Mallee Dune Seeps

Drilling and Well Installation Report

Pope Subcatchment

A report produced for Natural Resources South Australian Murray–Darling Basin by Juliet Creek Consulting Pty Ltd.

March 2016

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Australian Government

National Landcare Programme

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Introduction

Mallee Dune Seepage is a phenomenon that occurs in dune-swale landscapes where excess water moves through sandy soils, and then moves laterally as groundwater seepage. Seepage water can appear as discharge in lower-lying areas, forming severely waterlogged areas known as seeps.

This report documents drilling and monitoring well installation at the Pope dune–swale subcatchment near Karoonda in the South Australian Murray Mallee (6 km southwest of the town). A previous report produced in February 2016 for Natural Resources SA Murray–Darling Basin documented initial soil characterisation investigations and land unit mapping within the same subcatchment: 'Mallee Dune Seeps: Pope Subcatchment – Soil Characterisation and Land Unit Mapping' (Hall 2016).

Investigations in 2015 at other dune–swale subcatchments in the SA Murray Mallee at Kulde and Mannum East – which included soil characterisation, land unit mapping, deep drilling and monitoring well installation – were documented in the reports 'Mallee Dune Seeps: Land, Soil and Water Investigations of Dune Seepage Systems in the South Australian Murray Mallee' (Hall 2015b) and 'Well Construction Report for the Mallee Dune Seeps Project' (Henschke 2015). The former report summarised the findings from investigations and the issue of dune seepage in some detail, and included recommendations for further work. Field trial work looking at agronomic and land use changes to improve plant water use is also being conducted at a number of sites (see McDonough 2015). (See **Figure 1**).

These investigations have been undertaken to improve understanding of the issue of Mallee Dune Seepage in the SA Murray Mallee, which has caused considerable areas of productive farmland to be lost to production owing to the formation of severely waterlogged seep areas (see **Figure 2**). Specific subcatchment investigations are building upon the knowledge and information developed by the State Land & Soil Mapping Program (see Soil & Land Program 2007; Hall et al. 2009). Natural Resources SA Murray–Darling Basin and the National Landcare Program are supporting investigations into the processes involved, as well as mitigation, prevention and rehabilitation of seeps (see **Figure 1**).

Mallee dune seepage and the formation of seeps are a water balance issue within affected subcatchments. Anecdotal evidence suggest that the occurrence of seeps is most prominent where continuous cropping has been implemented as the core farming system.

Discussion

Dune seepage is caused by excess water moving through sandy soils beyond the plant root zone. The excess water then forms 'perched watertables' upon deep layers of low permeability clay. This low permeability clay has been determined to be the geological layer known as Blanchetown Clay (see Hall et al. 2009) – which is common across the South Australian Mallee. Similar materials of similar age are common across much of agricultural South Australia. The perched water then seeps laterally and can appear in the landscape where restrictive clay layers occur at shallow depth (e.g. 1–3 m), forming an area of severely waterlogged land known as a seep or soak. This especially occurs in lower-lying areas adjacent to sand dunes, but can also occur on sloping land.

Anecdotal evidence suggests that most seeps in the SA Murray Mallee have formed since 2004. The occurrence of seeps, however, is unpredictable.

These perched watertable systems are 'local groundwater flow systems' (cf. 'intermediate' and 'regional') (see Coram 1998, Walker et al. 2003; also see www.environment.nsw.gov.au/salinity/basics/hydrogeology.htm). They are also freshwater systems. It has been determined from investigations that Blanchetown Clay forms the 'aquatard' upon which a zone of saturation (perched watertable aquifer) develops. The saturated zone is within sandy clay to sandy clay loam layers that occur below the upper sandy soil layers. The severely waterlogged seep areas are seepage discharge sites. It is important to note that the perched watertable system is not directly connected to the much deeper regional groundwater.

Groundwater discharge causing seepage typically occurs in low lying/depression areas. Discharge can also occur as seeps on hillsides and at break-in-slopes, especially on long slopes. The expansion and contraction of seepage areas is generally thought of as a cyclical phenomenon exacerbated by summer rains and large out of season rainfall events. However, in the case of the mallee dune seeps investigated so far, it is more likely that altered farming practices are the major cause. It has also been observed that many seeps are increasing in size.

To date, there has been little information available regarding hydrological processes of dune–swale systems, or the regolith layers below the 1.5–2.0 metres depth investigated via soil characterisation. Electromagnetic Mapping (EM) is being tested to ascertain its effectiveness in identifying clay layers, but is limited to the top couple of metres. Deep drilling to characterise materials to greater depths is essential in providing a greater understanding of regolith materials below the soil and of the movement of water in dune–swale systems.

The installation of monitoring wells in this subcatchment is intended to monitor changes in perched watertables and seep discharge, especially as a result of changes to farming practice. All seeps in this subcatchment, except for the main farm seep (see **Figure 3**), have formed since 2004. It is known that the main farm seep was present before 2001, and that it has expanded significantly since then.

Drilling was carried out and monitoring wells installed at five sites on 12th and 15th February 2016. Descriptions of soil and underlying regolith samples from various depths together with monitoring well details are provided in **Appendix 2**. Monitoring well installation details are also given in **Table 1** and **Table 2** below, while water level and quality data are given in **Table 3** and **Table 4**.

Three holes were drilled along a toposequence in 'Paddock A' on the northern side of the area investigated (Sites MDS P05, P06 and P07), ending with the main farm seep (see **Figure 3**). While two holes were drilled in 'Paddock B' on the southern side of the area investigated (Sites MDS P08 and P09). In this paddock only upper slope and lower slope (seep) sites were drilled, as it was not possible to drill a mid-slope site owing to the presence of hard, shallow calcrete. PVC casing was installed in bore holes. The casing was slotted in the region of the perched groundwater, with washed gravel installed around the slotted length. Bentonite clay pebbles were applied above this and then wetted to form a seal to prevent water leaking down along the outside of the tube from above.

The drilling rig used is owned by Primary Industries & Regions SA (Loxton Research Centre). The rig is truck mounted with a rotary auger.

Water depth measuring dataloggers were installed in piesometer tubes at two sites (see **Table 3**). Installation of automatic water level datalogger probes will help to determine the nature and frequency of rainfall events that cause recharge to the perched groundwater, as well as the impact of any agronomic or land use changes. These data can be correlated with the soil moisture monitoring that is occurring within the subcatchment.

Main Findings

Drilling has confirmed the presence of perched groundwater within this subcatchment. Free water and/or saturated layers were observed at depth at mid-slope and lower slope (seep) locations. Upper slope sites did not produce water at depth when drilled (February 2016), but layers at field capacity water content or greater were observed, and these layers would be expected to yield water for much of the year.

Drilling has also confirmed that Blanchetown Clay (see Hall et al. 2009) forms the base of the local perched groundwater system. Depth to Blanchetown Clay has been measured between 4 and 7 m at upper and mid slope sites, and between 2 and 3 m at seep area sites (see **Appendix 2**). Having Blanchetown Clay as the system base correlates with findings at the Kulde and Mannum East subcatchments. At all three subcatchments it has been determined that the majority of the excess water moves laterally at depth along the Blanchetown Clay. This has been found to be a year-long event, at least from mid to lower slopes. A much lesser but not insignificant proportion of excess subcatchment water likely moves upon subsoil surfaces at much shallower depth – but seasonally when subsurface soils are saturated and probably only for short periods. These findings have implications for the siting and selection of deep-rooted perennials and for overall farm planning.

The processes of land degradation in seep areas (erosion and accumulation of salts) and strategies to minimise degradation are given in Hall 2015b. A range of recommendations was also given in that report, as well as general strategies for managing seepage and seeps, that is: (1) do nothing; (2) manage seep areas differently to surrounding cropping land to minimise degradation; (3) make changes to farm management to improve overall plant water use, which may include the addition of deep-rooted perennial plants into the framing system and the introduction of summer crops.

Key spatial information that would improve farm planning and water use management is the depth to Blanchetown Clay across the landscape. Modern air-borne or proximal geophysical sensing techniques should be investigated for their potential in mapping depth to Blanchetown Clay.

Drilling was carried out and monitoring wells installed at five locations: sites P05, P06 and P07 on 12th Feb 2016 and sites P08 and P09 on 15th Feb 2016. Monitoring well installation details are given in **Table 1** and **Table 2** below. Water level and quality data are given in **Table 3** and **Table 4** below. Site drilling reports, including descriptions of samples from various depths, are given in **Appendix 2**.

Table 1 Positions and relative elevations of monitoring wells

SITE	POSITION	EASTING A	NORTHING A	ELEVATION (m) B
P05	upper slope	394 694	6109 993	17.04
P06	mid-slope	395 000	6110 166	8.59
P07	lower slope (seep)	394 885	6110 442	1.54
P08	upper slope	394 145	6109 489	-
P08	lower slope (seep)	393 906	6109 756	-

A Easting and Northing are in WGS84 (GDA94) coordinate system, zone 54H.
B The datum for elevation is taken from the bare eroded area in the middle of the main farm seep a few metres northeast of Site P07 (see **Figure 3**).

Table 2 Monitoring well specifications

SITE	TOTAL DEPTH (m TOC)	RISER HEIGHT (m AGL)	DEPTH (m BGL)	SCREEN INTERVAL (m)
P05	5.69	1.0	4.69	3.19–4.69
P06 A	7.18	0.98	6.20	3.2–6.2
P07	4.5	1.0	3.5	2.0–3.5
P08	8.5	1.0	7.5	5.5–7.5
P09 B	2.9	0.48	2.42	1.42–2.42

BGL = depth of tube below ground level
AGL = height of tube above ground level
TOC = top of tube casing
A Logger 01 installed 15th Feb 2016 with logger capsule close to top of well and with 1.5 m sensor length.
B Logger 02 installed 15th Feb 2016 with logger capsule close to top of well and with 1.5 m sensor length.

Table 3 Groundwater levels for 12th Feb 2016 (P05, P06, P07) and 15th Feb 2016 (P08, P09)

SITE	DTW (metres TOC)	SWL (metres BGL)
P05	well dry	well dry
P06	6.08	5.1
P07	-	-
P08	-	-
P09	-	-

DTW = depth to standing water from reference point (TOC = top of tube casing)
SWL = standing water level below ground level (BGL = below ground level)

Table 4 Water chemistry and quality data for 12th Feb 2016 (P05, P06, P07) and 15th Feb 2016 (P08, P09)

SITE	TEMP (°C)	pH	REDOX POTENTIAL (mV)	EC (µs/cm)	TDS (mg/L)
P05	-	-	-	-	-
P06	-	-	-	-	-
P07	-	-	-	-	-
P08	-	-	-	-	-
P09	-	-	-	-	-

EC = electrical conductivity in microSiemens per cm (µS/cm)
TDS = total dissolved solids (calculated using a factor)

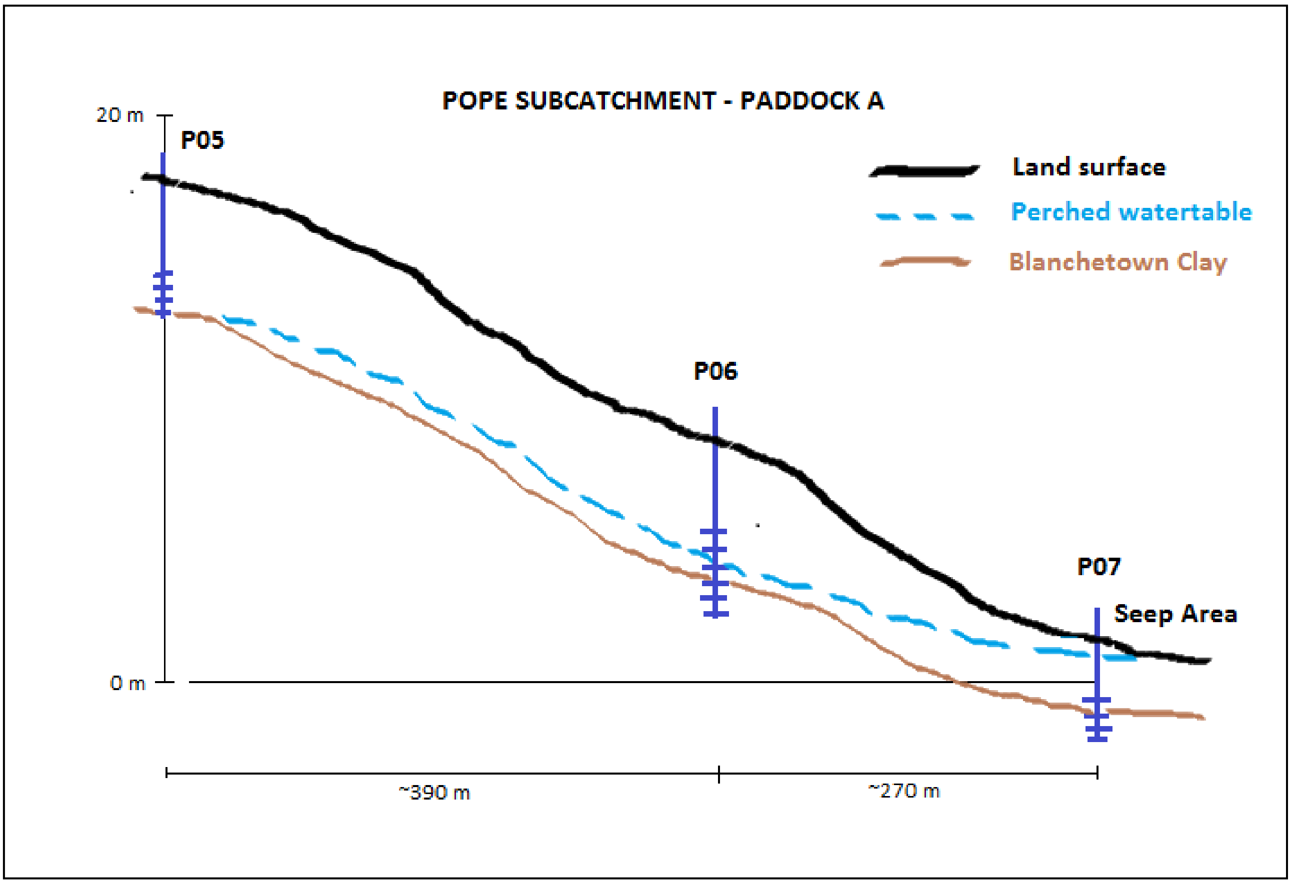

Diagram 1 Hydrological cross-section of the long slope of Paddock A in the Pope subcatchment.

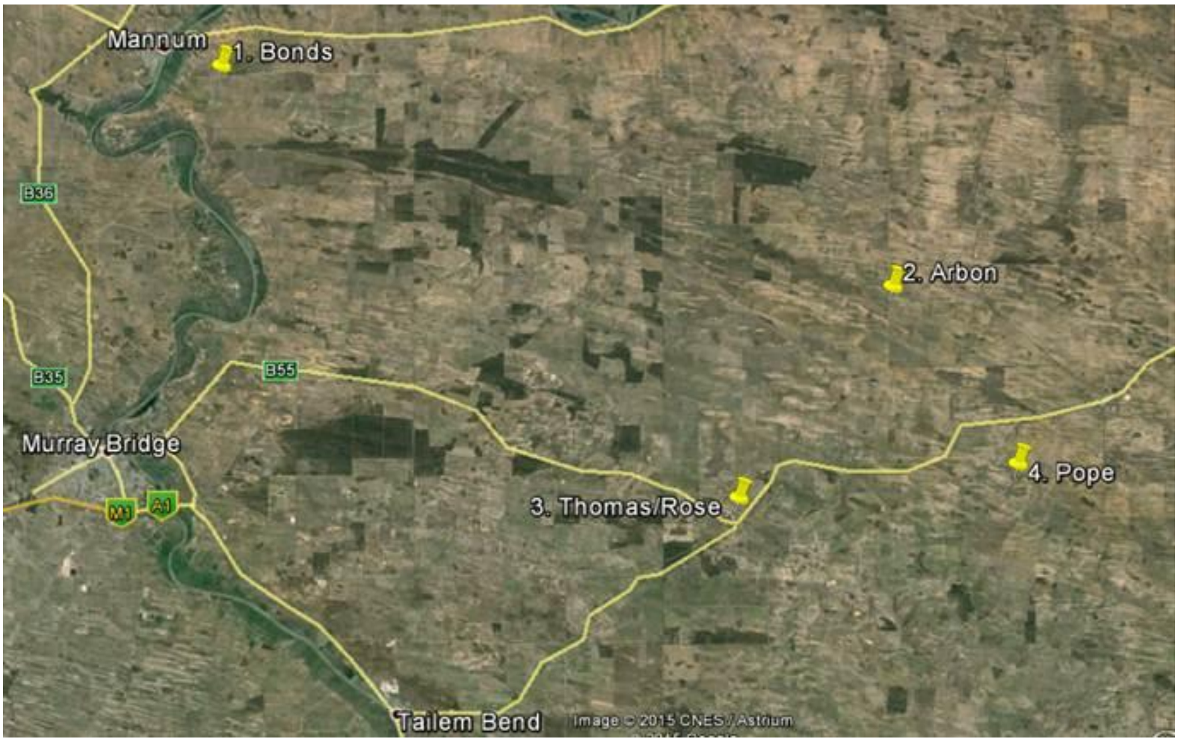

Figure 1 Locations of subcatchments in the SA Murray Mallee where dune seepage processes have been investigated and field trial work looking at increasing plant water use has been established. Soil characterisation investigations, land unit mapping, as well as drilling and monitoring well establishment have been conducted at Mannum East (Bonds), Kulde (Thomas–Rose) and Karoonda (Pope).

Figure 2 Scene of the severe dune seep at the Pope subcatchment in the summer of 2015–16, below the investigated toposequence of soil characterisation sites (see Hall 2016). Note the bare scalded surface, water seeping from the soil, and the barley crop in background. The seep area is expanding upslope.

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Appendix 1 – Maps

Figure 3 Pope subcatchment near Karoonda in the South Australian Murray Mallee showing approximate locations of soil characterisation sites (in blue – see Hall 2016) together with drilling and well establishment sites (in green). Sites P05, P06 and P07 are situated within 'Paddock A', with drainage from P05 toward P07 and the main farm seep; while sites P08 and P09 are situated within 'Paddock B', with drainage from P08 to P09. A 2001 aerial photograph merged with a 2013 photo is shown as background. Seeps show as bare or darker areas in the landscape.

Appendix 2 – Drilling Reports

It needs to be noted that drilling is a very uncertain business; and that materials disturbed by the drill head do not necessarily travel up the auger to the land surface at an even rate or, in some cases, do not travel up the rotating auger at all (e.g. heavy clay and wet materials). Consequently, it is often uncertain which depths certain materials are derived from, and so depths are mostly indicative (or sometimes are not recorded). Nonetheless, upper and lower depths are certain and provide a reference for all other samples. It is inferred that each recorded sample derives from an approximately 50 cm thick sample (excluding the surface sample) if all materials travel-up the auger as expected. It can also be reasonably assumed that materials deposit at the land surface in sequential order. Colours are also mostly indicative, as materials of different colours are mixed – however, the bottom-most material (Blanchetown Clay at each drill site) has been viewed relatively intact on the retrieved lower auger section.

Site MDS-P05 (Paddock A) – Drilling report

Easting	394 694
Northing	6109 993
Location	Karoonda
Landholder	Stuart Pope
Date	12th Feb 2016
Driller	Simon Knowles
Logged by	James Hall / Brian Hughes
Drilling method	Solid flight augers (125 mm diameter)
Position	Upper slope (see **Figure 3**).

Profile description

Layer	Depth (cm)	Description (texture / colour / soil water status / consistence / effervescence of fine carbonate / dispersion / repellence (affected layers only) (See NCST 2009; Munsell 1988)
1	surface	loamy sand / dark yellowish brown / dry / very weak / slightly calcareous / - / non-repellent
2	90	sandy loam / yellowish brown / dry / very weak / slightly calcareous / -
3	-	sandy clay loam / yellowish brown / moderately moist / very weak / highly calcareous / - [Calcrete]
4	150	sandy clay loam / yellowish brown / dry / very weak / highly calcareous / - [Calcrete]
5	200	sandy light medium clay / very pale brown / moderately moist / weak–firm / highly calcareous / non-dispersive
6	-	sandy light medium clay / very pale brown / moderately moist / weak–firm / highly calcareous / -
7	-	sandy light medium clay / very pale brown / moderately moist / weak–firm / highly calcareous / -
8	-	sandy light medium clay / very pale brown / moderately moist / weak–firm / highly calcareous / -

9	400	sandy light clay / very pale brown / moderately moist / weak–firm / highly calcareous / slightly dispersive
10	-	sandy light clay / very pale brown / moist–wet / firm / highly calcareous / moderately dispersive [Layer just above field capacity water content]
------------------------------------ discontinuity ---		
11	470	medium clay / yellow brown & yellowish red (disturbed sample); yellowish red, brighter yellowish red & very pale brown (undisturbed sample) / moist–wet / firm / moderately calcareous / slightly dispersive [Layer just below field capacity water content] [Blanchetown Clay] [Sample]

The last ~30 cm of material (~440–470 cm) was Blanchetown Clay, which forms the aquatard upon which a moist to wet but not saturated layer was observed.

Completion details

Casing	50 mm class PN18 PVC-U
Screen	Vertically slotted for 1.5 m (3.19–4.69 m depth)
Gravel pack	Washed gravel to cover the screen
Bentonite seal	Bentonite pebbles poured down to form watertight seal above the gravel pack to within 0.2 m of the ground surface
Riser height	Piesometer tube is 1.0 m above ground surface.

Figure 4 Installation of piesometer well tubing at Site MDS-P05.

Site MDS-P06 (Paddock A) – Drilling report

Easting	395 000
Northing	6110 166
Location	Karoonda
Landholder	Stuart Pope
Date	12th Feb 2016
Driller	Simon Knowles
Logged by	James Hall / Brian Hughes
Drilling method	Solid flight augers (125 mm diameter)
Position	Mid-slope (see **Figure 3**).

Profile description

Layer	Depth (cm)	Description (texture / colour / soil water status / consistence / effervescence of fine carbonate / dispersion / water repellence (affected layers only) (See NCST 2009; Munsell 1988)
1	surface	loamy sand / dark yellowish brown / dry / loose / non-calcareous / - / repellent
2	-	light sandy loam / dark yellowish brown / dry / loose / non-calcareous / -
3	100	sandy loam / yellowish brown / dry / very weak / highly calcareous / - [Layer contains hard carbonate segregations]
4	-	heavy sandy clay loam / brownish yellow / moderately moist / weak / highly calcareous / moderately dispersive [Layer contains hard carbonate segregations]
------------------------------------ discontinuity ------------------------------------		
5	200	sandy light medium clay / light yellowish brown / moist / weak / highly calcareous / moderately dispersive
6	-	medium clay / brownish yellow / moist / weak / highly calcareous / -
7	300	medium clay / brownish yellow / moist / weak–firm / highly calcareous / -
8	-	medium clay / brownish yellow / moist / weak–firm / highly calcareous / -
9	-	medium clay / very pale brown / moist–wet / weak / highly calcareous / slightly dispersive
10	-	medium clay / very pale brown / moist–wet / weak / highly calcareous / slightly dispersive
11	-	medium clay / very pale brown / moist–wet / weak / highly calcareous / slightly dispersive
12	-	light medium clay / very pale brown / wet / loose / moderately calcareous / slightly dispersive [Layer saturated but no free water observed in sample]
------------------------------------ discontinuity ------------------------------------		
13	470–620	heavy clay / red & light yellowish brown / moderately moist / very firm / non-calcareous / slightly dispersive [Blanchetown Clay] [Sample]

From ~470–620 cm is Blanchetown Clay, as observed on the lowest auger sections when they were retrieved. However, this heavy clay material did not travel-up the auger, which makes depths of upper materials uncertain. The Blanchetown Clay forms the aquatard upon which a saturated layer was observed. After installation, free water was observed in the well.

Completion details

Casing	50 mm class PN18 PVC-U
Screen	Vertically slotted for 3 m (3.2–6.2 m depth)
Gravel pack	Washed gravel to cover the screen
Bentonite seal	Bentonite pebbles poured down to form watertight seal above the gravel pack to within 0.2 m of the ground surface
Riser height	Piesometer tube is 0.98 m above ground surface.

Figure 5 Drilling at Site MDS-P06.

Site MDS-P07 (Paddock A) – Drilling report

Easting	394 885
Northing	6110 442
Location	Karoonda
Landholder	Stuart Pope
Date	12th Feb 2016
Driller	Simon Knowles
Logged by	James Hall / Brian Hughes
Drilling method	Solid flight augers (125 mm diameter)
Position	Lower slope, within the scaled area of main farm seep, several metres from upper seep edge (see **Figure 3**).

Profile description

Layer	Depth (cm)	Description (texture / colour / soil water status / consistence / effervescence of fine carbonate / dispersion / water repellence (affected layers only) (See NCST 2009; Munsell 1988)
1	surface	loamy sand / yellowish brown / moist / loose / slightly calcareous / - / non-repellent

2	-	loamy sand / very pale brown / moist / loose / non-calcareous / -
3	90	sandy light clay / brownish yellow / wet–moist / weak / highly calcareous / highly dispersive
4	150	calcrete
5	-	sandy clay loam / light brown / wet / loose / highly calcareous / moderately dispersive [Layer saturated with free water in sample]
6	260	sandy clay loam / pink / wet / loose / highly calcareous / - [Layer saturated with free water in sample]
------------------------------------- discontinuity ---		
7	350	heavy clay / dark red & greenish grey / moderately moist / strong / non-calcareous / moderately dispersive [Blanchetown Clay]

From ~260–350 cm is Blanchetown Clay. The Blanchetown Clay forms the aquatard upon which the saturated layers of the seep were observed.

Completion details

Casing	50 mm class PN18 PVC-U
Screen	Vertically slotted for 1.5 m (2.0–3.5 m depth)
Gravel pack	Washed gravel to cover the screen
Bentonite seal	Bentonite pebbles poured down to form watertight seal above the gravel pack to within 0.2 m of the ground surface
Riser height	Piesometer tube is 1.0 m above ground surface.

Figure 6 Drilling at Site MDS-P07.

Figure 8 Drilling at Site MDS-P07 – looking upslope.

Figure 7 A close-up of Blanchetown Clay from Site MDS-P07.

Site MDS-P08 (Paddock B) – Drilling report

Easting	394 145
Northing	6109 489
Location	Karoonda
Landholder	Stuart Pope
Date	15th Feb 2016
Driller	Simon Knowles
Logged by	James Hall / Brian Hughes
Drilling method	Solid flight augers (125 mm diameter)
Position	Upper slope (sand dune crest on east–west orientated ridge) (see **Figure 3**).

Profile description

Layer	Depth (cm)	Description (texture / colour / soil water status / consistence / effervescence of fine carbonate / dispersion / water repellence (affected layers only) (See NCST 2009; Munsell 1988)
1	surface	loamy sand / dark yellowish brown / dry / loose / non-calcareous / - / strongly repellent
2	-	light sandy loam / yellowish brown / dry / very weak / non-calcareous / -
3	100	light sandy loam / yellowish brown / dry / very weak / non-calcareous / -
4	-	sandy loam / brownish yellow / moderately moist / very weak / highly calcareous / -
5	200	sandy loam / brownish yellow / moderately moist / very weak / highly calcareous / -
6	-	fine sandy clay loam / yellow / moderately moist / very weak / highly calcareous / non-dispersive
7	300	fine sandy clay loam / yellow / moderately moist / very weak / highly calcareous / -
8	-	fine sandy clay loam / yellow / moist / very weak / highly calcareous / -
9	400	fine sandy clay loam / yellow / moist / very weak / highly calcareous / non-dispersive
10	-	sandy clay loam / brownish yellow / moist / very weak / highly calcareous / -
11	500	sandy clay loam / brownish yellow / moist / very weak / highly calcareous / slightly dispersive
12	-	sandy clay loam / brownish yellow / moist / very weak / highly calcareous / -
12	600	sandy clay loam / brownish yellow / moist / very weak / highly calcareous / -
13	-	fine sandy light clay / light yellowish brown / wet / weak / moderately calcareous / -
14	-	fine sandy light clay / light yellowish brown / wet / very weak / moderately calcareous / slightly dispersive [Layer at more than field capacity water content but with no free water in sample]
------------------------------------ discontinuity ------------------------------------		
12	750	heavy clay / red & pale olive / moderately moist / strong / - / - [Blanchetown Clay]

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From ~700–750 cm is Blanchetown Clay, as observed on retrieved auger. The Blanchetown Clay forms the aquatard upon which the wet layer was observed.

Completion details

Casing	50 mm class PN18 PVC-U
Screen	Vertically slotted for 2 m (5.5–7.5 m depth)
Gravel pack	Washed gravel to cover the screen
Bentonite seal	Bentonite pebbles poured down to form watertight seal above the gravel pack to within 0.2 m of the ground surface
Riser height	Piesometer tube is 1.0 m above ground surface.

Site MDS-P09 (Paddock B) – Drilling report

Easting	393 906
Northing	6109 756
Location	Karoonda
Landholder	Stuart Pope
Date	15th Feb 2016
Driller	Simon Knowles
Logged by	James Hall / Brian Hughes
Drilling method	Solid flight augers (125 mm diameter)
Position	Lower slope (southern end of large, scalded swale seep) (see **Figure 3**).

Profile description

Layer	Depth (cm)	Description (texture / colour / soil water status / consistence / effervescence of fine carbonate / dispersion / water repellence (affected layers only) (See NCST 2009; Munsell 1988)
1	surface	light sandy loam / dark yellowish brown / moderately moist – moist / loose / moderately calcareous / - / non-repellent
2	-	light sandy loam / strong brown / moist / very weak / moderately calcareous / -
3	-	fine sandy clay loam / reddish yellow / wet / very weak / highly calcareous / - [Calcrete] [Free water in sample]
4	-	fine sandy clay loam / reddish yellow / wet / loose / highly calcareous / slightly dispersive [Free water in sample] [Sample]
------------------------------------ discontinuity ------------------------------------		
5	240	heavy clay / red & olive / moderately moist / strong / slightly calcareous / slightly dispersive [Blanchetown Clay] [Sample]

The Blanchetown Clay forms the aquatard upon which the saturated layers of the seep were observed.

Completion details

Casing	50 mm class PN18 PVC-U
Screen	Vertically slotted for 1 m (1.42–2.42 m depth)
Gravel pack	Washed gravel to cover the screen

Bentonite seal	Bentonite pebbles poured down to form watertight seal above the gravel pack to within 0.5 m of the ground surface
Riser height	Piesometer tube is 0.48 m above ground surface.

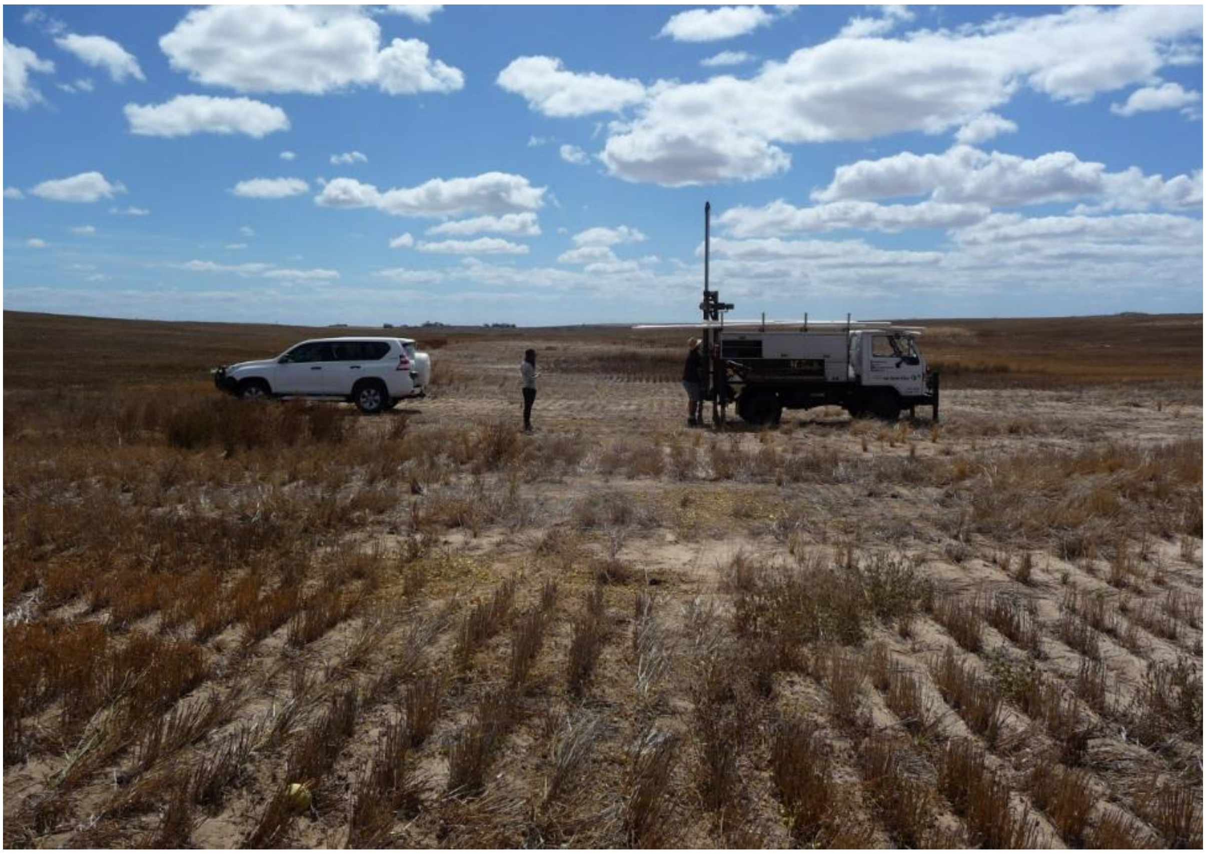

Figure 9 Drilling at Site MDS-P09.