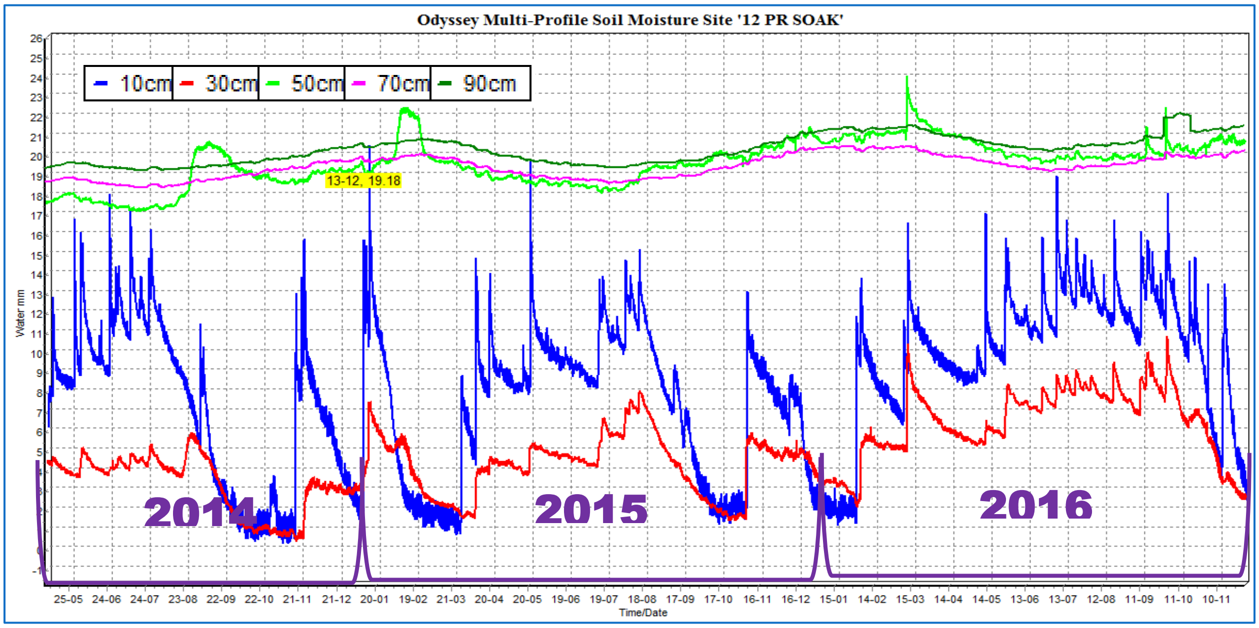


Fig 23. Matching cumulative moisture data from midslope probe (May 2014 – Nov 2016)

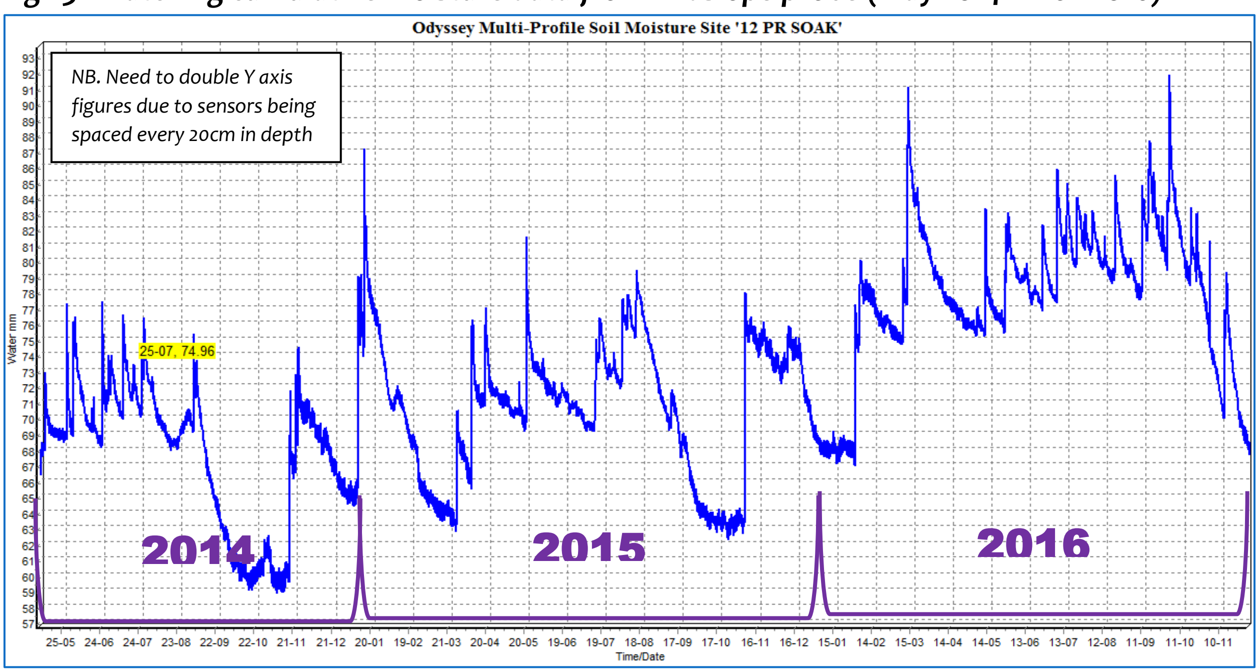
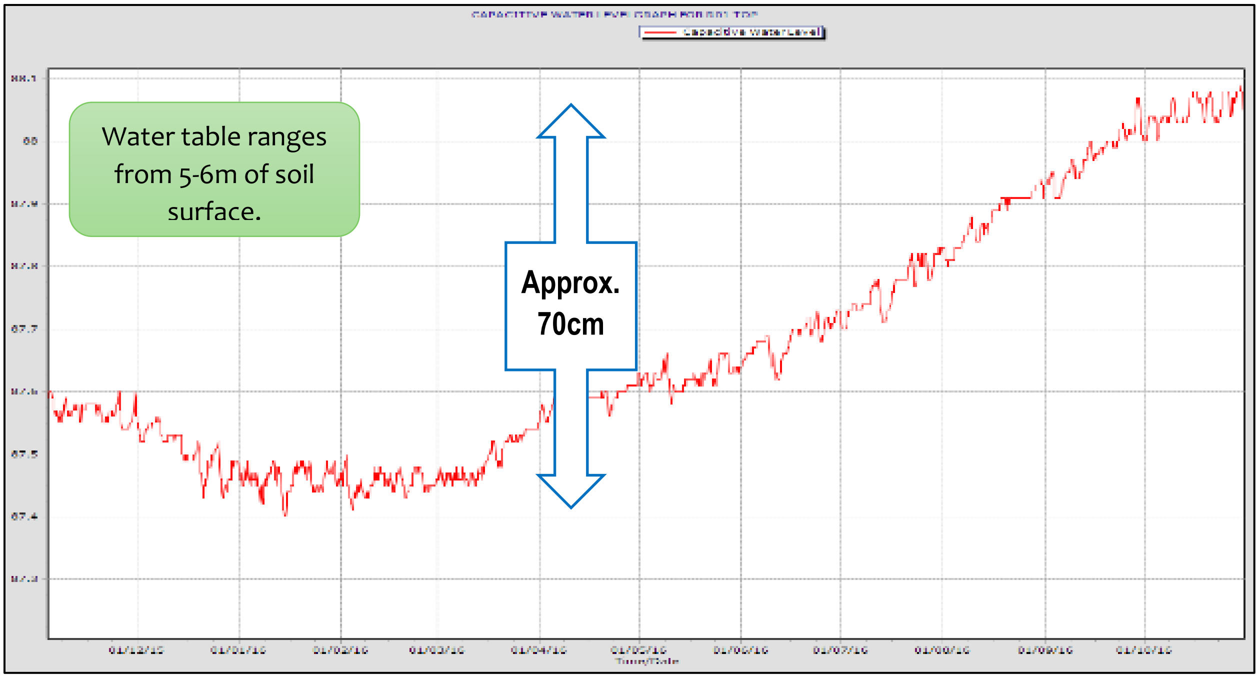


Fig 24. Piezometer readings for top of sand hill (RO1), Nov 2015 - Oct 2016



3.2.3 Top of Sandy Rise

The piezometer readings from the top of the sandhill shows a steady rise in of 70cm since the March rainfall event (Fig 24). Since the water table is 5-6m below the surface it is not surprising that there has been no dramatic fluctuation in water level. There appears to be a slight leveling of the graph towards the end of October.

As this peizometer is at the top of the sandhill it is likely that the rise in water table has come directly form the infiltration of the season rainfall, rather than any lateral movement from the regional catchment. This particular sand would have very poor water holding properties, so it is understandable that the high rainfall year (240mm above average) has so strongly and directly caused a 70cm water table rise, and that much of this recharge would have contributed to lateral moisture movement to lower areas in the catchment along the top of the impermeable blanchetown clay layer.

3.2.4 Catchment snapshots

The following photos and descriptions show clear evidence of the catchment dynamics and the growing seep areas. Photos 29-33 show overflows from the main soak area expanding into a newer seep and scald area that is rapidly enncroaching into cropping land.

Of note is the clear succession vegetation as seeps develop from cropping areas to saline scalds (Photos 25-27 and 35).

Photos 36-38 show another sandy section where the farmer has opportunistically and succesfully grown sunflower as a summer crop to use up excessive sesaonal moisture. Summer crops in the mallee are usally fairly high risk and rely on good summer rainfall.

Photo 19. Piezometer R03 at base of main soak on Oct 31.

Photo 20. Main seep view from midslope piezometer R02.

Photo 21. Newer seep southeast of main seep, showing remnants of last seasons stubble

Photo 22. Seep development on Thomas side, north of monitoring sandhill

Photo 23. Open soil piut near main seep showing shaallow water table, Dec 2016

Photo 24. Main seep on Thomas side surrounded by lupin crop

Photo 25. Succession of crop to ryegrass to salt tolerant grass to bare scald

Photo 26. Slat tolerant grasses and bare scald on southern side of main seep

Photo 27. Clear salt crystals at the seep scald surface with some salt tolerant grass.

Photo 28. Southern view of main seep area from mid-slope Peizometer RO2

Photo 29. South west view of newer seep development from Piezometer RO3.

Photo 30. Channel that was cut with the overflow of the main seep to the newer seep area

Photo 31. Newer seep scald looking back toward main seep, showing preivous seeding lines

Photo 32. Edge of new seep area encroaching into sown crop area on eastern side

Photo 33. Edge of new seep area encroaching into sown crop area on western side

Photo 34. Barley crop on norhern face of sandill above main soak, showing soil moiture probe

Photo 35. Succession of crop to dry ryegrass to green ryegrass on north side seep

Photo 36. Farmers opprotunistic establishment of sunflower as summer crop option

Photo 37. Sunflower seedlings establishing (Dec 2016)

Photo 38. Successful sunflower crop in Jan 2017

3.3 Arbon Site, Wynarka

The Arbon site north of Wynarka is attempting to utilize moisture in the developing soak areas by establishing the fodder perennial plantings of saltbush and tree lucerne to dry up soaks and provide strategic grazing opportunities (Figs 25 and 26). There was also a plantation of native trees along a sandy rise fence line area above one developing seep area to try and intercept the lateral flow of moisture and prevent its spread. These strategies were designed to best fit the farmers system of increasing grazing options, as well as utilizing existing farm layout to create efficiencies with tree line plantings.

As describes in previous reports, the tree lucerne was unsuccessful, mainly due to grazing of seedlings by hares (and possibly rabbits and kangaroos). The saltbush was more successful with a 40-50% survival rate. The rows of trees on the deep sands were also largely unsuccessful due to moisture stress, vermin and competition issues. There are plans to reestablish these sites in 2017 with more effort applied to site preparation and maintenance.

3.3.1 Catchment snapshots

The following photos and descriptions provide pictorial evidence of the progress and issues at this site. These seep areas do not appear to be strongly saline at this point, as is evidenced by the strong growth of ryegrass in developing wet areas. However, maintaining soil cover to prevent evaporation and capillary rise concentrating salts at the surface will be an important management strategy, and the use of salt tolerant grasses in developing scalded areas should be an important strategy.

Fig 25. Google Earth from Oct 2016 showing main sand areas that contribute to seeps.

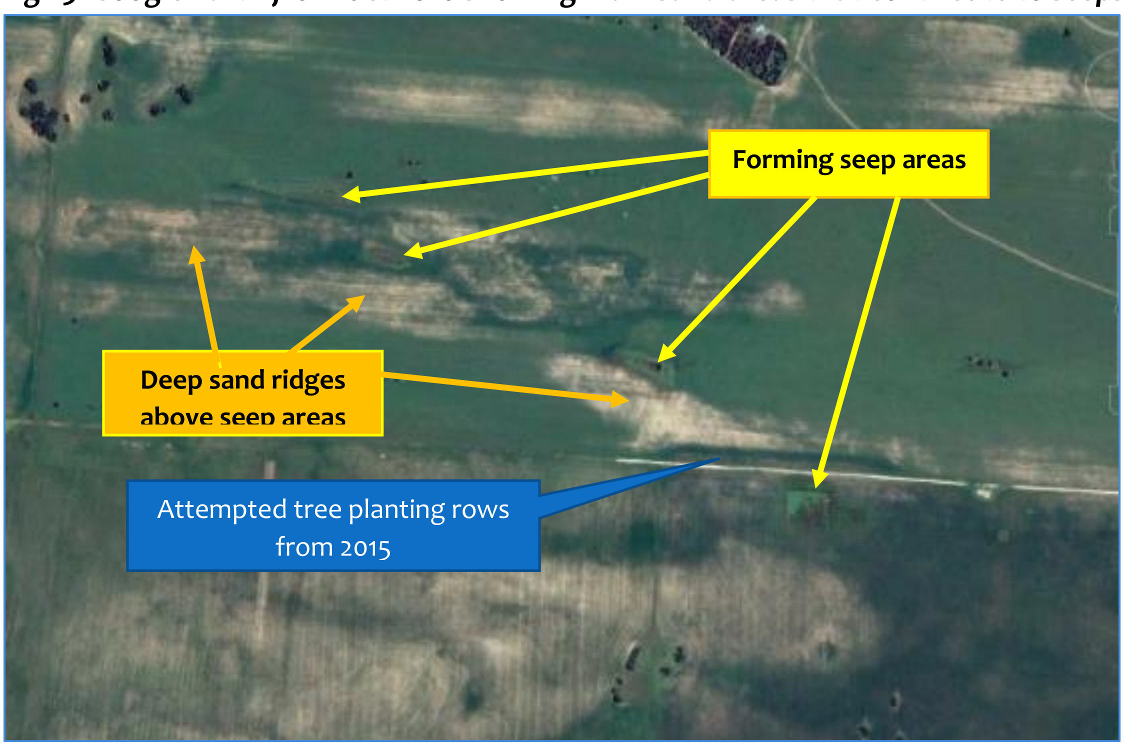


Fig 26. Site map showing plantation areas being monitored.

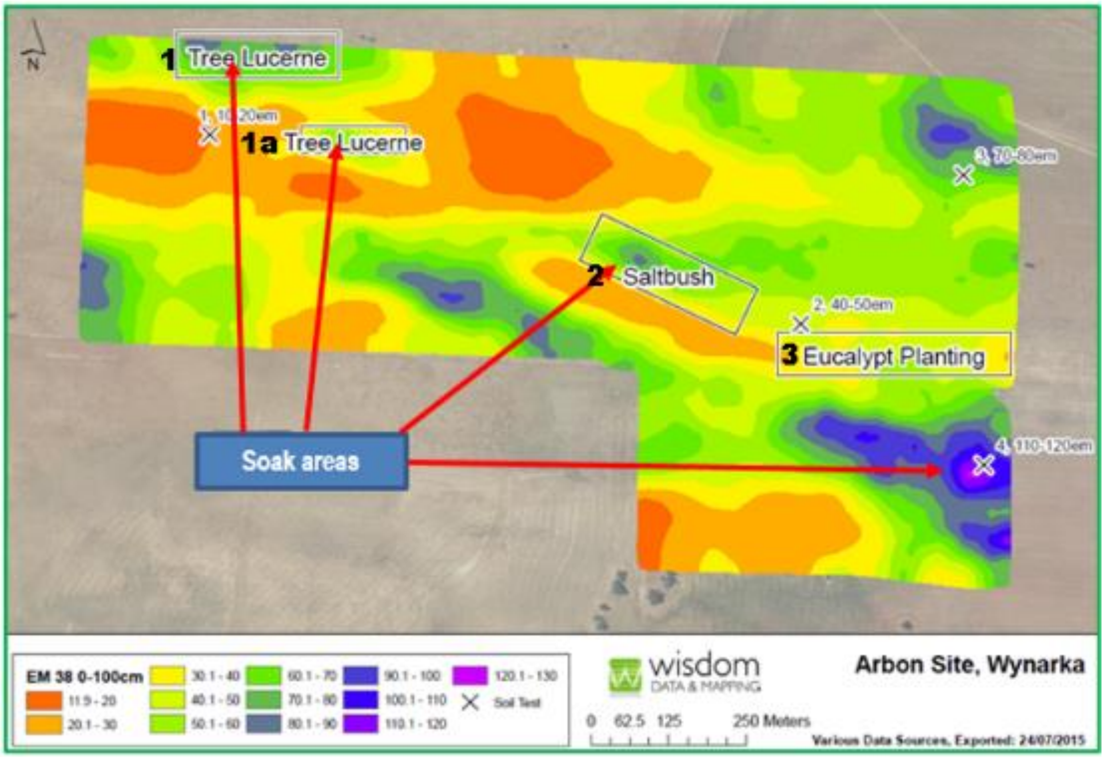


Photo 39. Thick ryegrasss in developing seep area below fenceline where trees were planted

Photo 40. Developing seep, sand over clay at 20-30cm, with very moist soil at this depth

Photo 41. Wet Clayey Sand at 25cm at developing seep, October 2016

Photo 42. Evidence of surfacewater movement through saturates sand, deveoping seep

Photo 43. Weedy are above soak where trees were originally planted but few survived

Photo 44. Surviving mallee eucalypt plantings on deep sands in along fenceline

Photo 45. Surviving saltbush on deep sands in along fenceline planting

Photo 46. Successful saltbush establishmetn on seep area 2.

Photo 47. Saltbush through seep area 2 and ryegrass showing area not saline yet

Photo 48. Evidence of rabbit activity through saltbush plantings

Photo 49. Bare scald area forming crusty surface layer and saturated soil at 20cm. At this stage the bare patches are more likely due to periodic water ponding rather than accumulating salinty, but this may change, and soil testing may be useful to monitor this.

3.4 Bond Site, Mannum

There are numerous seep areas developing throughout the Bonds property south east of Mannum. In 2015 a 19ha strip of lucerne was established over a long sandy rise above a main seep area. This is surrounded by well managed Notill continuous cropping of cereals, pulses and canola. The paddock area being monitored adjacent to the lucerne has been cereal cut for hay in both 2015 and 2016.

The main monitoring at the Bond site has revolved around three main aspects:

1. the measurable differences in soil water dynamics between the 2 different farming systems at the site (lucerne for hay with deep rooted perennial growing all year verses continuous annual cropping system active only in growing season, with clean summer and autumn weed control), using moisture probes.
2. the water table levels at the seep and on the sandy rise, using piezometers,
3. estimated gross margins associated with the various farming systems involved (to be detailed in the next site report).

Mannum received well above average rainfall in 2016 recording 132mm higher than the annual average, as can be seen in Table 6 and Fig 27. The wettest months were March, July, September and December.

Table 6. Rainfall data for Mannum, 2016.

mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	15.7	17.1	18.4	25	29.9	31.9	28.6	30.6	29.9	26.6	21.1	21.6	295.5
2016	21.4	12.4	48.4	9.4	31	28.8	49.1	24.2	79.1	18	31.8	73.8	427.4

Fig 27. Monthly rainfall data presentation for Mannum 2016 against site mean.

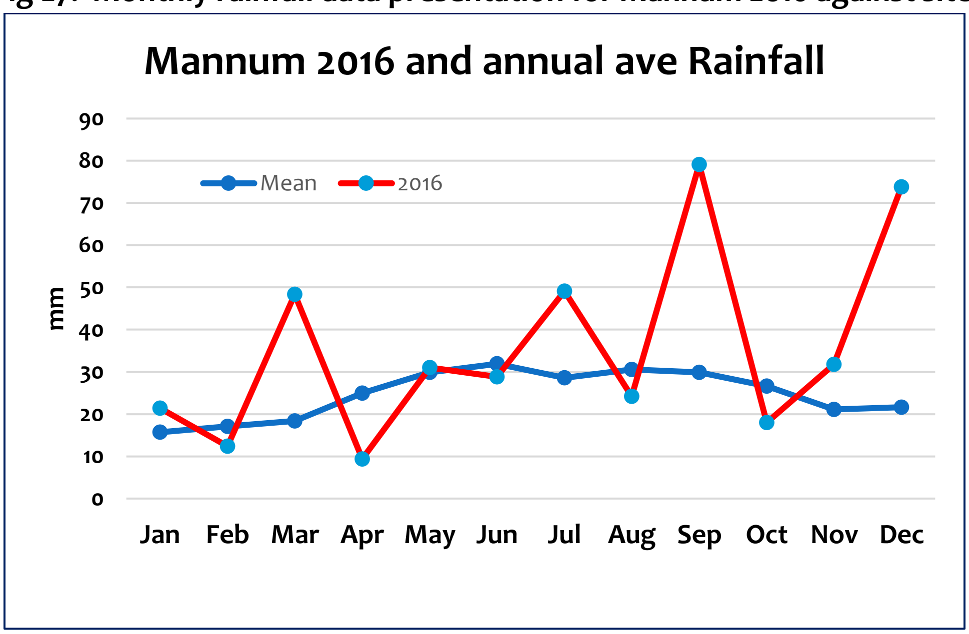


Fig 28. Map of Bond Lucerne Trial showing monitoring zones and equipment sites

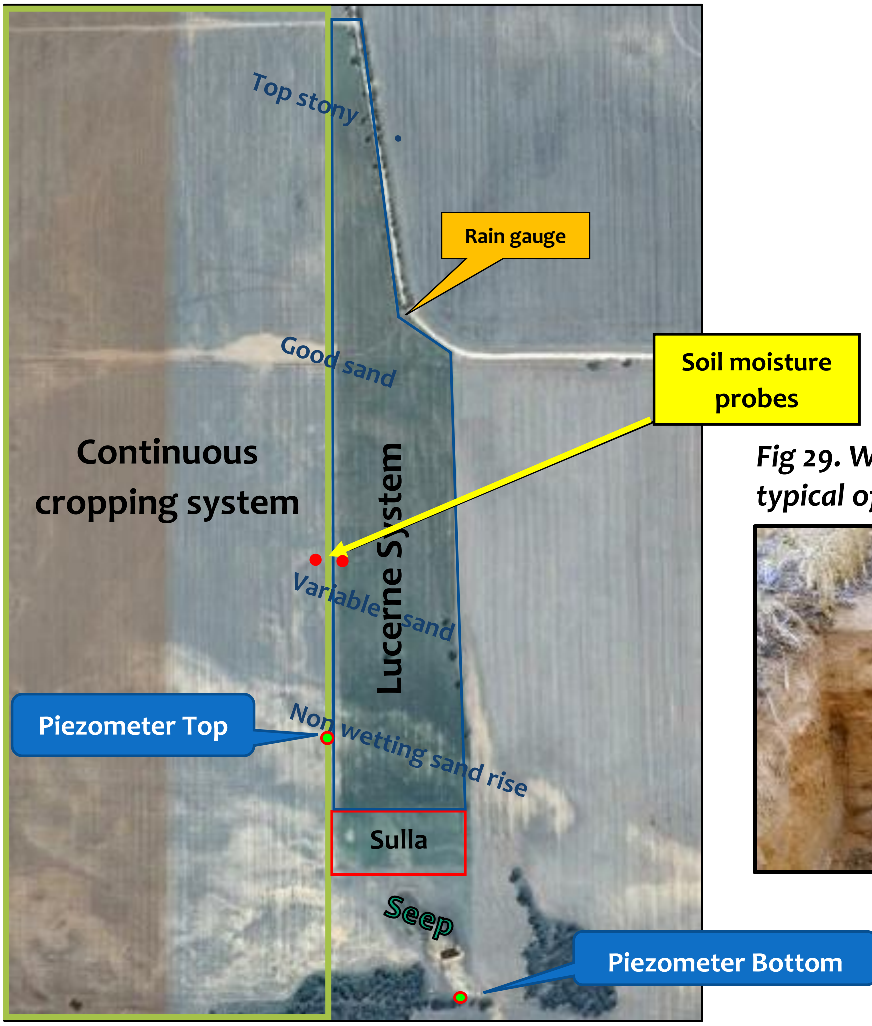


Fig 29. White sand over clay profile typical of this site

3.4.1 Water table dynamics

Figure 31 shows that days of rainfall totaling about 25mm in Feb 2016 was not enough to cause any water table rise. However, the 30-35mm event in March lead to a very sharp rise in water of about 40mm at the main soak area. These water levels remained steady until the season opening rains in late May of about 25mm, which began a rise of about 60cm throughout the growing season. This started to decline towards the end of August, but then recharged again after the very high Sept rainfall. Levels dropped quickly by about 70cm through October and into November, as surrounding crops were at maximum water use prior to senescence.

This is followed by a 25mm event in November that registered only a minor rise in water table at the main soak area, most likely due to the dry root zones of the surrounding soils at this time. Photos 50 and 51 show evidence of the significant water table changes at different times of the year at the main seep pit.

Fig 30. Rainfall records for site, Nov 2015 to Nov 2016

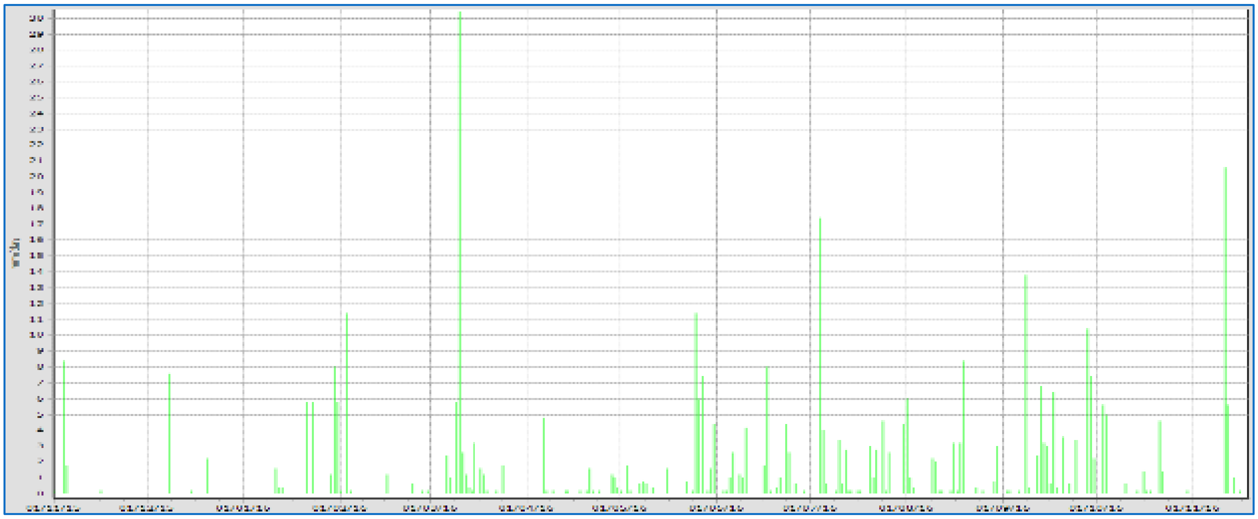


Fig 31. Piezometer B01 readings for Bottom soak area, Nov 2015 - Nov 2016

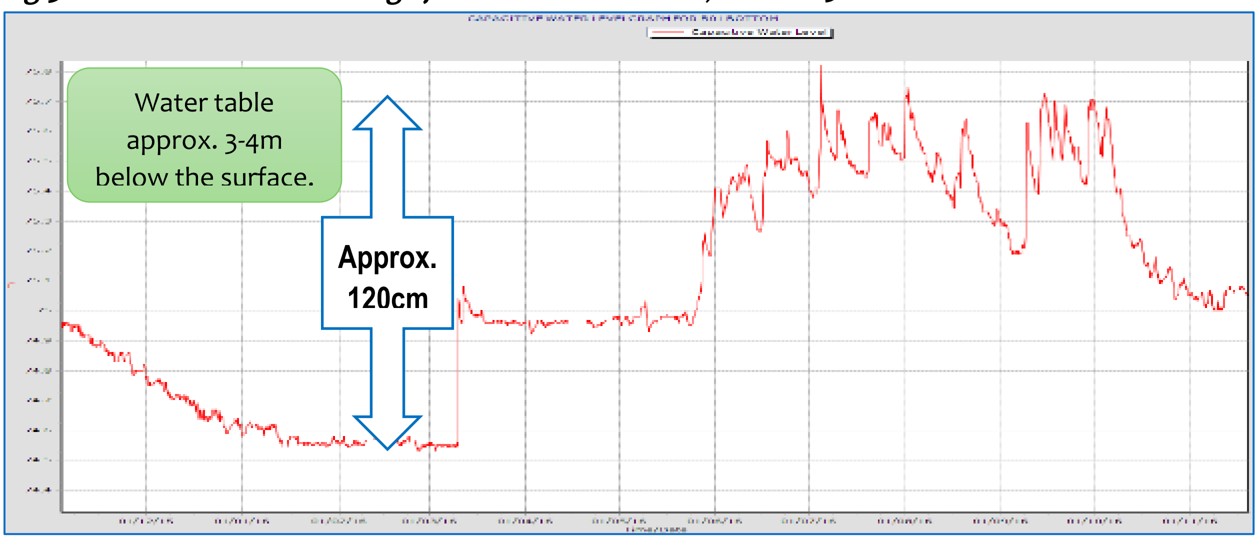
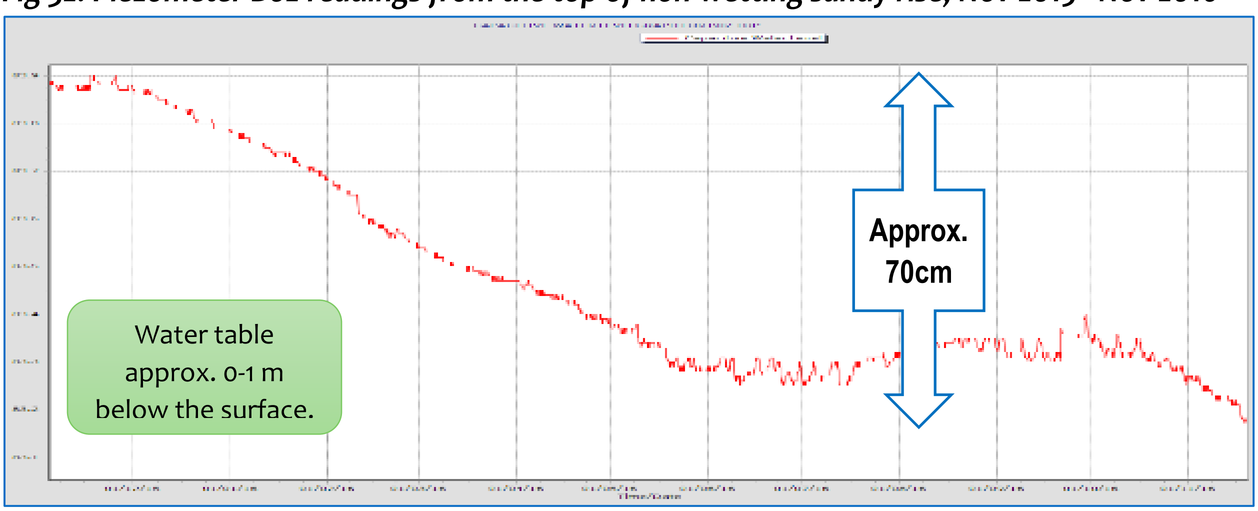


Fig 32. Piezometer B02 readings from the top of non-wetting sandy rise, Nov 2015 - Nov 2016



Piezometer B02 at the top of the non-wetting sandy rise just north of the main soak area is behaving very differently, as is shows a general decline in water level of about 60cm from Dec 2015 until July 2016. This is followed by a slight rise of about 10cm between July and September, most likely due to the high winter and spring rainfall, followed by a further 20cm drop through October and November. **This steady drop in water level, which is different to the trends in the other sites, could well be due to the fact that this piezometer is placed right on the edge of the lucerne patch which is likely to be strongly reducing soil moisture.**

Fig 33. Cereal cropping moisture probe readings, Nov 2015 – Nov 2016

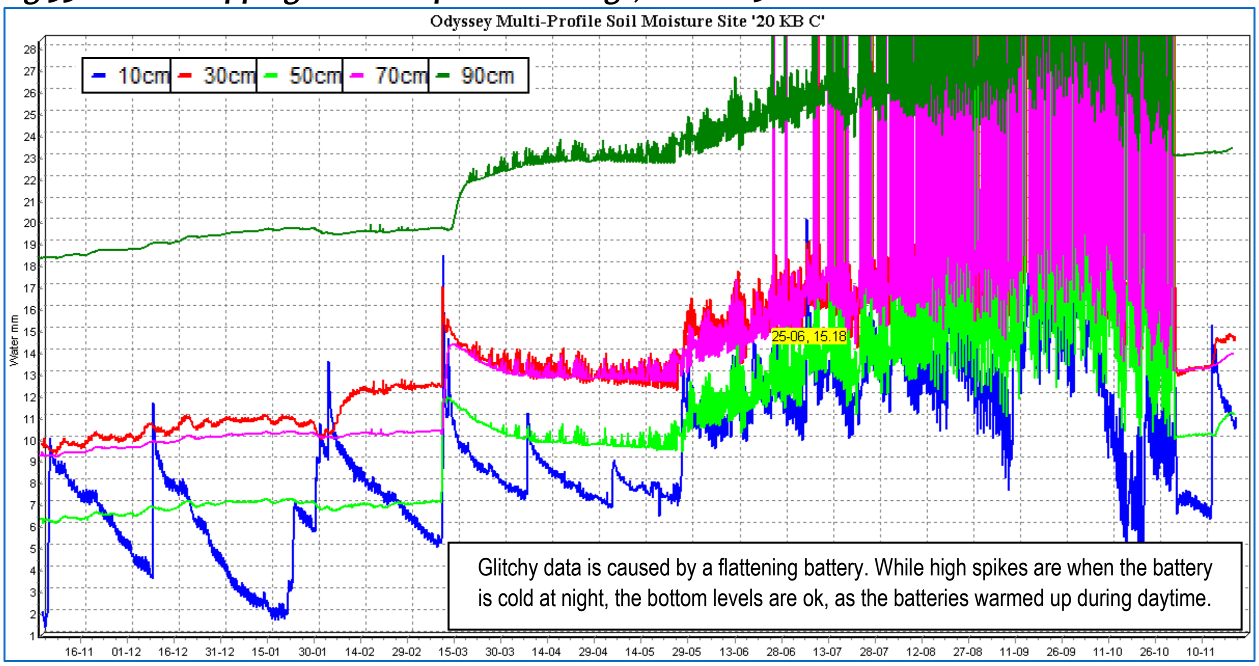


Fig 34. Cereal cropping summed moisture probe readings, Nov 2015 – Nov 2016

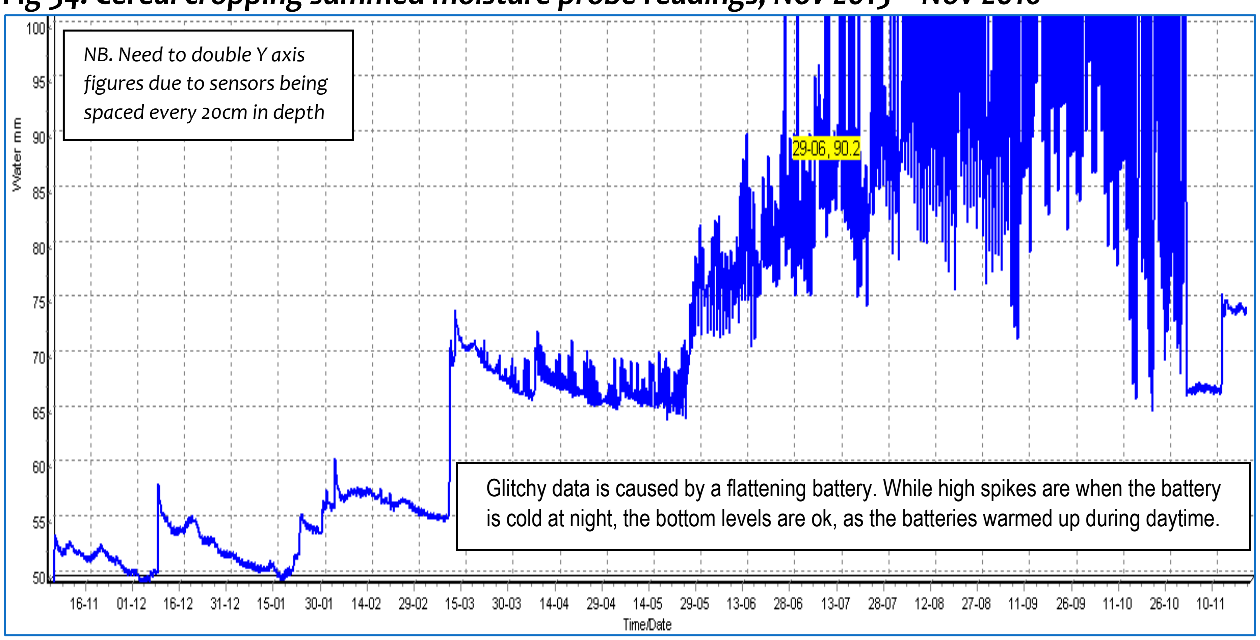


Fig 62. Lucerne system moisture probe readings, Nov 2015 – Nov 2016

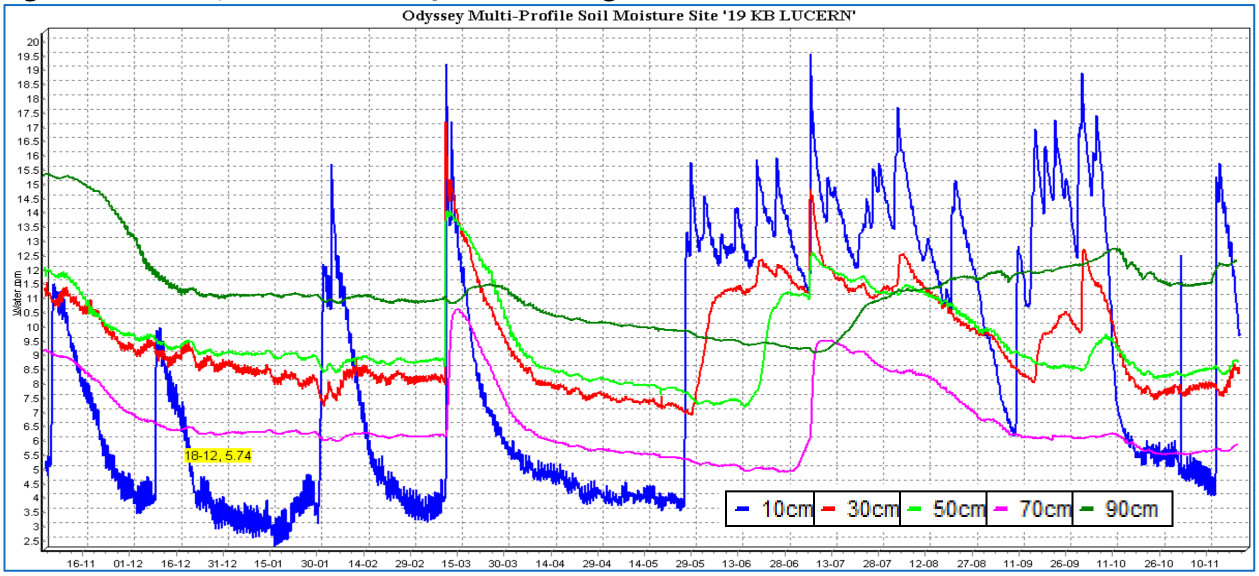
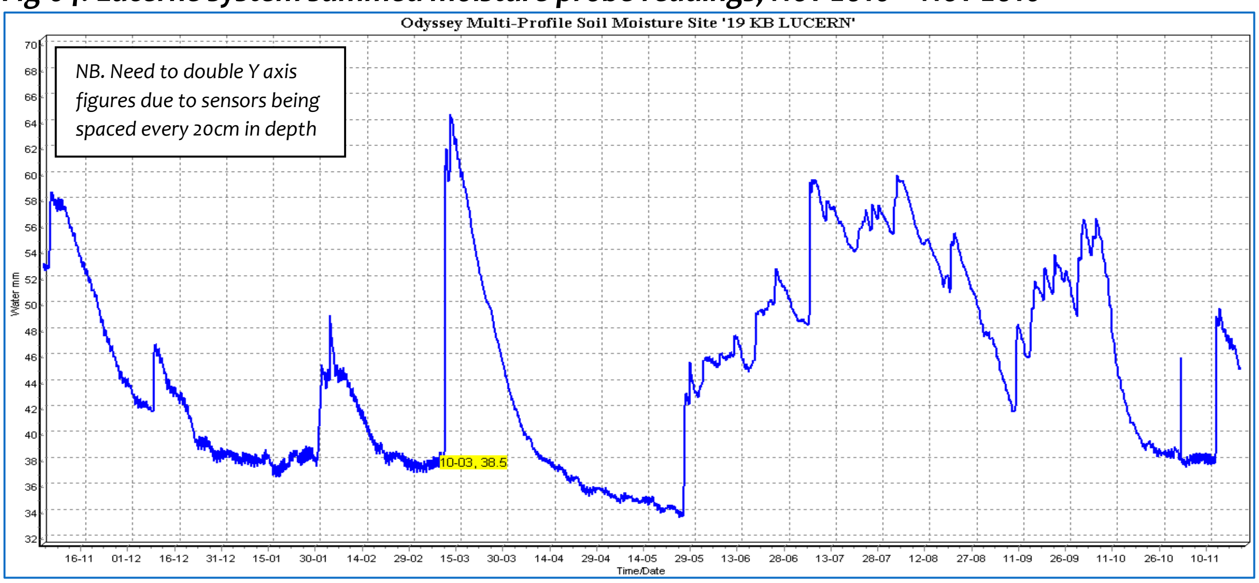


Fig 64. Lucerne system summed moisture probe readings, Nov 2016 – Nov 2016



3.4.2 Farming system water use.

The moisture probe results over the last 12 months from the different farming systems reveal large differences in soil water use. Figures 61 and 62 show that by the time the March 2016 rainfall occurred, the cereal cropping area had 30-40mm more moisture in the top 90cm than the adjacent lucerne area (Figs 63 & 64) which was twice cut for hay over the season. At the end of the 2016 growing season, the lucerne area was measured at 50mm less than the cereal side. This is a very significant difference that could have a major impact on soil moisture flows within the catchment area.

Glitchy data in the cereal probe caused by a flattening battery means that it is hard to accurately assess any spikes in the 70cm or 90cm on the cereal side, whereas the bottom side of the colored strips should reasonably indicate the actual soil moisture levels. The lucerne probe, however, shows no sharp spikes in the 70cm or 90cm sensors, and is not indicating any strong evidence of recharge, which is important, given the very high rainfall for 2016.

It is noteworthy that the moisture penetration into the deeper layers after the late May rains in Figure 62 is progressively delayed the further down the soil profile one looks. All of this moisture sits within the lucerne's root zone, as is evidenced by the strong draw down at each level through October and November.

Data form both the piezometers as well as the soil moisture probe suggest that the strategic planting of lucerne within the catchment area could significantly reduce recharge and limit the spread of seep affected areas.

3.4.3 Catchment snapshots

The following photos and descriptions provide pictorial evidence of the progress and issues at this site.

Photo 50. Large pit at seep area nearly empty in Feb 2016

Photo 51. Large pit at seep area full at Nov 2016

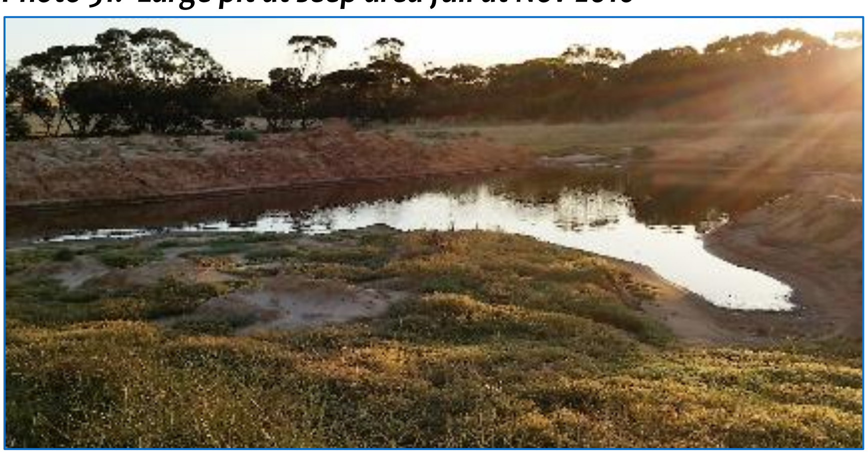


Photo 52. Seep succession form good crop to thick ryegrass to salt tolerant growth

Photo 53. Seep succession from thick ryegrass to salt tolerant growth to bare scald

Photo 54. View from top piezometer B02 looking down toward main seep area

Photo 55. View from top piezometer B02 looking north at lucerne and cereal hay sections

Photo 56. Excellent lucerne growth evident in Nov 2016

Photo 57. Lucerne growth and cereal hay cut area just above moisture probe sites.

Photo 58. Lucerne growth at top of catchment near rain gauge.