REPORT ON
GROUNDWATER EXPLORATION AND DEVELOPMENT PROGRAMME
OCTOBER-NOVEMBER 2015
FOR
AUSTRALIAN ABRASIVE MINERALS

1. INTRODUCTION

The long-term water-supply requirement for the Harts Range Spinifex Bore Garnet Project is 21 L/s for 20 years, the water to be used for ore processing. The medium-term requirement is 10 L/s.

Previous works have established a borefield (Spinifex Borefield) capable of supplying 14 L/s for at least 5 years, as indicated by computer modelling.

Groundwater exploration has been undertaken in September 2014, April 2015 and October-November 2015, with the aim of locating more production bore sites to supply the additional long-term water-supply requirement, and a source for the medium-term requirement closer to the Plant Site.

Drilling in September 2014 (referred to as Phases 1 and 2A) was concentrated on a potential weathered and fractured rock aquifer to the north and northwest of the Spinifex Borefield, where shallow mineral exploration bores had encountered indications of groundwater. Four bores were drilled including one test-production bore. The test-production bore (W5) was evaluated by pumping tests, and shown to have a sustainable yield of only 0.9 L/s. None of the other three bores gave promising results. This potential resource was therefore adjudged unlikely to be useful to the AAM Garnet Project.

The five original production bores forming the Spinifex Borefield (OLY1, OLY4, OLY7, OLY8 and OLY9) were redeveloped by airlifting as part of the Phase 1 programme.

Attention was then directed to investigating possible extensions of the Spinifex Bore aquifer (referred to as Phase 2B). This campaign was carried out in April 2015. Five bores were drilled over the period 25-29 April 2015, to investigate whether the Spinifex Bore aquifer extended eastwards and westwards beyond its currently proven extent. Three bores were drilled to the east, and two to the west, obtaining promising results in two of the eastern bores and in one of the western ones.

The Phase 3 programme, carried out in October-November 2015, is described in the current report. Two exploratory bores were drilled to the southwest of the existing borefield, and three additional production bores were constructed and test-pumped in the same vicinity. Additional production capacity of 5.5 L/s has been established by the Phase 3 programme.

2. DRILLING RESULTS

The general sequence in all Phase 2B and phase 3 bores is similar, as follows:

SILTY SAND : 6 – 15m thick
CALCRETE : 9 – 15m thick
CLAY : Grey and yellow, 47 – 103m thick. Sand or interbedded sand and clay aquifer near base of sequence, 5 – 15m thick.
BEDROCK : Quartz-biotite schist in west, weathered granite in east.

Two exploration bores designated 2015/9 and 2015/10 were drilled to the south and southwest of existing production bore OLY4. Bore 2015/10 intersected 5m of interbedded clay and sand between 101 – 106m depth, and produced an airlift yield of 3.5 L/s. Bore 2015/9 recorded 4m of clayey sand between 79 – 83m depth, but produced very little water, less than 0.5 L/s. These two bores were drilled using air-circulation, and collapsed on withdrawal of the drill string, preventing them being completed as monitoring bores.

Three sites were completed as production bores: one at site 2015/1, where 6.5 L/s had been obtained in an exploration bore in the April drilling campaign; one at site 2015/10, and one at OLY4. Bore OLY4 is cased with 100mm diameter casing, and was redrilled as OLY4P with 150mm diameter production casing and screen to accept a larger diameter production pump.

It was evident that the two deeper production bores planned would not be able to be completed using air-circulation, so the lower section of Bores 2015/10P and OLY4P were drilled by the mud-rotary method.

The exploration bore at site 2015/10 was also cleaned out using mud-circulation, and completed as a monitoring bore.

Details of all Phase 3 bores are summarised in Table 1 below.

TABLE 1: PHASE 3 BORES

BORE NO.	DATE DRILLED (OCT 15)	CO-ORDINATES		DEPTH DRILLED (m)	SCREEN DEPTH (m)	AQUIFER DEPTH (m)	AIRLIFT YIELD (L/s)	SWL (mbns)[1]	BEDROCK DEPTH (m)	STATUS
		NORTH	EAST							
2015/9	17 - 18	7460993	488496	114	-	-	<0.5	-	99	Back-filled
2015/10	18 - 19	7461503	489735	124	98.5 – 104.5	101-106	3.5	34.4	113	Monitor
2015/1P	19 - 20	7461576	488501	66	54 - 60	54 - 59	7.0	18.6	63	(Production)
2015/10P	25 - 27	7461507	489925	119	100 -106	101-106	3.5	36.7	113	Production
OLY4P	21 - 23	7462111	489753	125	99 - 108	99 – 108 115 - 118	3.0	37.5	125	Production

Note: 1. mbns – metres below natural surface

The three production bores are cased with 168 mm O.D (outside diameter), 4.8mm wall thickness steel casing and screened with 1 mm aperture stainless steel screen. A 6m sump is included below the screen to store any very fine sand or silt which may accumulate over time. The annulus of each bore is gravel-packed with 2 – 3 mm diameter gravel. Surface casing of 273 mm O.D has been installed to 5.5m below ground and capped with a flange and bolted-on cap. The surface casing is set in a 1m square concrete plinth.

Monitor Bore 2015/10 is cased with 50 mm Class 18 PVC tubing, machine-slotted against the open interval. A bolted cap is fitted to 168 mm O.D surface casing set in a concrete plinth.

3. TEST PUMPING

The three production bores were each tested by a step-drawdown test followed by a 24-hour constant discharge test.

3.1 Step-Drawdown Tests

The step-drawdown test consisted of three or four pumping phases of 30 minutes duration at different rates, separated by 30-minute recovery (non-pumping) periods.

Details of the tests are set out in Table 2 below; including the drawdown after 30 minutes of pumping during the constant discharge test.

TABLE 2: STEP-DRAWDOWN TEST RESULTS

BORE	PUMPING PHASE	PUMPING RATE Q (L/s)	DRAWDOWN Sw (m)	SPECIFIC DRAWDOWN (Sw/Q)
2015/1P	STEP 1	1.0	0.99	0.99
	STEP 2	2.5	2.22	0.89
	STEP 3	5.1	4.51	0.88
	STEP 4	6.0	5.29	0.88
	CONSTANT DISCHARGE	5.1	4.45	0.87
2015/10P	STEP 1	1.0	14.40	14.4
	STEP 2	2.0	25.19	12.6
	STEP 3	2.5	29.00	11.6
	CONSTANT DISCHARGE	2.3	26.17	11.4
OLY4P	STEP 1	1.0	8.63	8.6
	STEP 2	2.5	21.01	8.4
	STEP 3	3.75	33.27	8.8
	CONSTANT DISCHARGE	3.0	25.70	8.6

The similar values for specific drawdown across the range of pumping rates, for the tests on Bores 2015/1P and OLY4P, show no significant well losses and hence well constructed and developed bores.

The reducing values for specific drawdown in the step test on Bore 2015/10P indicate that the bore was still developing, and indeed the discharged water in Steps 1 and 2 was somewhat turbid with drilling mud. The similar values for Step 3 and the constant discharge test show that the bore was fully developed by that stage.

3.2 Constant Discharge Tests

The three production bores were each pumped for 24 hours at constant discharge. The results are shown in Table 3 below.

TABLE 3: CONSTANT DISCHAGE TEST RESULTS

SITE	BORE	RADIAL DISTANCE (m)	DISCHARGE RATE (L/s)	FINAL DRAWDOWN (m)	80% RECOVERY TIME (mins)	TRANSMISSIVITY (m^2/day)	STORATIVITY
2015/1	PR[1]	-	5.1	22.3	7500	4	-
	OB[2]	24.15	-	20.0	8500	4	-
2015/10P	PR[1]	-	2.3	33.9	110	7	-
	OB[2]	19.00	-	10.3	680	8	3×10^{-4}
OLY4P	PR[1]	-	3.0	35.5	65	9	-
	OB[2]	11.10	-	9.69	700	12	7×10^{-4}

Note: 1. PR - Production Bore
2. OB - Observation Bore

Bore 2015/10P gave a leaky artesian response to pumping, and has an estimated sustainable yield of 2.5 L/s. Neither Bore OLY4P or OLY4 reacted to pumping from Bore 2015/10P.

Bore OLY4P also gave a leaky artesian response and has an estimated sustainable yield of 3 L/s. Neither Bore 2015/10P or 2015/10 reacted to pumping from Bore OLY4P, but OLY1 drew down by 1.6m during the constant discharge test on OLY4P.

Although Bore 2015/1 maintained a higher pumping rate for a lower amount of drawdown than the other two production bores, the rate of drawdown increased progressively throughout the test, indicating that the pumped aquifer was very limited in extent. This was

confirmed by the large drawdown in the observation bore and very slow recovery time. This bore is tapping a different aquifer than the main Spinifex Borefield, with a significantly higher water-level (see Table 1). Although the final drawdown trend would suggest that this bore could sustain a long-term pumping rate of 1 L/s, the very slow recovery rate indicates that the aquifer would become progressively dewatered with longer term pumping. This bore would only be usable for short-term standby.

4. GROUNDWATER CHEMISTRY

Samples were taken from the three production bores at the end of the constant discharge tests, and analysed by ALS Environmental in Sydney.

The analytical results are shown on Table 4 below.

TABLE 4: GROUNDWATER CHEMISTRY

PARAMETER	BORE 2015/1P	BORE 2015/10P	BORE OLY4P
pH	7.36	7.68	7.70
EC (microS/cm)	2720	2080	1580
Calcium (mg/L)	64	46	43
Magnesium (mg/L)	25	31	44
Sodium (mg/L)	451	285	240
Potassium (mg/L)	8	7	8
Bicarbonate (mg/L)[1]	74	217	248
Sulphate (mg/L)	410	324	238
Chloride (mg/L)	573	388	269
Nitrate (mg/L)[2]	<0.5	7.6	7.1
Ferrous Iron (mg/L)	0.26	<0.05	<0.05
Fluoride (mg/L)	1.6	1.8	1.8
Sum of Ions (mg/L)	1607	1307	1099

Notes: 1. Converted from bicarbonate alkalinity.
2. Converted from nitrate as nitrogen.

All samples are of sodium chloride-sulphate type and are slightly alkaline. The sample from Bore 2015/1P, although from a different aquifer, is generally similar in chemistry, although slightly more saline, and with less bicarbonate.

5. CURRENT STATUS OF SPINIFEX BOREFIELD

There are six available production bores with significant yields, as shown on Table 5 below.

TABLE 5: PRODUCTION BORES

PRODUCTION BORE	ELEVATION (mAHD)	STICKUP (m)	WATER[1] LEVEL (mbct)[2]	SCREEN DEPTH (m)	SUSTAINABLE YIELD (L/s)	PUMP INTAKE SETTING (m)	SALINITY (mg/L TDS)
OLY1	542.9	0.75	33.76	92.0 – 98.0	5.8	87.0	1,188
OLY4P	546.7	0.50	37.46	99.0 – 108.0	3.0	94.0	1,099
OLY7	535.4	0.55	31.51	71.5 – 77.5	2.9	66.5	3,460
OLY8	532.9	0.80	29.88	58.0 – 64.0	1.2	53.0	N.D
OLY9	537.2	0.50	33.89	83.4 – 89.4	1.7	78.5	1,620
2015/10P	N.D	0.50	33.70	100.0 – 106.0	2.5	95.0	1,307

Note: 1 - October 2015.
2 – Metres below casing top.

The sustainable yields given above for Bores OLY7, OLY8 and OLY9 are derived from computer modelling described in the 2007 Rockwater report. This model simulated pumping from five

production bores OLY1, OLY4, OLY7, OLY89 and OLY9, and from an additional conceptual production bore in the north-western part of the borefield. These sustainable yields allow for mutual drawdown interference, assuming that the entire borefield is in operation.

The quoted sustainable yields for OLY1, OLY4P and 2015/10P are "stand-alone" yields, that is not allowing for any mutual drawdown interference. Any interference will be at least partially offset by leakage, both OLY4P and 2015/10P having shown a leaky artesian response to pumping. No realistic estimate of mutual interference can be given at this stage, because of the leaky artesian nature of the aquifer; any such interference can be estimated after the first three months of borefield operation. There was no interaction between 2015/10P and OLY4P during the testing programme, but OLY1 did draw down by 1.6m in response to pumping from OLY4P.

Ten monitoring bores are available for water-level measurements and are shown on Table 6 below.

TABLE 6: MONITORING BORES

BORE	ELEVATION (mAHD)	STICK-UP (m)	WATER* LEVEL 26/10/5 (m)	OPEN INTERVAL (m)	REMARKS
OLY4	546.7	0.25	37.36	108 - 118	-
OLY5	537.5	0.55	33.80	81 - 90	-
OLY6	541.4	0.40	36.83	86 - 101	-
NEW14	535.4	-	31.51	77 – 89	Adjacent OLY7
NEW15	533.2	-	30.18	67 – 79	Adjacent OLY8
NEW16	536.6	1.10	33.81	90 – 96	-
NEW17	532.8	1.10	30.51	71 – 77	-
NEW18	538.3	-	34.99	83 – 95	Adjacent OLY9
2015/10M	ND	0.45	34.41	98.5 – 104.5	-
W5	ND	0.70	11.44	23.3 – 47.3	Fractured Rock

Note: * - Below casing top.
ND - Not determined.

OLY2, although accessible, is screened against an interval of clay strata, and does not reflect the water-level in the Spinifex Bore aquifer.

6. CONCLUSIONS

1. Two new production bores, 2015/10P and OLY4P, have been constructed and tested on the south-western side of the Spinifex Borefield. OLY4P is a 150mm diameter bore adjacent to a previous smaller diameter (100mm) bore, OLY4.

   These two bores have a combined sustainable yield of 5.5 L/s.

   A third production bore, 2015/1P, constructed further to the west, intersected a higher-level aquifer of limited extent. This bore only has potential for small, short-term supply.

2. The two new bores, together with Bore OLY1, which has a sustainable yield of 5.8 L/s, have the capacity to provide the current medium-term process water requirement of 10 L/s.

The estimated combined salinity of the groundwater pumped at these rates from the three bores is about 1200 mg/L TDS.

3. The combined yields of the three bores, 2015/10P, OLY4P and OLY1 may be affected in the longer term by mutual drawdown interference. Bore OLY7 should be equipped to allow for this, and to provide standby capacity for bore and pump maintenance. Bore OLY7 has a sustainable yield of at least 2.9 L/s.

4. The Phase 2B and Phase 3 drilling campaigns have proved that the Spinifex Bore aquifer extends 650m further to the south-southwest and 3000m further to the east, than previously known. The limits of the aquifer have not yet been verified in either direction.

7. RECOMMENDATIONS

1. Four production bores should be equipped to supply the medium-term requirement for process water of 10 L/s, and allowing for standby capacity (Bore OLY7).

   The estimated sustainable yields, and recommended pump inlet depths, are as follows:

BORE	SUSTAINABLE YIELD (L/s)	RECOMMEND OF PUMP INLET DEPTH (m)
OLY1	5.8	87
OLY4P	3.0	94
OLY7	2.9	66.5
2015/10P	2.5	95

2. When the borefield is brought into operation, the following water-level and water-quality monitoring programme should be undertaken. This programme is essential for careful management of the borefield, and to satisfy requirements for reporting to DME:

   2.1 MEASUREMENT OF WATER-LEVELS:
   - Bores OLY1, OLY4P, OLY7 and 2015/10P;
   - Bores OLY4, NEW14 and 2014/10M;
   - Bore OLY8 or NEW15;
   - Bore OLY9 or NEW18.

   - Water levels in these bores should be measured:
     - Weekly for the first month of operation;
     - Monthly thereafter.

   - If possible, water-levels should be measured in each production bore after the pump has been turned off for at least 4 hours, and the duration of this recovery period noted at time of measurement.

   2.2 WATER QUALITY:
   - All operating production bores;
   - EC and pH every quarter (on-site);
   - Annual samples for full chemical analysis.

   2.3 ABSTRACTION:
   - All operating production bores;
   - Metered abstraction every month.

2.4 REVIEW OF MONITORING:

- Water-levels and abstraction records should be reviewed after 3 months, and again after 12 months, to evaluate any mutual drawdown interference between bores, and to make any consequent adjustment in pumping rates which may be necessary.

John Barnett
Hydrogeologist

Note on Spinifex Bore

There is some doubt on the depth of Spinifex Bore itself. Steve Cadzow (*pers.comm*) reported it to be 110 feet (i.e 33.5m) deep and hence not within the same aquifer as the Spinifex Borefield itself.

On the other hand the Northern Territory Government record for Spinifex Bore (RN 13309) records its depth as 67m, that is 5m above the top of the aquifer in nearby OLY7.

BORE 1/2015P
7461576N; 488501E

0 – 6m	**SAND**	Silty and slightly clayey, very fine to very coarse grained, poorly sorted, subangular to rounded, quartz, ferruginous grains, trace garnet. Calcareous cemented layers 2 - 6m.
6 – 16m	**CALCRETE**	Pink, sandy. Sand up to gravel size, subangular to rounded, poorly sorted, quartz, ferruginous grains, minor heavy minerals and garnet.
16 - 18m	**CLAY**	Brown, sandy, sand as above.
18 – 54m	**CLAY**	Pale grey and yellow, a few slightly sandy bands.
54 – 59m	**SAND**	Coarse to very coarse, mainly coarse-grained, well sorted, subrounded to rounded, quartz, trace heavy minerals.
59 – 63m	**CLAY**	Slightly shaley, grey, red and purple.
63 – 66m	**QUARTZ-BIOTITE SCHIST**	Slightly weathered (no garnets).

Drilled Air-rotary.
Airlifted at 7 L/s after 2 hours.
168mm OD Steel casing +0.45 – 54m, and sump 60 – 66m. 150mm screen, 1mm aperture 54 – 60m.

BORE 2015/9
7460993N; 488496E

0 – 5m	**SAND**	Silty, red-brown, slightly clayey, very fine to coarse, mainly fine-grained, moderately sorted, subrounded to rounded, quartz, minor black heavy minerals, trace garnet.
5 - 6m	**SAND**	Minor gravel, minor garnet, otherwise as above.
6 – 13m	**CALCRETE**	Sandy, sand as far 5 – 6m, trace garnet.
13 – 17m	**CALCRETE**	White, Slightly sandy, trace garnet.
17 – 19m	**CALCRETE**	White, minor yellow, sandy fine to gravel, poorly sorted, subrounded to rounded quartz.
19 – 61m	**CLAY**	Yellow, minor brown and pink.
61 – 66m	**CLAY**	Grey.
66 – 79m	**CLAY**	Yellow, minor grey.
79 – 83m	**SAND**	Clayey, fine to very coarse, poorly sorted, subrounded to rounded quartz, minor black heavy minerals.
83 – 99m	**CLAY**	Grey and brown.
99 – 108m	**CLAY**	Grey-green and brown with small quartz crystals, slight schistose texture (VERY WEATHERED BEDROCK).
108 – 114m	**HORNEBLENDE-QUARTZ SCHIST**	No garnets

Very low water yield (<0.5 L/s) from 84m on.
Collapsed at 76m, unable to run 50mm PVC.

BORE 2015/10
7461503N; 489735E

BORE 2015/10P
7461507N: 489753E

0 – 6m	**SAND**	Slightly silty and clayey, very fine to coarse, mainly very fine to fine grained, moderately sorted, subrounded to rounded, quartz, minor black heavy minerals, trace garnet.
6 – 15m	**CALCRETE**	Pink, sandy, a few pebbles of green amphibolite schist, sand fine to gravel, poorly sorted, otherwise as above. Trace garnet.
15 – 20m	**CALCRETE**	Hard, white, brown and grey, slightly sandy, sand as for 6 – 15m, with a few quartz pebbles. Trace garnet.
20 – 101m	**CLAY**	Mainly yellow, minor pale grey, pink and brown, red-brown 90 – 101m; very slightly sandy 90 – 94m and 99 – 101m, sand fine to gravel, subrounded to rounded quartz, minor heavy minerals.
101 – 106m	**INTERBEDDED CLAY and SAND**	Sand very fine to medium grained, mainly fine to medium, well sorted, subrounded to rounded, quartz, minor black heavy minerals. Clay, yellow and pale grey.
106 – 113m	**CLAY**	Red-brown.
113 – 120m	**VERY WEATHERED BEDROCK**	Grey-green micaceous clay.
120 – 124m	**MICA-SCHIST**	Dark green, soft, weathered.

2015/10 Monitor Bore:
Class 18 PVC, 50mm ND.
Slotted 98.5 – 104.5 m bgl.
Airlift 3.5 L/S after 1 hour.

2015/10P Production Bore:
Air-rotary (Hammer bit) to 42m, mud-rotary (Drag bit) 42 – 119m.
Final Airlift 2015/10P 3.5 L/s.
Screen 100 – 106m, 6m Sump.

BORE OLY4 (P)
7462111N; 489925E

0 – 6m	**SAND**	Silty, slightly clayey, very fine to coarse, mainly fine to medium grained, moderately sorted, subrounded to rounded, quartz, minor black heavy minerals, trace garnet.
6 – 14m	**SANDY CALCRETE**	Sand as above, trace garnets.
14 – 22m	**CALCRETE**	Hard, cemented, sandy, grey and white. Rare garnets.
22 – 92m	**CLAY**	White and minor yellow 22 – 42m, pale grey and yellow 42 – 92m, some brown 42 – 53m.
92 – 118m	**INTERBEDDED CLAY and SAND**	Sand layers common 99 – 108m and 115 – 118m, minor sand layers 92 – 99m and 108 – 115m. Clay pale grey and yellow; sand fine to coarse grained, poorly sorted, subangular to subrounded, quartz, minor black heavy minerals.
118 – 125m	**CLAY**	Pale grey, dark grey and red-brown. A few fragments of very decomposed mica-schist at 125m.

CASED: +0.5 – 99m, 168mm Steel.
99 – 108m, 150mm Screen, 1mm aperture.
108 – 114m, 168mm Steel Sump, Bottom Cap.
6 bags 2 – 3mm gravel.
Airlifted 5 hours: Final airlift: 3 L/s.