OPAL VALE PTY LTD

REPORT ON:
GROUND WATER ASSESSMENT,
11 CHITTY ROAD,
TOODYAY, WA
JULY 2015

Stass Environmental
Environmental Science & Engineering

REPORT TITLE: **GROUND WATER ASSESSMENT, 11 CHITTY ROAD, TOODYAY, WA.**

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ABN 73 976 537 552

July 2015

GROUNDWATER ASSESSMENT,
11 CHITTY ROAD ,
TOODYAY, WA

1 INTRODUCTION

Opal Vale Pty Ltd (Opal Vale) intends to develop a landfill on this site of the old clay pit at 11 Chitty Road, Toodyay, at some stage. To fulfill regulatory requirements, a groundwater review had to be undertaken.

To be able to define the groundwater conditions at the site, nine groundwater monitoring bores were installed to provide information on:

1. the depth of the water table,
2. the groundwater quality; and
3. the geology below the site

The regional geology and hydrology of the area was reviewed by a literature review of available data on the region obtained from the Geological Survey of Western Australia.

The site was found to be located on weathered schists (fine clayey) geologic materials with expected low transmissivity and groundwater yield. This would suggest that the site is suitable for the activities which are intended by Opal Vale in that the impact on groundwater from the proposed landfill is expected to be minimal if any.

This report provides the detail of the groundwater investigations and monitoring bore installation programme as well as the groundwater quality analytical results for the site.

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2 OBJECTIVES

The objectives of this study are to:

- Review of available regional groundwater and geology data.
- Install groundwater monitoring bores to suit the proposed landfill
- Obtain baseline groundwater quality data from the site.
- Provide a detailed report on the work

3 TERMS OF REFERENCE

Mr. Sam Mangione of Opal Vale Pty Ltd requested that Stass Environmental submit a proposal for the groundwater site assessment, baseline groundwater quality database and installation of groundwater monitoring bores at the Opal Vale facility.

4 SCOPE OF WORK

The following scope of work was carried out:

a) Review of all available data and reports

Review all available data on the groundwater studies performed to date for the development.

b) Provide a short synthesis of the available information

The reviewed reports are to be synthesized into a short form format, to provide a summary of the groundwater status at the site.

c) Assessment of available information

The available information is to be assessed for correctness and adequacy in terms of the proposed development and installation and logging of monitoring bores.

d) Reporting

The information and the interpretation of the data are presented in this document as a stand-alone report.

5 DISCRIPTION OF THE REGION

5.1 LOCATION

The Toodyay geological zone lies approximately 70km east of Perth in Western Australia and covers an area of approximately 2km^2 (Figure 1).

5.2 CLIMATE

The region experiences a Mediterranean climate, characterised by warm dry summers and cool wet winters. During summer (September to March) a belt of anticyclones lies over the region producing dry easterly winds and high temperatures. During winter this belt moves north and the predominant winds blow onshore from the south-west bringing cool temperatures and cold fronts that produce 90% of the region's total annual rainfall. Average annual rainfall varies between 300mm and 420mm and the average daily temperatures range from 17°C to 30°C in summer and from 6 °C to 17 °C in winter.

TABLE 1 Rainfall Records, Northam Station No 010111 (shown as mm/month)

Month	Mean 1902-2014	Mean 1980-2010	2013	2014
January	10.3	17.7	18.4	1.2
February	13.2	16.9	5.8	2.4
March	18.3	16	65.7	0.6
April	23.3	20.2	12.2	48.8
May	55.4	51.1	54.4	77.2
June	79.5	69.8	5.6	45.2
July	82.3	74.7	65.1	87.0
August	60.6	55.6	80.1	41.2
September	37.5	39.2	75.3	41.8
October	24.8	22.1	24.7	50.8
November	12.4	17.3	0.2	8.6
December	9.3	10.1	3.2	
TOTAL ANNUAL	427.1	410.8	410.7	

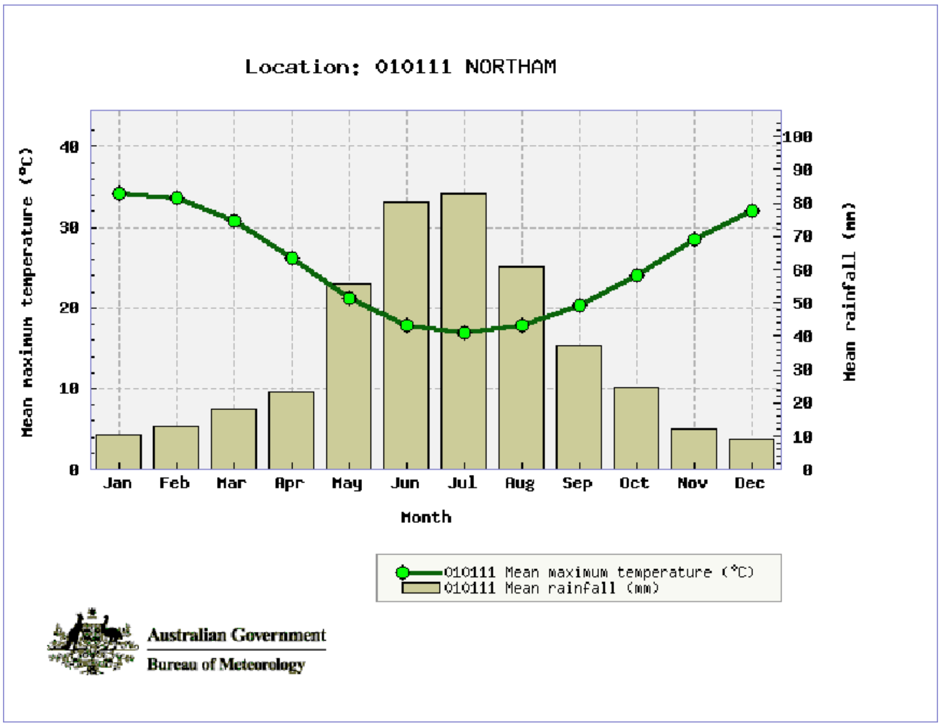
Over the period 1877 to the present the following rainfall statistics apply:

Mean – 427.1 mm/yr *Median* – N/A mm/yr

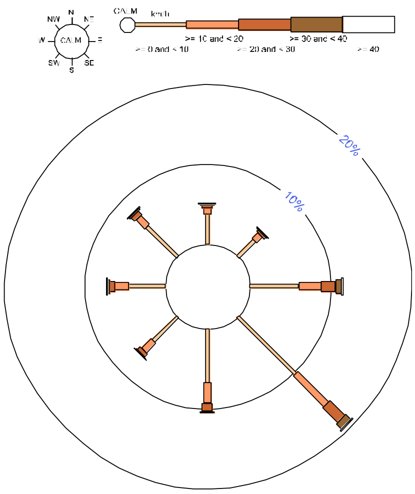
Lowest – 194.1 mm/yr *Highest* – 710.9 mm/yr

TABLE 2 Mean maximum temperature records, Northam, Station No.010111 (in degrees C)

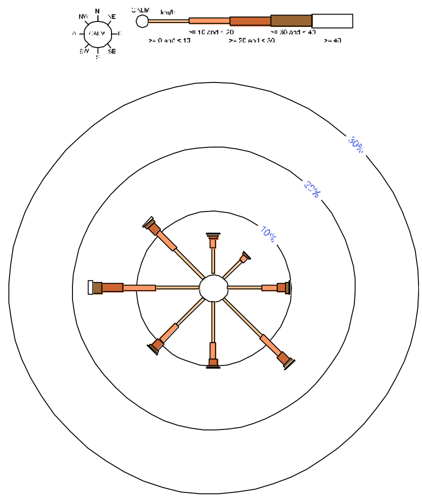
Month	Mean 1902-2014	2012	2013
January	34.2	34.6	34.5
February	33.7	33.2	36.1
March	30.8	32.1	29.2
April	26.1	27.6	29.0
May	21.2	23.4	21.1
June	17.9	18.6	19.0
July	16.9	18.0	17.9
August	18.0	19.4	19.5
September	20.4	21.6	20.1
October	24.1	26.6	25.7
November	28.5	28.2	31.1
December	32.1	33.8	33.6
Annual Average	25.3	26.4	26.4



Wind Roses – Annual wind direction and velocity statistics



Morning winds



Afternoon winds

5.3 GEOLOGY AND LANDFORMS

5.3.1 Geology - Regional

Main geological components of the southwest Yilgarn Craton

The area is characterized by discrete, linear metamorphic belts enveloped by diffuse areas of migmatite, containing isolated rafts of the earlier gneissic sequences (Wilde, 1990). The present distribution of gneiss and migmatite is largely controlled by the emplacement of Late Archaean granitoids which typically post-date metamorphism and regional tectonism. The high-grade gneisses and supracrustal rocks have been grouped within the Jimperding, Chittering and Balingup Metamorphic Belts (Wilde, 1980 and 1990). Migmatite is locally developed at the margins of these belts and also forms more extensive areas in the eastern part of the region. There are also a number of small greenstone belts, ranging in metamorphic grade from greenschist to granulite facies, widely distributed across the region (Fig. 1). All these sequences are intruded by a variety of granitoids, including charnockites in the east.

Metamorphic Belts

The chief rock-type in the Jimperding, Chittering and Balingup Metamorphic Belts is layered quartz-feldsparbiotite gneiss. Some units are paragneiss and show gradations to arkosic quartzite and quartz-mica schist and are interleaved with orthoquartzite, banded iron formation and rare calc-silicate rocks. This association is a characteristic feature of the Jimperding Metamorphic Belt east and southeast of Toodyay and of the south-eastern part of the Balingup belt. It has been interpreted as indicating stable shelf sedimentation on a pre-existing sialic basement (Gee ***et*** *al.,* 1981; Wilde, 1990). In contrast, the Chittering and western portion of the Balingup Metamorphic Belt consist mainly of pelite, semi-pelite and greywacke. Banded iron formation and quartzite are absent and this association has been interpreted to be the result of rapid, trough-style sedimentation along a continental margin (Gee ***et*** al.,1981; Wilde, 1990).

The Jimperding Metamorphic Belt shows a progressive eastward increase in metamorphic grade fiom lower amphibolite to granulite facies, with the presence of andalusite, sillimanite and cordierite indicating low pressure. In contrast, the Chittering and Balingup Metamorphic Belts are chiefly at amphibolite facies, with the presence of kyanite, sillimanite and staurolite indicating moderate pressure, Barrovian-type metamorphism (Wilde, 1990). This contrast in grade between the metamorphic belts appears to be in part related to their location, with the higher pressure assemblages occurring at the western margin of the craton, associated with ductile shear zones related to early movement along the Darling Fault Zone (Blight ***et*** *aZ.,* 1981; Bretan, 1985). This zone has been reactivated at several later periods, resulting in local retrogression to greenschist facies assemblages.

Greenstone Belts

There are a number of small greenstone belts present in the Western Gneiss Terrain. In the south-eastern portion (Fig. l), areas of mafic and felsic granulite are interleaved with a variety of metasedimentary rocks. These were interpreted as 'keels' of original greenstone belts by Wilson (1969) and this interpretation is supported by more recent work on the mafk granulites (Wilde and Pidgeon, 1987; Nemchin ***et aZ.,*** in press). The mineralogical features indicate that this area underwent low to moderate pressure granulite facies metamorphism and the enclosing granitoids commonly include hypersthene-bearing charnockites (Wilde, 1990).

Three lower grade greenstone belts are present near the western margin of the Yilgam Craton; the Saddleback, Morangup and Wongan Hills Greenstone Belts. The Saddleback Greenstone Belt (Wilde, 1976 and 1990) near Boddington (Fig. 1) is poorly-exposed due to an extensive cover of Tertiary laterite. It is composed of mafic and felsic volcanic rocks, with minor sedimentary units, metamorphosed to greenschist facies and generally in faulted contact with orthogneiss, migmatite and granite. However, in the extreme southwest, granite intrudes metasediments and felsic pyroclastic rocks (Wilde, 1976). The Morangup Greenstone Belt near Toodyay (Wilde and Pidgeon, 1990) consists predominantly of metabasalt with a greenschist facies assemblage of tremolite-actinolite, albite and clinozoisite. Porphyritic andesite and fine grained metasedimentary rocks are also present. The sequence is also poorly exposed and the full extent of the belt is unknown. The Wongan Hills Greenstone Belt consists predominantly of basalt, dacite, chert, banded iron formation and mica schist, interleaved with paragneiss and intruded by small ultramafic units, all metamorphosed to upper amphibolite facies (Carter and Lipple, 1982). The presence of cordierite indicates low pressure conditions, similar to those in the nearby Jimperding Metamorphic Belt (Pidgeon ***et al.,*** 1990).

Granitoids

Granitoids occur as two large batholiths that occupy a considerable portion of the southwest Yilgarn Craton. The granitoids east of Meckering and Quairading and around Lake Grace were informally referred to as the "Wheat Belt" granites by Wilson (1958), whereas the western area has been termed the Darling Range Batholith (Wilde and Low, 1978). The zone of mignatite referred to above separates the two batholithic areas.

Around Katanning many porphyritic granites are hypersthene-bearing and petrographically and geochemically identical to those developed further east within the zone of migmatite and gneiss south of Quairading and in the "Wheat Belt" batholith. Wilde and Pidgeon (1987) describe reaction textures from near Lake Grace which indicate that hypersthene and subsequent mafic minerals followed a magmatic crystallisation sequence and that these charnockites are of igneous origin.

The granitoids of the Darling Range Batholith are quite diverse and show considerable textural variation. They range in composition from granodiorite to granite; the compositional variations being commonly independent of textural changes. Where cross-cutting relations can be identified, granodiorite is invariably the earliest phase. Most granitoids are undeformed, although plutons of porphyritic granite that occur close to the eastern boundaries of the Chittering and Balingup Metamorphic Belts show evidence of intense ductile shearing. There is a westward increase in deformation, resulting in a progressive change from porphyritic granite to augen gneiss, mylonite and ultramylonite (Blight ***et*** *aL,* 1981). This deformation is related to early movement along the Darling Fault Zone, accompanied by medium pressure, amphibolite facies metamorphism (Wilde, 1990).

There are also a number of small bodies of quartz-poor granitoids of dioritic, monzonitic and syenitic affinity within the granite batholiths. More extensive areas of quartz monzonite occur south of Darkan (Fig. 1) and these are rich in amphibolite xenoliths. A distinctive, tectonised quartz monzonite (the Gibralter Quartz Monzonite) forms a narrow, discontinuous zone along the eastern boundary of the Balingup Metamorphic Belt (Wilde and Walker, 1982 and 1984) in association with migmatite.

5.3.2 Geology - Site

The site is located on the dissected Darling Plateau. The locality consists of an elongate narrow plateau remnant that runs north west along the ridge line in the west, at an elevation of 280 metres AHD ranging down to about 240 metres in the north west.

The general area is located in a drainage basin of the Avon River system and geologically, is are part of the Pre-Cambrian meta sedimentary complex which is known as the Jimperding Metamorphic Belt. The Jimperding Metamorphic Belt Series extends as a 120 kilometre long belt in a north-westerly direction from York to Clackline and from there to Jimperding and then Chittering, where it becomes the higher grade metamorphic Chittering Metamorphic Belt.

Williamson's Pit is located on the crest of a hill, at an elevation of about 290 metres AHD.

To the west of the pit the land is gently undulating before sloping relatively uniformly to the river flat. To the immediate east of the pit the land slopes gently down to a small drainage line (draining from south to north) at about 280 metres and from there the land slopes gently upwards to about 330 metres.

The Jimperding Series consists of inter-bedded schists, quartzites and minor metamorphosed volcanics. They are steeply dipping and trend northerly and then north-westerly. However under the void only weathered schists are encountered, because these are the only parts of the regolith that are suitable for brick manufacture.

The area to be filled is a void cut into deep micaceous clays formed from the weathering of schists of the Jimperding Metamorphic Belt. The rocks are predominantly weathered andalusite and kaolin-quartz-mica schists that are near vertical and striking generally north. These schists have been subjected to a long period of weathering, in the Mesozoic - Cainozoic, to produce the laterite erosion surface, of which a remnant caps the nearby hills.

A number of hydrothermal quartz veins intersect the exposed geological sequences, presumably intruded along fracture lines. The quartz veins are either massive white quartz veins or a reddish coloured quartz which has been fractured, presumably due to earlier metamorphic events, These older quartz veins tend to have the fractures infilled with a clay/silt matrix.

Weathering of the rocks is deep, and, from a drilling program conducted by Austral Brick, shows the depth of weathering as over 30 metres. The base of the weathered material was not found because the clay quality reduced with depth and drilling was stopped.

Williamson's Pit is located in an area of micaceous silty clay which becomes fresher with depth and shows some laterisation. Clayey sands are present in small amounts.

Only clays suitable for brick making are excavated.

5.3.3 Soils

The soils which overlay the weathered schists (clay) belong to the Yalanbee and Leaver soil landscape units. In the vicinity of Williamson's Pit is a yellow gravelly loamy sand and loam which overlies sandy clay at a depth of about 0.5 metres.

6 SITE HYDROGEOLOGY

6.1 Regional Hydrogeology – Previous Investigations

The local hydrogeology has been characterised from an interpretation of the exploration drilling undertaken by Austral Brick and hydrogeological studies completed by Martinick McNulty in 1998.

On 24 March 1998 ten holes were drilled by Wallis Drilling with a Mantis drilling rig which was mounted on a Toyota Landcruiser, to assess the local geology and groundwater conditions.

Water was generally not encountered during drilling, with the exception of some holes which are located approximately 1 kilometre to the northwest of the pit. In these holes granite was intersected and water was found to be present in weathered basement.

Hydraulic testing of all of the monitoring bores (WF 1 to WF 11) was undertaken by Martinick McNaulty to determine the in-situ hydraulic properties of the schistose clay. Testing comprised injection of a known volume of water into the bore and subsequently monitoring the rate at which the water level declined. Analysis of the response was completed using the Bower and Rice method.

From the results of the hydraulic testing it was concluded by Martinick McNulty, that the schistose clay present in the pit and its vicinity has a low to very low permeability and that the groundwater regime in that area is classified as an aquitard/aquiclude. That is to say, although groundwater is present there is no defined aquifer system. The sandy clays are partially saturated and the local groundwater levels and vary with changes in topography.

6.1.1 Permeability

Six piezometers were installed by Martinick/McNulty around the perimeter and another four within the clay pit at that time. Whilst the clay pit has been enlarged in the past decade, the results provide a good indication of the geotechnical properties of the weathered schist.

In each piezometer a PVC standpipe of 50 millimetre diameter was installed immediately after the hole was drilled. The casing was slotted for the entire depth of the hole and all of the piezometers were surveyed by Scanlan Surveying in May 1998. A summary of monitoring bore details is provided in Table 3 (Martinick McNaulty 2002).

Two clay samples were collected by Martinick/McNaulty from the floor of Williamson's Pit adjacent to bores WF2 and WF4. These samples were analysed for particle size distribution, optimal moisture content for compaction and permeability of the compacted clay.

Table 3 Permeability Testing (Martinick McNaulty 1998)

Drill Hole	East	North	Top of Casing	Local RL	Permeability m/d	Permeability m/s
WF1	449865	6449588	88.41	81.91	0.0164	1.1 x 10-7
WF2	449915	6495825	89.2	81.69	0.0041	4.7 x 10-8
WF3	449761	6495895	82.07	80.71	0.0037	4.2 x 10-8
WF4	449870	6495734	86	81.2	0.0064	7.4 x 10-8
WF5	449756	6496127	85.5	80.49	0.038	4.4 x 10-7
WF6	49956 6	495896	99.57	85.3	0.00034	3.0 x 10-9
WF7	449845	6495626	86.37	80.99	0.0017	1.9 x 10-8
WF9	449658	6495750	90.5	86.89	0.006	6.9 x 10-8
WF10	0449632	6495903	86.44	83.90	0.0030	3.4 x 10-8
WF11	1449606	6495610	84.62	80.88	0.0204	2.4 x 10-7

The distribution of particle sizes demonstrated that the material in Williamson's Pit consists of a clayey silty sand with minor gravel. The clay content varies from 4 to 8%, the silt content varies from 26% to 33% silt, and the sand content varies from 53 to 56%. Golder Associates have repeated the tests on in situ material from the site in 2014 and found the following results:

- Gravel (> 2.36 mm): 3%
- Sand (2.36mm to 75 µm) : 42%
- Silts (<75 µm): 40%
- Clay (<2µm) : 15%

The falling head permeability tests for samples compacted to 90% standard compaction at optimal moisture content, gave coefficients of permeability of $3.12x10^{-9}$ and $1.49x10^{-8}$ metres per second respectively for WF2 and WF4. The compaction tests indicate that maximum dry densities of 1.87 and 1.74 tonnes per cubic metre at optimum moisture contents of 13% and 17% could be achieved for the material obtained from WF2 and WF4, respectively.

The above tests indicate that the clay can be used as landfill liner material, if compacted.

6.1.2 Permeability Testing, Excavated Clays, Golder Associates 2014

Golder Associates (2014) (Golder) have performed a number of geotechnical tests on materials from the Opal Vale quarry during 2014. Their results (based on 6 samples colected from the quarry indicated a very low permeability geological materials as shown in Table below:

Table 4: Golder (2014) falling head permeability testing (refer to Golder report for further information).

Sample ID	Permeability m/s
Opal 1	7.2×10^{-9}
Opal 2	3.90×10^{-9}
Opal 3	5.80×10^{-9}
Opal 4	6.80×10^{-9}
Opal 5	2.20×10^{-9}
Opal 6	9.10×10^{-9}

6.1.3 Bore Permeability Testing in July 2015

Further permeability tests (rising head slug test) were carried out by Stass Environmental in July 2015 on bores around the pit (SE1, SE 2, SE 3, SE 5 and SE 6). The permeability tested was of the actual geological material which contained water at depth and were found to be more permeable than the surface materials, as shown in the table below:

Table 5 Material permeabilities at depth in monitoring bores surrounding the quarry (July 2015)

Sample ID	Permeability m/s	Permeability m/d
SE 1	5.9×10^{-7}	0.0432
SE 2	1.3×10^{-7}	0.0086
SE 3	2.0×10^{-7}	0.0172
SE 5	1.4×10^{-7}	0.0086
SE 6	4.9×10^{-7}	0.0345

These results indicate that even at depth in saturated conditions, permeabilities in the order of 0.0086m/d to 0.043 m/d indicate an aquitard (as opposed to aquifer) geological conditions. They also compare well to testing done by Martinick/McNaulty in 1998. Data on the field tests is provided in Appendix K.

6.2 REGIONAL GROUNDWATER QUALITY

The regional groundwater quality is highly variable, with water quality ranging from 500 mg/l as TDS to 3000 mg/l TDS. Ground water tends to be slightly acidic with pH in the range of 4 to 5 not uncommon.

7 MONITORING BORE INSTALLATION

Drilling at the site commenced in June 2011 and was completed in 5 days. Further installation of monitoring bores was required as the outcome of the SAT process in 2013, and a further 5 monitoring bores were installed in April 2013. All fieldwork undertaken, including a summary of the investigation methodology utilised is summarised in the following sections in chronological order.

7.1 LOCATION OF GROUNDWATER MONITOR WELLS

7.1.1 Previously Installed Monitor Wells

No previously installed wells (pre 2011) were observed at on site. Wells drilled for previous investigations have been decommissioned or were unusable. Other bores in the general area to 2 km radius, registered with Department of Water are shown below. No registered bores are located within a radius of 2 km from the site. The nearest bore is located 2.2 km up hydraulic groundwater gradient, to the east of the site.

7.1.2 Monitor Well Site Selection

Nine new groundwater monitor wells (designated SE-1 to SE-9) were installed at the site during this investigation. The locations for these wells were selected after an evaluation of the regional groundwater flow direction (previous groundwater monitoring).

Monitor wells SE-1 to SE-3 were installed within the south-western areas. Monitor well SE-4 targeted the aquifer up-hydraulic gradient boundaries of the site. Monitoring bores SE 5 and SE 6 targeted the south and south east side of the pit edge, while monitoring bores SE 7, and SE 8 the north and north western edges. Monitoring bore SE 9 was installed to record the far western side of the proposed development.

Prior to the commencement of drilling activities, all services within the site area were identified and located to prevent potential damage. Accurate locations of the nine newly installed monitoring bores are shown on Figure 6.

7.1.3 Drilling

The nine monitor wells (SE1 to SE9) were installed by Mick Lewis Drilling under supervision by Stass Environmental using the down hole hammer rotary drilling technique (refer Appendix B, Photographs 1). At all drilling locations, natural clays and muscovite schists were encountered throughout the entire profile therefore allowing trouble free well completion.

Drilling locations SE 1 to SE 9

- After positioning the drill rig, 150mm diameter holes were drilled to approximately 50 to 60m.
- The casing was inserted and sand packed to one metre above the slotted interval (see Figure 8 to 17).
- Bentonite pellets were placed immediately above the sand packing and measured with a weighted tape until a one metre thick seal was formed.
- The annulus of the hole was backfilled with local drilled materials mixed with cement grout to the ground surface and sealed with bentonite at the ground surface to prevent surface water leakage to groundwater. A cement pad measuring 300mm from the centre of the bore annulus was also placed to further reduce the potential for surface waters to short circuit down the bore annulus.

Steel protective surface covers, protruding approximately 600mm above the ground surface were also installed over all PVC casings and lockable with padlocks. Monitor well logs and construction diagrams are contained within Appendix B.

Five in-pit bores were also installed to a depth of approximately 10 m, to monitor any sub-surface waters within the pit (again, as part of the SAT outcome).

7.1.4 Development

Immediately following well installation, monitor wells SE-1 SE 9 were developed to remove sediment initially using compressed air from the drill rig and later an electric submersible pump (Grundfoss MP1 and other electric pumps).

7.1.5 Position and level survey

A position and level survey was undertaken by a licensed surveyor to determine Australian Map Grid (AMG) coordinates and Australian Height Datum (AHD) elevations of each monitor well casing including the wells from 2011 installation and newly installed monitor well (2013). During the level survey, elevations of each monitor well were obtained from the highest point on the bore protective cover opening, which was also permanently marked for future reference. These reference points were used during the collection of water levels as described in Section 7.6. The results of this position and level survey are shown below in Table 6:

Table 6 MONITOR WELL SURVEY DATA

Monitor Well	Easting (mAMG)	Northing (mAMG)	PVC Casing Elevation (mAHD)	Descriptive Location
SE1	6495635.67	449807.22	274.4	Close to drainage line
SE2	6495913.82	449616.1	285.59	Along the downgrad. Road
SE3	6496194.1	449382.8	291.67	Along the downgrad. Road
SE4	6495785.76	450377.9	299.86	Upstream of quarry
SE 5	6495858.19	449809.33	286.78	South edge of pit
SE 6	6495855.09	450039.37	289.08	East edge of pit
SE 7	6496095.83	450043.12	292.86	North edge of pit
SE 8	6496172.63	449770.44	278.62	North east of pit
SE 9	6496373.32	449643.15	274.89	Far north east of pit
pit 1	6496054.74	449813.3	273.84	In pit shallow bore
pit 2	6496122.84	449804.3	273.61	In pit shallow bore
pit 3	6496068.4	449783.3	273.37	In pit shallow bore
pit 4	6496037.65	449909.91	277.14	In pit shallow bore
pit 5	6495956.53	449711.11	274.18	In pit shallow bore

Note: mAHD – metres above Australian Height Datum

mAMG – metres relative to Australian Map Grid

All positions were determined by a licensed surveyor using a differential GPS instrumentation, calibrated to within +/- 2mm accuracy. AHD elevations were surveyed to +/- 2mm. These levels of accuracy are judged to be within the requirements of this study.

Photo plate 1 - Drill cuttings sampled at 1 m intervals. Water struck at 39 m depth.

Photo plate 2 - cuttings sampled at 1 m intervals. Water struck at 44 m depth.

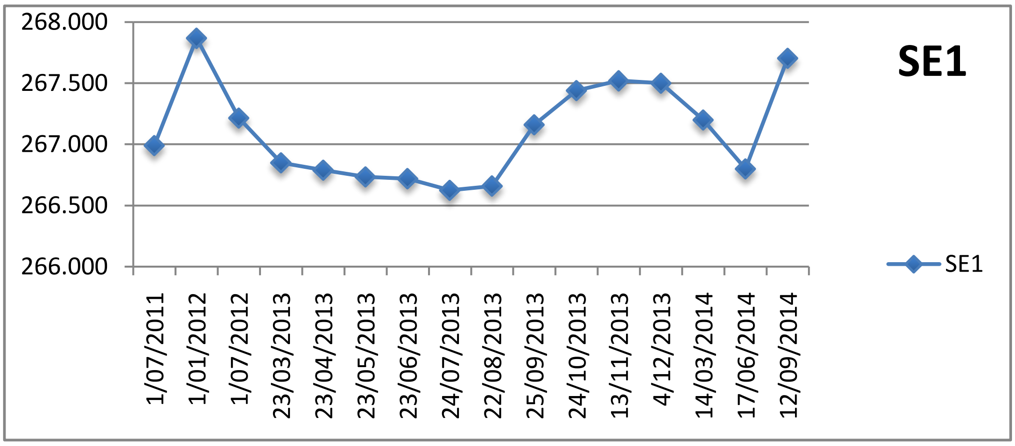
7.2 Water Level Measurement

Water levels were measured in all monitor wells on-site prior to the purging and sampling of each well (described earlier in Section 7). These levels were assessed to be suitable for hydrogeological interpretation. The highest of these levels, measured quarterly between 2011 and 2014 reduced to AHD using the level survey data are shown in Table 7 below.

Table 7 Highest water levels 2011 to 2014

Monitor Well	Easting (mAMG)	Northing (mAMG)	Highest Water Elevation (mAHD)
SE1	6495636	449807.2	267.868
SE2	6495914	449616.1	272.46
SE3	6496194	449383	273.94
SE4	6495786	450377.9	278.34
SE 5	6495858	449809.3	271.78
SE 6	6495855	450039.4	272.885
SE 7	6496096	450043.1	273.275
SE 8	6496173	449770.4	271.94
SE 9	6496373	449643.2	270.715
pit 1	6496055	449813.3	270.565
pit 2	6496123	449804.3	271.75
pit 3	6496068	449783.5	270.275
pit 4	6496038	449911.2	270.5
pit 5	6495948	449707.9	271.92

The data obtained from the quarterly measurements of the static water level at the bores is provided in the graphs below:


SE1
268.000
267.500
267.000
266.500
266.000
SE1
1/07/2011
1/01/2012
1/07/2012
23/03/2013
23/04/2013
23/05/2013
23/06/2013
24/07/2013
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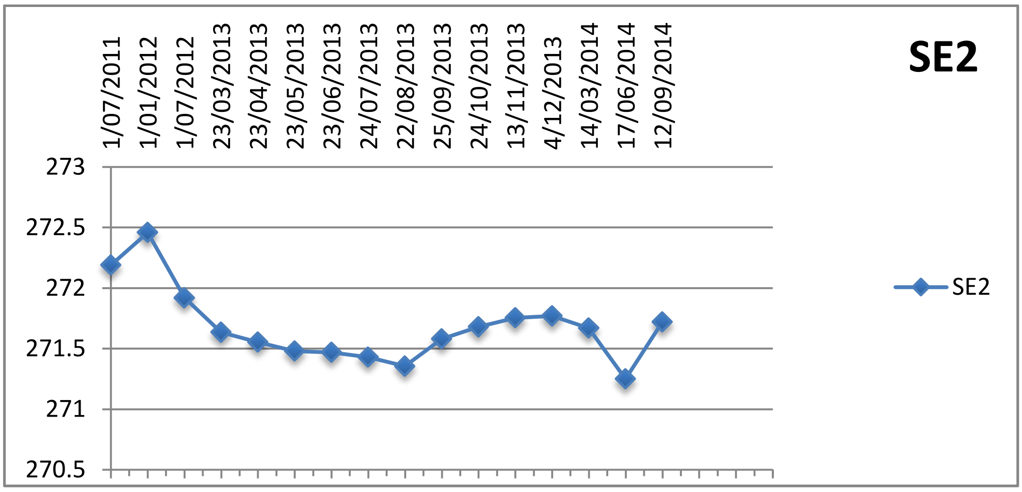
12/09/2014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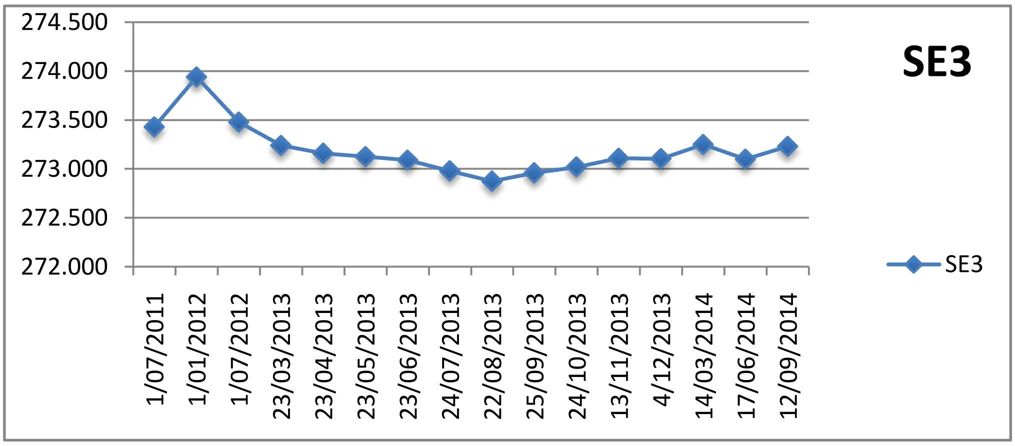
SE2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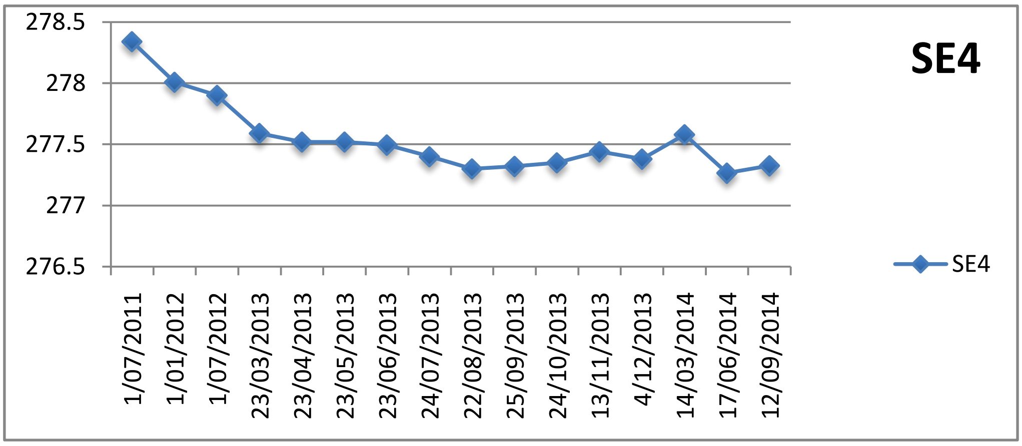
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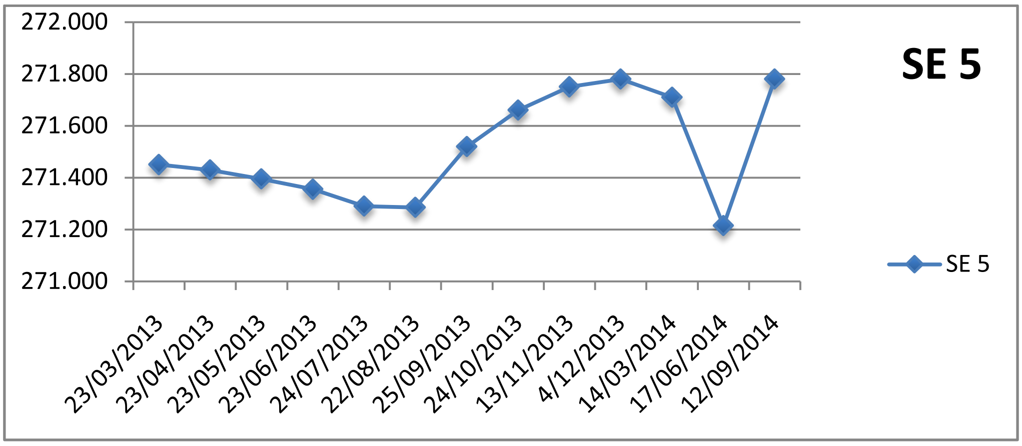
SE4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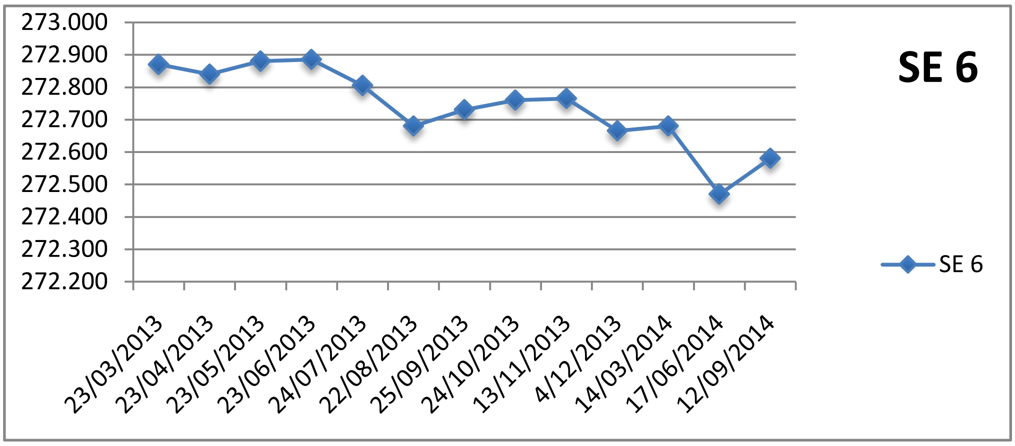
SE 5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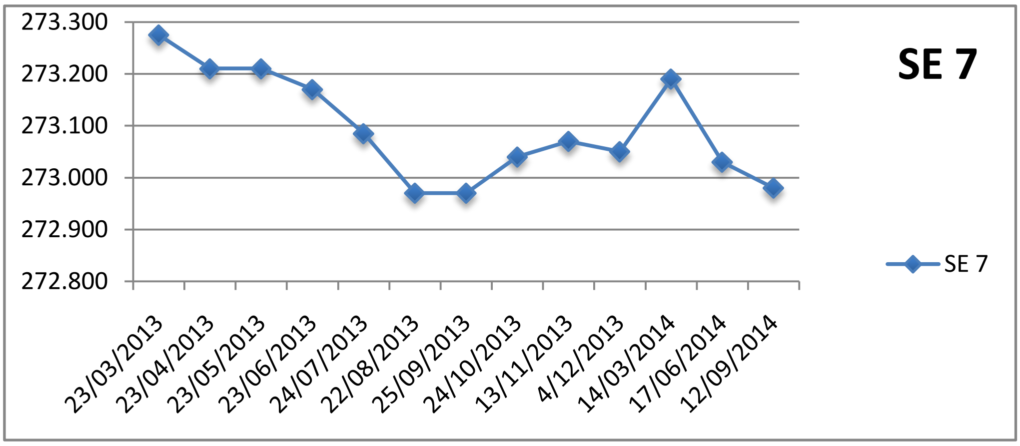
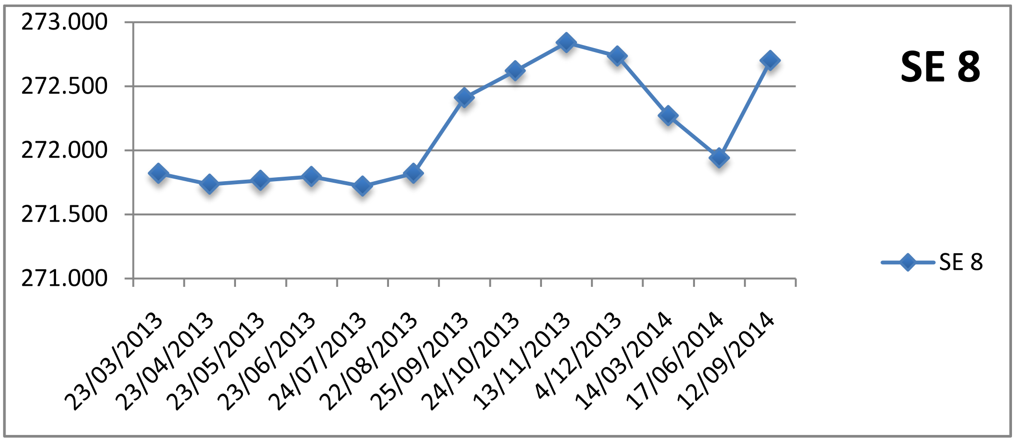
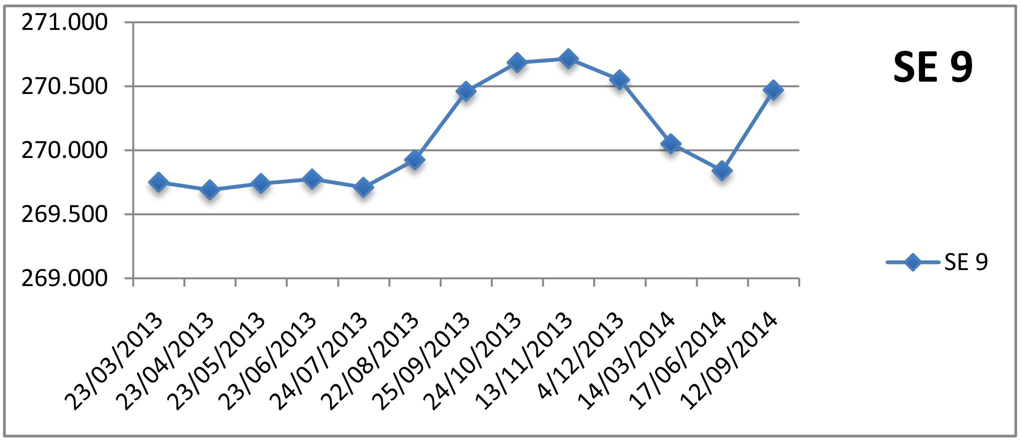
SE 6







7.2.1 Purging and Sampling

Groundwater samples were obtained from a total of 4 locations on and around the site from the 9 new monitoring wells. Prior to sampling, each monitor well was purged at a rate of approximately 5 L/min using a decontaminated submersible pump for a minimum of 15 minutes (i.e. purge volume of greater than 75L).

Groundwater samples were collected in laboratory supplied and preservative treated containers from each monitor well after withdrawing the submersible pump. Groundwater samples were collected in accordance with AS 5667.1:1998 . All samples were stored on ice and transported MGT Eurofins laboratories in Melbourne for analysis with appropriate chain-of-custody documentation. In addition, one duplicate sample was obtained at each monitoring event and submitted for quality control purposes.

The laboratory certificates of all of these analyses are provided in the Appendix D.

7.2.2 Field Water Quality Data

Water quality of the groundwater samples was tested in the field. The following Table 8 presents the average results over the period 2011 to 2014:

Table 8 Average of the field water quality record (June 2011 to October 2014)

Bore ID	pH	Elect. Cond Us/cm	TDS ppm
SE 1	3.7	3744	1886
SE 2	4.45	7536	3904
SE 3	6.9	8640	4490
SE 4	5.8	488	257
SE 5	4.9	4188	2326
SE 6	4.4	6936	3415
SE 7	3.7	10628	4836
SE 8	6.01	692	346
SE 9	5.2	12854	981

Field water quality records were recorded at all bores, from SE-1 to SE-9 between March 2013 and October 2014. Previous to that bores SE-1 to SE-4 were sampled when installed in 2011 and then again quarterly to 2014.

It is apparent from the field water quality results that two different groundwater aquifers have been intersected by the 9 bores installed around the site. Bores SE-1, SE-2, SE-3, SE-5, SE-6 and SE-7 report poor water quality of brackish nature, whereas bores SE-4, SE-8 and SE-9, which are located to the east and north of the site report relatively fresh water conditions.

The field water quality records for pH, electrical conductivity and field salinity testing are provided in Tables 9 to 11. It is worth noting that while most of the bores presented a relatively steady water quality, the variation in both pH and EC at bore SE 9 was at times significant, with salinity increasing with reduction in acidity (rise in pH) of the groundwater.

Table 9 - Field water quality record - pH

Bore ID	SE1	SE2	SE3	SE4	SE 5	SE 6	SE 7	SE 8	SE 9
Northings	6495635.667	6495913.7	6496193.886	6495786	6495858	6495855.090	6496096	6496173	6496373
Eastings	449807.222	449616.1	449382.966	450377.9	449809.3	450039.370	450043.1	449770.4	449643.2
1/07/2011									
18/01/2012	3.590	4.03	3.910	6.23					
18/07/2012	4.620	6.4	4.360	8.89					
13/01/2013	3.740	4.4	4.720	6.15					
23/03/2013	4.050	5.630	3.870	6.140	5.860	5.170	4.300	6.760	6.370
24/07/2013	3.190	4.650	36.980	5.360	4.730	4.510	3.620	6.15	4.93
24/10/2013	3.750	4.300	4.220	4.710	4.780	4.450	3.620	6.020	5.130
13/11/2013	3.800	4.270	3.540	5.410	4.640	4.660	3.520	5.550	6.150
4/12/2013	3.340	4.240	3.890	5.070	4.520	3.980	3.410	5.650	4.860
14/03/2014	3.630	4.000	3.350	5.680	5.000	4.220	3.660	6.530	5.350
17/06/2014	3.520	3.330	3.450	5.080	4.620	4.240	3.530	5.670	4.620
12/09/2014	3.520	3.700	3.550	5.260	4.710	4.270	3.650	5.790	4.420
Average	**3.705**	**4.450**	**6.895**	**5.816**	**4.858**	**4.438**	**3.664**	**6.015**	**5.229**

Table 10 - Field water quality record - Electric Conductivity in µS/cm

Bore ID	SE1	SE2	SE3	SE4	SE 5	SE 6	SE 7	SE 8	SE 9
Northings	6495635.667	6495913.7	6496193.886	6495786	6495858	6495855.090	6496096	6496173	6496373
Eastings	449807.222	449616.1	449382.966	450377.9	449809.3	450039.370	450043.1	449770.4	449643.2
18/01/2012	4300	6070	7690	327					
18/07/2012	3920	5200	7880	473					
9/01/2013	3750	5670	7750	540					
23/03/2013	3620	5600	8500	532	5090	5870	6480	1358	597
24/07/2013	3770	5440	12490	507	5260	5640	11230	570	952
24/10/2013	3650	5860	5570	479	4130	5570	11600	529	2310
13/11/2013	3620	5790	5450	504	3990	5640	10960	527	841
4/12/2013	3600	6080	12260	452	4270	6950	10950	523	852
14/03/2014	3710	10200	8770	453	3830	7900	11350	635	3320
17/06/2014	3640	12880	9650	644	3680	8610	11180	979	700
12/09/2014	3600	14110	9030	455	3250	8510	11270	415	698
Average	**3744**	**7536**	**8640**	**488**	**4188**	**6836**	**10628**	**692**	**1284**

Table 11 - Field salinity record in mg/l

Bore ID	SE1	SE2	SE3	SE4	SE 5	SE 6	SE 7	SE 8	SE 9
Northings	6495635.667	6495913.7	6496193.886	6495786	6495858	6495855.090	6496096	6496173	6496373
Eastings	449807.222	449616.1	449382.966	450377.9	449809.3	450039.370	450043.1	449770.4	449643.2
18/01/2012	2976	4231	5315	327					
1/01/2012	1310	2880	4430	236					
1/07/2012	1840	2810	3800	260					
23/03/2013	1810	2800	4250	261	2470	2890	3240	675	3000
24/07/2013	1890	2720	6290	252	2620	2830	5540	285	474
24/10/2013	1830	2940	2790	239	2080	2790	5800	260	1170
13/11/2013	1810	2900	2740	251	2000	2820	5480	262	422
4/12/2013	1800	3040	6130	226	2140	3470	5500	263	426
14/03/2014	1860	5120	4300	227	3830	3950	5680	321	1660
17/06/2014	1820	6440	4830	323	1840	4310	1820	490	350
12/09/2014	1800	7060	4520	228	1630	4260	5630	208	349
Average	**1886**	**3904**	**4490**	**257**	**2326**	**3415**	**4836**	**346**	**981**

8 LABORATORY ANALYSIS

8.1 Analytes

All groundwater and quality control samples were analysed using National Association of Testing Authorities (NATA) registered methods and analytical techniques for the following determinants.

- Major anions and cations, pH, conductivity, ammoniacal nitrogen and total dissolved solids (TDS);
- Heavy metals including arsenic, cadmium, chromium, copper, nickel, lead, zinc and mercury;

The chain-of-custody documentation and analytical data as presented by the laboratories appears within Appendix D.

8.2 Quality Control

The following sections describe the testing methodologies and quality assurance/quality control (QA/QC) procedures used for analysis of the water samples obtained during the field activities.

8.3 Field Duplicates and Blank Samples

One field blank sample (designated SE-5) was obtained. The results of the field duplicate and blank analyses are included in the Appendix D.

The Relative Percentage Difference (RPD) values calculated for the duplicated groundwater analysis ranged from incalculable where results were below laboratory practical quantitation limits (PQLs).

Analysis of the blank groundwater sample (designated SE 5) reported concentrations below the respective practical quantization limits (PQLs). Expected background concentrations were reported for major anions, cations and the heavy metals analyses conducted.

8.4 Laboratory Control Samples, Spike Recoveries, Duplicates and Blanks

Laboratory control and spiked samples were analysed by ARL and MGT Eurofins for all analytes (where applicable). All recovery results were within recommended control limits, indicating the results of the sample analyses are adequate for the purposes of this report, with a general tendency to slightly overestimate the concentrations of each individual analyte. All laboratory blank samples reported concentrations less than the PQL.

Laboratory duplicate analysis was conducted for heavy metals, cations, anions, ammonical nitrogen and total nitrogen. All RPDs were well within acceptable limits. These are provided in water quality summary tables in Appendix C.

9 GROUNDWATER QUALITY

The groundwater analytical results are summarised in Appendix C. Based on the analytical results obtained, the following conclusions can be derived.

9.1 Major Ions and Groundwater Parameters

Analysis of groundwater samples reported all major ions and parameters

9.2 Heavy Metals

Analysis of most of downgradient and upgradient groundwater reported dissolved heavy metal concentrations above the DEC (2010) fresh water guidelines. Bores SE-4, SE-8 and SE-9 are located north and east of the proposed landfill and water within these bores is characterised by relatively low salinity (ranging some 200 to 1000 mg/l as TDS), the absence of heavy metals (arsenic, cadmium, copper, nickel, lead and zinc) and moderate pH (close to neutral). In general, the water quality to the north and east of the proposed landfill can be described as relatively good.

To the south and west of the site, the groundwater displays poor water quality. The water is brackish with TDS ranging from 2000mg/l to over 6000 mg/l. Heavy metals are present for all sampling events, with nickel being the main heavy metal of concern as the concentrations of this water quality variable have in the past been in the order of 200 times over the drinking water guidelines. Lead and copper are also prevalent, with occasional presence of small amounts of cadmium and arsenic. Table 12 presents water quality analyses from the most recent sampling event included in this report which is for September 2014. These analyses can be considered as representative of all other sampling events.

Summaries of the water quality in the bores are presented in Appendix C.

9.3 Nitrate

Unlike with the heavy metals, nitrate (or other nitrogen species) is not present in the groundwaters to the south and west of the proposed site, but is present to the north and east. This is most likely as a consequence of land use - the land is stocked with sheep.

The water quality with respect to all the nitrogen species complies with DER water quality guidelines for drinking water.

Table 12 – Water Quality Results - September 2014

	SE1	SE2	SE3	SE4	SE5	SE6	SE7	SE8	SE9	NG2
Chloride	**1000**	**4800**	**2900**	100	**910**	**2800**	**3900**	48	59	58
Conductivity (at 25Â°C)	**3700**	**14000**	**9400**	440	**3300**	**8700**	**12000**	400	**700**	**700**
pH	**3.5**	**3.8**	**3.4**	6.1	5.9	**4.3**	**3.7**	7.1	7.4	5.9
Sulphate (as S)	41	240	190	5.6	44	110	60	12	66	67
Total Dissolved Solids	**1900**	**9000**	**5100**	260	**1800**	**4500**	**6800**	270	490	480
Alkali Metals										
Calcium	1.1	25	3.7	0.9	1.7	2.2	5.5	< 0.5	< 0.5	< 0.5
Magnesium	40	420	300	9.9	70	100	100	1.3	1.8	1.9
Potassium	2.8	53	66	1.5	17	11	7.2	2.3	1.9	1.8
Sodium	**550**	**2100**	**1200**	70	470	**1500**	**1800**	81	130	130
Heavy Metals										
Arsenic (filtered)	0.001	0.002	0.004	< 0.001	< 0.001	0.001	0.002	< 0.001	< 0.001	< 0.001
Cadmium (filtered)	0.0003	0.0019	**0.027**	< 0.0002	0.0004	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.0002
Chromium (filtered)	0.001	0.004	< 0.001	< 0.001	< 0.001	0.005	0.002	< 0.001	< 0.001	< 0.001
Copper (filtered)	0.46	1.8	0.01	0.013	0.003	0.085	0.093	0.002	0.007	0.007
Lead (filtered)	**0.096**	**0.66**	**0.1**	< 0.001	< 0.001	**0.014**	0.003	< 0.001	< 0.001	< 0.001
Manganese (filtered)	0.093	1.2	1.8	0.017	1.6	0.055	0.1	< 0.005	< 0.005	< 0.005
Mercury (filtered)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nickel (filtered)	**0.098**	**1.2**	**3.8**	0.014	**0.49**	**0.029**	**0.046**	< 0.001	0.003	0.003
Zinc (filtered)	0.1	0.91	3.2	0.024	0.38	0.052	0.058	0.004	0.038	0.039
Total Nitrogen Set (as N)										
Nitrate & Nitrite (as N)	< 0.05	< 0.05	< 0.05	7.7	< 0.05	0.13	0.98	5.7	7.5	8
Total Kjeldahl Nitrogen (as N)	< 0.2	0.3	< 0.2	0.3	< 0.2	< 0.2	< 0.2	< 0.2	0.2	< 0.2
Total Nitrogen (as N)	< 0.2	0.3	< 0.2	8	< 0.2	< 0.2	1	5.7	7.7	8

All results in mg/l.
Values in bold exceed drinking water guidelines

10 GROUNDWATER CONDITIONS

10.1 Groundwater Hydraulics

Regional ground water was inferred to be flowing in a north to north-westerly direction south of the site and also north-westerly, north of the site. This observation is based on observed flow directions of local creeks and brooks and also the topography which is expected to provide some control on regional groundwater flow. Figures 4a, 4b and 4c illustrate the direction of groundwater flows based on lines of equal potential derived from the groundwater elevation in each monitor well (Section 7) during high SWL monitoring events after the wet cycle.

No shallow groundwater or perched aquifers were observed at the site during the monitoring events from 2011 to 2015. To test this observation, the northern pond at the base of the quarry was pumped out in November 2014, exposing a 200 m long and 5 to 8 m high geological section below the floor of the pit. The faces of these exposed pond walls were inspected at the end of November 2014 and no signs of any seepage from these walls were observed either on the south or north sides of the empty pond. This confirmed that no shallow water table existed below the floor of the pit.

During February 2015, unseasonably large rainfall (twice the long term average) allowed a significant inflow of surface waters to the emptied pond, and again in March 2015 good rainfall also added to the pond water level. The pond was again inspected at the end of March 2015 and the exposed walls of the pond (approximately 4 m high) did not indicate any seepages into the pond. Representative photographs of these inspections are provided in Appendix L.

Ground water (as a deep confined aquitard) appears to exist underneath the whole of the proposed landfill. Hydraulic conductivities in the aquitard range from 0.008 m/d to 0.04m/d (refer to permeability testing in Section 6.1.3). Ground water migrates from the east and the predominant flow direction from the proposed landfill site is to the south and north west, with a relatively steep hydraulic gradient of approximately 0.03, when calculated with respect to a closest potential groundwater pathway to the Jimperding Brook. The site sits on a topographical saddle which is also reflected in the groundwater potentiometric surface morphology.

10.2 Conceptual Hydrogeological Model

A conceptual groundwater model has been derived from a review of previous reports relating to the drilling, and the recent installation of more piezometers at the site.

Figure 7a and 7b illustrates the major features of the conceptual hydrogeological model of the quarry area and surrounds. The major elements of the model are:

- The local geology is characterised by weathered micaceous schists with steep paleo-bedding which strikes northwards. The weathered zone above fresh bedrock extends to between 40 and 50m. This zone is primarily a white to beige silty/clay with inclusions of quartzite, mica and is criss-crossed by a number of hydrothermal quartz veins. No local faulting has been observed from aerial photography nor is reported in geological maps of the area. The clayey schists are underlain by quartzite at depths greater than 50m from the surface (based on the fact that no quartzite has been observed in drilling of the 9 bores around the quarry, some of which were drilled to 50 m depth).

- Recharge to the local aquifers is likely to be from zones to the east (quartzite), and potentially a long distance away. Local geology is of very low permeability and is unlikely to provide rainfall recharge of any magnitude. The closest groundwater discharge to the site is the Jimperding Brook, located about 1 km to the south of the site.
- The upper 10 to 15 m of this weathered zone is mined for clay. Below this level the clay becomes saline and is no longer suitable for brick and tile production.
- The aquitard has a steep groundwater gradient with respect to Jimperding Brook (0.03). Seasonal groundwater level fluctuations over the site are in the order of 0.5 to 1.2 m.
- The aquitard which is located in weathered micaceous schists at depth and is confined by between 30 and 50 m thick bed of weathered micaceous to gritty silt/clays, from the ground surface (see Figure 7a and 7b). This indicates that the aquitard is separated from the surface by some 30m (in the east) to 50m (in the west) of clay beds. This was borne out during the drilling of the monitor wells (see geological logs of SE-1 to SE-9), as groundwater strikes were all well below the current potentiometric surface. This also shows that the depth to groundwater aquitards increases westwards.
- It is concluded that this is a deep sitting saturated geological material is a confined aquitard, with relatively poor water yield.
- Significant upward piezometric pressure due to confinement by clay rich stratigraphy and steep aquifer gradient.
- The quarry area appears to be an area of groundwater knoll, with flow directions either side of a water divide running along the hill brow from east to west (which is being mined for clay).
- Stabilised potentiometric head relatively close to the surface (within 10 to 20 m from the natural ground surface). Potentiometric head is the result of the confining pressure at the aquifer level. Lateral groundwater flow is likely to be restricted by the clay rich mineralisation, resulting in poor transmissivity (measured at 0.008 m/d to 0.04 m/d in the saturated zone. This was shown by the relatively long time (up to 2 days) it took the monitoring bores to stabilise a SWL after drilling was completed (see cross sections in DWG OV-03-ACW and site plan in DWG OV-02-ACW)
- Ground water chemistry recorded for the period July 2011 to September 2014 shows that the waters south and south-west of the site are not fit for human consumption. Ground water to the east and north east of the site is of good quality.

- It is proposed that the easterly part of the study area, closer to the massive quartzite outcrops/hills, is an area of potential recharge with good groundwater quality (see bore SE 4). Water seeping south and west through the clays/silt is impacted by salinity and some heavy metal content, and as such the groundwater water quality to the south west and north west of the study area is of a much poorer quality (see SE 1 to SE 3).
- The potential primary beneficial use of groundwater in proximity to the site is (i) aquatic environment in the Jimperding Brook 900 m to the south and south-west, (ii) stock watering from the Jimperding Brook, (iii) possible future groundwater abstraction at residences to the north, potentially for domestic purposes (see DWG OV-01- ACW).

Geological logs for the bores drilled during June 2011 and April 2013 are shown in Figures 8 to 16.

10.3 Groundwater flow

The potentiometric groundwater surface elevation is shown in Figures 4a to 4c and the aquifer/aquitard location is derived from the water strikes recorded during drilling of the monitoring bores. Figures 4 (*a* to *c*) are generated from the highest recorded water level events over the period July 2011 to September 2014.

The local land gradient is towards the south and north-west from the site. The local groundwater flow direction (July 2011) is recorded to the south, calculated from the potentiometric isoclines. Groundwater also flows north-west to the north of the study area (calculated after the addition of bores SE 5 to SE 9 in 2013) in conformity with surface morphology. A groundwater knoll and a groundwater divide are expected to exist at the top of the hill which is being excavated for clay (the quarry study area). The Jimperding Brook forms a boundary to the groundwater flow at the southern end of the study area.

The southerly flow directions is used in the risk assessment for impact on potential receptors, as Jimperding Brook is the closet potential receptor to the site (912 m south).

A worst case scenario, where a preferential groundwater flow path would exist directly connecting the landfill with a receptor is set up. This would connect the landfill directly south to Jimperding Brook. No such feature is known to exist, but an imaginary one is used as a worst possible groundwater scenario, with known gradients and hydrogeological values sourced from literature which would provide a realistic, but worst case, scenario.

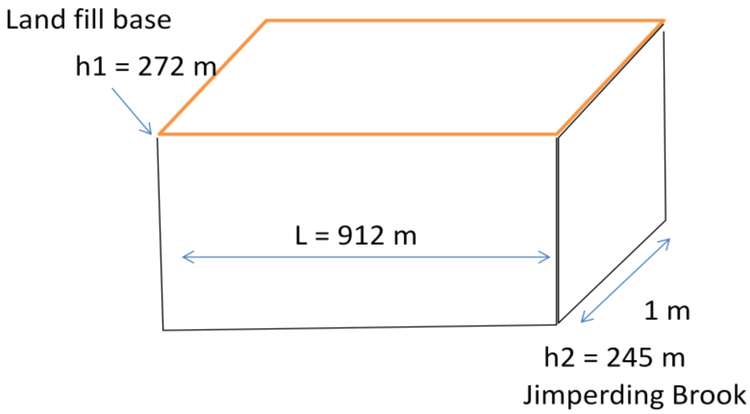
10.3.1 Direct Calculation for Travel Time from Proposed Landfill to Jimperding Brook:

The assumed hydrogeological connection between the site and Jimperding Brook is used to provide a worst case scenario for contamination impact of a sensitive receptor.

The receptor pathway would be along a quartzite geological structure which would allow groundwater flow from below the proposed landfill and be intercepted by the base flow of the Jimperding Brook.

The following model calculation seeks to provide the time period that a contaminant would take to reach the Brook, under purely advective groundwater flow conditions.

- Hydraulic conductivity through a fractured quartzite with a silt matrix - 0.08m/d (Freeze & Cherry, 1979)
- Porosity - 10%. While clay may have porosities in the order of 40%, silt is more likely to be in the 10% range.
- Gradient - 0.03 from the conceptualization below:



Not to scale

Calculation

Darcy's law is the basic equation that describes fluid flow through porous media. There are many ways to write Darcy's Law, and a few of them will be presented here. The first equation contains a velocity term, v (L/T), a conductivity term, K (L/T), a head term, h (L), and a distance term, l (L):

$v = -K(\Delta h/\Delta l)$

L =912m $K = 1 \times 10^{-6}$ m/s Porosity = 10% or 0.1

$A = 1 \times 27 = 27m^2$ $dh = (h_2 - h_1) = (272 - 245) = -27$ m

therefore,

$i = (27)/912 = -0.0296 = -0.03$

$v = -(10^{-6}) \times (-0.03) = 3 \times 10^{-8}$ m/s

$Q = -(10^{-6}) \times (-0.03) \times 27 = 0.81 \times 10^{-7}$ m^3/s

Note: To Calculate Average Linear Velocity which is what we use for groundwater calculations you must divide v by porosity.

Average Linear Velocity

v/porosity = $3 \times 10^{-8} / 0.1 = 3 \times 10^{-7}$ m/s

Therefore daily travel distance = $3 \times 10^{-7} \times 86{,}400 = 0.026$ m/day

and in a year, 0.026 x 365 = 9.5 m/year

To cover the full distance (912 m) it will take groundwater 96 years to reach Jimperding Brook.

NOTE:

Hydraulic conductivity assumed to be that of silt (0.08 m/day), which is worst case scenario, as the lithological material matrix is a silt-clay mix, which could be considered less permeable.

No dispersion or other solute transport assumptions taken into account.

10.3.2 Bioscreen Modelling

Bioscreen is a screening model which simulates a contaminant plume in one dimension. It is programmed in Microsoft® Excel, is based on the Domenico analytical solute transport model, and has the ability to simulate advection, dispersion and adsorption. For the purposes of this report a solute transport model, without decay, was used to simulate the worst case condition scenario.

A hypothetical direct preferential path from the proposed landfill to Jimperding Brook was modelled to again simulate the worst case condition. It should be noted that no such pathway has been observed to date, however, in the interest of providing a worst case condition scenario, the hypothetical pathway was assumed as the basis for the model. Hydrogeological material values are sourced from literature (Freeze and Cherry 1979).

Bioscreen was run for a period of 100 years to determine which contaminants were likely to reach the closest sensitive receptor (Jimperding Brook) at concentrations above the guideline values. A cross sectional area was estimated for the plume using the flow rate from the base of the landfill and the calculated seepage velocity. Flow rate was assumed to be conserved.

As an assumption was taken that a conservative contaminant (non-decay) at a concentration of 600 mg/l (say chloride) will leave the landfill through a 50 m wide and 2 m deep saturated contact zone (approximately 200 litres/day for the whole landfill site). This would be roughly equivalent to a loss of 10l/day/ha over the Stage 1 of the landfill. The Bioscreen input and output screens are provided over the next 3 pages.

The Bioscreen modelling results indicated that after 80 years the closest impact would be about 823m downgradient of the site, with a total plume mass of some 1510 kgs with concentrations of an arbitrary conservative contaminant reduced from 600 mg/l to less than 50 mg/l.

The Bioscreen model calculations use dispersion in addition to advection of a conservative contaminant, which allows for solute transport to be faster than by purely advective flow of groundwater (previous calculation). These calculations show that the first "breakthrough" of contamination to the Brook is possible within 100 years of the landfill developing a leak.

This concludes that if in fact there was a direct hydraulic connection between the base of the landfill and the Jimperding Brook, of higher permeability then the surrounding geology (for example a fractured quartz vein or similar structural geological; feature), the time frame for any water quality impact to the Jimperding Brook would be close to two decades, providing ample time for corrective action to be taken as required.

It should be pointed out that the modelling scenario is purely fictitious and only provided here to indicate what might be an outcome of a worst case scenario where the landfill was found to be leaking. The modelling does not purport to model flow through the landfill liner, rater accepts that the liner is damaged and allows contaminated leachate into environment.

INPUTS TO SOLUTE TRANSPORT CALCUALTIONS/MODELLING:

Geology

As per Stass Environmental Report - assumption of a preferential flow path through a fractured quartz zone.

Source

Assumed liner leak causing a 50 m wide and 2 m deep saturated zone below the liner

Width of potential source: 50 m (saturated zone under the liner)

Groundwater flow direction to the south (Stass Report 2014)

Hypothetic al Liner Leakage rate:

Leakage rate: *10 LlHa/day*

Contaminant: conservative at 600 mg/l in saturated zone

Groundwater Hydraulic Gradient (i)

- Maximum groundwater elevation 272 mAHD
- Minimum groundwater elevation 245 mAHD
- Distance to nearest sensitive receptor 912 m

Hydraulic Gradient I *0.03 m/m*

Hydraulic Conductivity (K)

- Hydraulic conductivity through a fractured quartzite with a silt matrix - 0.08m/d (Freeze & Cherry, 1979).
- Porosity 10% (conservative estimate)

Seepage Velocity

Seepage Velocity *9.5m/year (calculated by manual computation)*

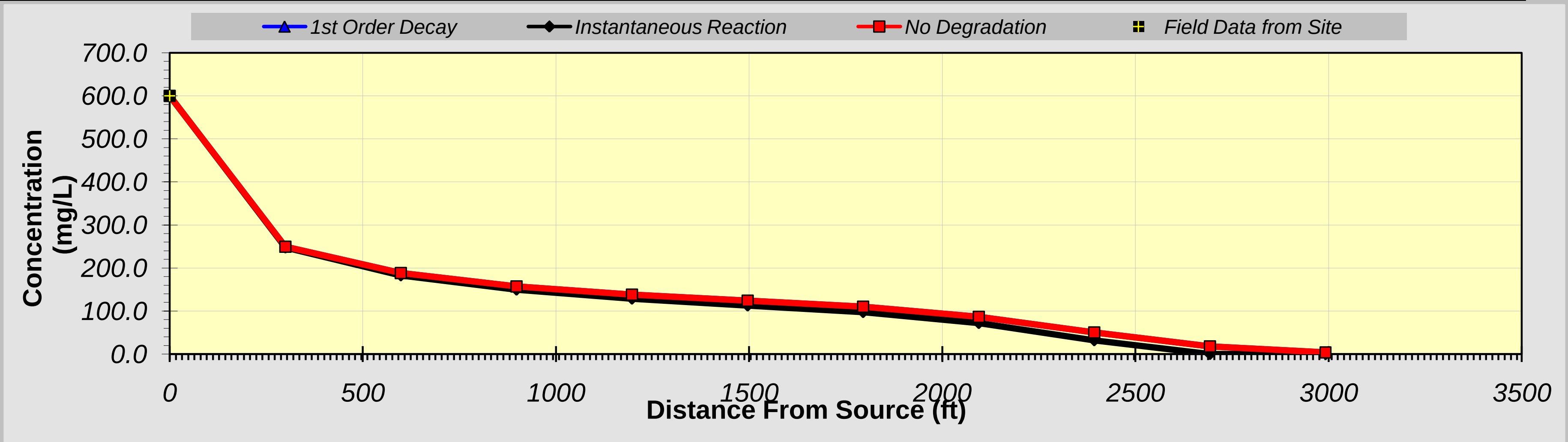
Sensitive Receptor:

Distance to nearest sensitive receptor *912* m Jimperding Brook south of the site

CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	299	598	898	1197	1496	1795	2094	2394	2693	2992
No Degradation	600.000	249.292	188.196	157.290	137.837	123.761	109.833	86.634	50.444	18.057	3.513
1st Order Decay	600.000	249.292	188.196	157.290	137.837	123.761	109.833	86.634	50.444	18.057	3.513
Inst. Reaction	600.000	247.234	182.754	149.471	128.315	112.912	97.566	71.839	31.591	0.000	0.000
Field Data from Site	600.000										



Replay Animation

Next Timestep

Prev Timestep

Time:

80 Years

Return to Input

Recalculate This Sheet

11 CONCLUSIONS

On the basis of this study, the following conclusions are reached:

- The site is underlain by a confined aquifer/aquitard of limited extent which is confined by thick beds (up to 30 m thick) of clays and weathered schist/quartzite.
- Based on the water yield and aquifer physical characteristics, the water body can be defined as a confined aquitard.
- The water quality in south and south west downgradient bores is poor, indicating impacts from salinity and geological weathering of in situ mineralisation (presence of heavy metals). Ground water quality to the north and east of the site is good.
- While the yield from the aquifer has not been tested, the geological materials recovered from the drilling suggest that this aquifer is potentially low yielding with poor aquifer transmissivity (low hydraulic conductivity).
- The recently installed bores are adequately located to define the local aquifers and are suitably positioned for monitoring of the groundwater below the site.
- The highest possible groundwater potentiometric surface (measured between July 2011 and September 2014) is below the current floor of the pit.
- The groundwater conditions at the site are favorable for the development of a waste management facility as the aquifer below and adjacent to the site cannot be considered a beneficial water resource due to likely low yielding water characteristics and in some locations poor water quality. This observation is related to the significant clay content in the matrix of the geologic materials recorded during installation of the site groundwater monitoring bores.
- Modelling of the most sensitive receptor pathways shows that it will take in excess of 90 years for water leaking from the landfill to reach the most sensitive and closest receptor - the Jimperding Brook. The Bioscreen model suggests that it may also take up to 100 years for a contaminant "breakthrough" to be observed at the Brook (first recorded concentration) if a preferential groundwater flow path exists in a direct line between the landfill and Jimperding Brook

- The beneficial groundwater use in the area is considered to be sufficient for “stock watering”. Groundwater to the east and north of the site is suitable for domestic use.
- Water yields from bores adjacent to the site are likely to be poor due to the low permeability of the aquitard.

12 RECOMMENDATIONS

The following recommendations are made, based on the investigations to date:

- As the downgradient groundwater quality exceeds the DER guidelines for fresh waters, it is recommended that the baseline water quality survey data is used as water quality triggers. If required, these water quality analyses can be performed again to confirm the water quality data base currently available.
- Static water level (SWL) and quality of the groundwater should be continue to be monitored at a quarterly interval.

13 REFERENCES

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- Landform Research, 2009. Management and Rehabilitation Program of Clay Pit Class 11 Landfill, Lot M2027, Chitty Road, Toodyay, Opal Vale Pty Ltd.

14 GLOSSARY OF TERMS

Abstraction Pumping groundwater from an aquifer.

AHD Australian Height Datum; equivalent to: Mean Sea Level (MSL) + 0.026 m; Low Water Mark Fremantle (LWMF) + 0.756 m.

Alluvium Unconsolidated sediments transported by streams and rivers and deposited.

AMG Australian Map Grid.

Anticline Sedimentary strata folded in an arch.

Aquifer A geological formation or group of formations able to receive, store and transmit significant quantities of water.

Confined A permeable bed saturated with water and lying between an upper and a lower confining layer of low permeability.

Baseflow Portion of river and stream flow coming from groundwater discharge.

Basement Competent rock formations underneath sediments.

Bore Small diameter well, usually drilled with machinery.

bns Below natural surface.

Colluvium Material transported by gravity downhill of slopes.

Confining bed Sedimentary bed of very low hydraulic conductivity.

Conformably Sediments deposited in a continuous sequence without a break.

Conductivity The flow through a unit cross sectional area of an aquifer under a unit hydraulic gradient.

Dewatering Abstraction of groundwater from bores to assist in mining.

Evapotranspiration A collective term for evaporation and transpiration.

Gradient The rate of change of total head per unit distance of flow at a given point and in a given direction.

Head The height of the free surface of a body of water above a given subsurface point.

Hydraulic Pertaining to groundwater motion.

Flux Flow.

Fault A fracture in rocks or sediments along which there has been an observable displacement.

Formation A group of rocks or sediments which have certain characteristics in common, were deposited about the same geological period, and which constitute a convenient unit for description.

Porosity The ratio of the volume of void spaces, to the total volume of a rock matrix.

Potentiometric An imaginary surface representing the total head of groundwater and defined by the level to which water will rise in a bore.

Specific yield The volume of water than an unconfined aquifer releases from storage per unit surface area of the surface.

Semi-confined A semi-confined or a leaky aquifer is saturated and bounded above by a semi-permeable layer and below by a layer that is either impermeable or semi-permeable.

Semi-unconfined Intermediate between semi confined and unconfined, when the upper semi-permeable layer easily transmits water.

Unconfined A permeable bed only partially filled water and overlying a relatively impermeable layer. Its upper boundary is formed by a free watertable or phreatic level under atmospheric pressure.

Transmissivity The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Transpiration The loss of water vapour from a plant, mainly through the leaves.

Watertable The surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

Well Large diameter bore, usually dug by hand.

15 LIMITATIONS

1. The conclusions presented in this report are relevant to the condition of the site and the state of legislation currently enacted as at the date of this report. We do not make any representation or warranty that the conclusions in this report will be applicable in the future as there may be changes in the condition of the site, applicable legislation or other factors that would affect the conclusions contained in this report.

2. Stass Environmental has used a degree of skill and care ordinarily exercised by reputable members of our profession practicing in the same or similar locality. Conclusions are based on representative samples or locations at the site, the intensity of those samples being in accordance with the usual levels of testing carried out for this type of investigation. Due to the inherent variability in natural soils we cannot warrant that the whole overall condition of the site is identical or substantially similar to the representative samples.

3. This report has been prepared for Opal Vale and for the specific purpose to which it refers. No responsibility is accepted to any third party and neither the whole of the report or any part or reference thereto may be published in any document, statement or circular nor in any communication with third parties without our prior written approval of the form and context in which it will appear.

4. This report and the information contained in it is the intellectual property of Stass Environmental. Opal Vale is granted an exclusive licence for the use of the report for the purpose described in the report.