Hunter Valley Operations

2015 Annual Environmental Review

March 2016

Wedge-tailed Eagle at HVO North, Rehabilitated Land in the background

Name of Operations	Hunter Valley Operations
Name of Operator	HV Operations Pty Ltd
Development consent /project approval	DA 450-10-2003 / PA 06_0261
Name of holder of development consent/project approval	HV Operations Pty Ltd
Mining Lease Number	Contained within Section 1.4 of this report
Name of Mining Lease Holder	Contained within Section 1.4 of this report
Water Licence Number	Contained within Section 1.4 of this report
Name of Water Licence Holder	Contained within Section 1.4 of this report
MOP/RMP Start Date	HVO North – 1/07/2012 HVO South – 1/11/2015
MOP/RMP End Date	HVO North – 31/12/2018 HVO South – 31/12/2018
Annual Review Start Date	01/01/2015
Annual Review End Date	31/12/2015

I, *Tom Lukeman*, certify that this audit report is a true and accurate record of the compliance status of Hunter Valley Operations for the period 1 January 2015 to 31 December 2015 and that I am authorised to make this statement on behalf of Rio Tinto Coal Australia.

Note.

a) The Annual Review is an 'environmental audit' for the purposes of section 122B(2) of the Environmental Planning and Assessment Act 1979. Section 122E provides that a person must not include false or misleading information (or provide information for inclusion in) an audit report produced to the Minister in connection with an environmental audit if the person knows the information is false or misleading in a material respect. The maximum penalty is, in the case of a corporation, $1 million and for an individual, $250, 000.

b) The Crimes Act 1900 contains other offences relating to the false and misleading information: section 192G (Intention to defraud by false or misleading statement- maximum penalty 5 years imprisonment); sections 307A, 307B and 307C (False or misleading applications/information/documents – maximum penalty 2yeasrs imprisonment or $22,000, or both).

Name of Authorised Reporting Officer	Tom Lukeman
Title of Authorised Reporting Officer	General Manager – Hunter Valley Operations
Signature of Authorised Reporting Officer	
Date	24 March 2016

Executive Summary

This Annual Environmental Review (Annual Review) reports on the environmental performance of Hunter Valley Operations (HVO) during the 2015 calendar year and satisfies the requirements of the Hunter Valley Operations (HVO) Development Consents and Mining Leases. The structure of the 2015 Annual Review intends to align with the NSW Government *Post-approval requirements for State significant mining developments – Annual Review Guideline (October 2015).*

HVO produced 17.16 million tonnes of run-of-mine (ROM) coal during 2015, and 13.01 million tonnes of saleable coal, against an approved ROM coal production rate of 28 million tonnes per annum (mtpa).

Noise

HVO manages noise to ensure compliance with permissible noise limits at nearby private residences. During the reporting period two non-compliances where recorded against HVO's development consent limits. An additional four haul trucks were fitted with sound attenuating equipment to reduce noise output. A total of 2,024 hours of equipment downtime was recorded due to proactive and reactive measures to minimise noise.

Blasting

During the reporting period 304 blast events were initiated at HVO. One blast event on 17th July 2015 recorded an airblast overpressure result of 120.55 dB(L), against a limit of 120 dB(L). No community complaints were received in relation to this blast. HVO complied with all other blasting-related consent and licence conditions during the reporting period. HVO employs a blast fume management protocol to mitigate generation of post blast fume emissions. One category 4 and one category 3 fume event were recorded in 2015. Neither posed a risk to the public with the fume either dissipating over HVO or at height over neighbouring mine owned land. Zero category 5 events were recorded.

Air Quality

Air quality monitoring at HVO is undertaken in accordance with the HVO Air Quality Monitoring Programme. This comprises an extensive network of monitoring equipment which is utilised to assess performance against the relevant conditions of HVO's approvals. During 2015, HVO complied with all short term and annual average air quality criteria. A total of 3,835 hours of equipment downtime was recorded due to proactive and reactive measures to minimise dust. A total of 199 ha of land was aerial seeded during autumn to minimise wind eroded dust from overburden areas not yet available for rehabilitation.

Heritage

During the reporting period there were 57 Ground Disturbance Permits (GDPs) assessed for Cultural Heritage considerations at HVO. In all cases the ground disturbance works were conducted on an Aboriginal cultural heritage sites avoidance basis, so that no extant cultural sites were impacted upon by these activities.

The Stage One Chain of Ponds Stabilisation Programme commenced in November 2014 and was completed in May 2015. These works are being conducted under an approval granted by the Heritage Council of NSW and pursuant to Section 63 of the NSW Heritage Act 1977. These initial works aim to provide immediate structural integrity to the buildings to ensure their continued stability and safety in the medium term.

Surface Water

Surface water monitoring activities continued in 2015 in accordance with the HVO Water Management Plan. HVO maintains a network of surface water monitoring sites for mine site dams, discharge points and surrounding natural watercourses. Three incidents involving water required notification to government agencies, as detailed in Section 11.3 of this report. No material environmental harm resulted from these incidents. Each incident was investigated with corrective and preventative actions implemented.

During 2015 significant upgrade works were completed on the sediment basins on the south side of the Hunter River Bridge to improve water management and sediment control in this area. HVO did not extract any water from the Hunter River in 2015.

Groundwater

Groundwater monitoring activities were undertaken in 2015 in accordance with the HVO Water Management Plan. The monitoring results are used to establish and monitor trends in physical and geochemical parameters of surrounding groundwater potentially influenced by mining. No adverse water quality issues were identified in 2015.

Rehabilitation and Land Management

A total of 129.6ha of mined land was rehabilitated in 2015 and land disturbance of 172.8ha. Rehabilitation quality improvements were progressed including the use of mixed waste compost to improve soil fertility, direct drilling of seed, cover crops and utilising seed harvesting areas to facilitate use of locally sourced seed. During 2016, 191 feral pigs were trapped by control programmes undertaken by HVO and licensees on HVO owned non-mining land.

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1 STATEMENT OF COMPLIANCE

Table 1 is a Statement of compliance against the relevant approvals. Table 2 provides a brief summary of the non-compliances and a reference to where these are addressed within this Annual Review.

Table 1: Statement of compliance

Were all conditions of the relevant approval(s) complied with?	
PA 06_02161 (HVO South)	No
DA 450-10-2003 (HVO North)	No

Table 2: Non- compliances

Relevant approval	**Condition number**	**Condition description (summary)**	**Compliance status**	**Where addressed in Annual Review**
PA 06_02161 (HVO South)	Schedule 3 Condition 2	Noise impact assessment criteria	Non-Compliant (Low)	11.1
PA 06_02161 (HVO South)	Schedule 3 Condition 7	Airblast Overpressure impact assessment criteria	Non-Compliant (Low)	11.2
DA 450-10-2003 (HVO North)	Schedule 4 Condition 20.	Pollution of waters	Non-Compliant (Medium)	11.3

Compliance status key for Table 2[1]

Risk level	**Colour Code**	**Description**
High	Non-compliant	Non-compliance with potential for significant environmental consequences, regardless of the likelihood of occurrence
Medium	Non-compliant	Non-compliance with : • Potential for serious environmental consequences, but is unlikely to occur; or • Potential for moderate environmental consequences, but is unlikely to occur
Low	Non-compliant	Non-compliance with : • Potential for moderate environmental consequences, but is unlikely to occur; or • Potential for low environmental consequences, but is unlikely to occur
Administrative non-compliance	Non-compliant	Only to be applied where the non-compliance does not result in any risk of environmental harm (e.g. submitting a report to government later than required under approval conditions)

[1] *Source: Post-approval requirements for state significant mining developments (October 2015) – Annual Review Guideline*

2 INTRODUCTION

2.1 Document purpose

This Annual Review is written to satisfy the requirements of the Hunter Valley Operations (HVO) Development Consents and conditions of mining leases for events occurring during the 2015 calendar year. The Annual Review has been written in accordance with the NSW Government *Post-approval requirements for State significant mining developments – Annual Review Guideline (October 2015)*.

This report is distributed to:

- NSW Department of Planning and Environment (DP&E);
- NSW Department of Trade and Investment, Division of Resources and Energy (DRE)
- NSW Department of Primary Industries Water (DPI Water)
- Singleton Council and Singleton Library;
- Muswellbrook Shire Council (MSC) and Muswellbrook Library; and
- HVO Community Consultative Committee (CCC).

2.2 Background

HVO is situated in the Upper Hunter Valley between Singleton and Muswellbrook, approximately 24 km northwest of Singleton, and approximately 100 km northwest of Newcastle. The Hunter River geographically divides HVO into HVO North and HVO South; however they are integrated operationally with personnel, equipment and materials utilised as required. This improves operational efficiency, rationalisation of infrastructure and resource utilisation. Hunter Valley Operations is 67.4 per cent owned by Coal & Allied Industries and 32.4 percent owned by Mitsubishi Development.

The layout of the HVO pits and facilities is shown in Figure 1.

Figure 1: Hunter Valley Operations - Site Layout

2.3 Mine Contacts

Tom Lukeman	**General Manager – HVO**
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3 APPROVALS

3.1 Approvals, Leases and Licenses

3.1.1 Current Approvals

The status of HVO development consents, licenses and relevant approvals are listed in the following tables:

- Table 3: HVO Major Approvals
- Table 4: HVO Mining Tenements
- Table 5: HVO Licences and Permits
- Table 6: Water Related Approvals
- Table 7: Water Access Licences

Table 3: HVO Major Approvals

Approval Number	Description	Issue Date	Expiry Date
HVO North DA 450-10-2003 MOD 4	HVO West Pit Extension & Minor Modifications (2003); and associated modifications. Covers West Pit (approved production limit of 12mtpa), Carrington Pit (approved production limit of 10mtpa), HVCHPP (approved processing limit of 20mtpa) and WCHPP (approved processing limit of 6mtpa).	12/06/2004	12/06/2025
HVO South PA 06_0261 MOD 4	Hunter Valley Operations – South Coal Project & associated modifications Covers Riverview Pit, Cheshunt, Deep Cheshunt, and Lemington South, with a combined production limit of 16mtpa.	24/03/2009	24/03/2030

Table 4: Summary of Mining Tenements

Title	Mining Tenement	Purpose	Grant Date	Expiry Date	Status
AUTH 72	Authorisation	Prospecting	08/03/1977	24/03/2018	Granted
(Part) CCL 708	Sub-Lease	Prospecting and Mining Coal	17/05/1990	29/12/2023	Granted
CCL 714	Consolidated Coal Lease	Prospecting and Mining Coal	23/05/1990	30/08/2030	Granted
CCL 755	Consolidated Coal Lease	Prospecting and Mining Coal	24/01/1990	05/03/2030	Granted
CL 327	Coal Lease	Prospecting and Mining Coal	06/03/1989	05/03/2031	Granted
CL 359	Coal Lease	Prospecting and Mining Coal	21/05/1990	20/05/2032	Granted
CL 360	Coal Lease	Prospecting and Mining Coal	29/05/1990	28/05/2032	Granted
CL 398	Coal Lease	Prospecting and Mining Coal	04/06/1992	03/06/2034	Granted
CL 584	Coal Lease	Prospecting and Mining Coal	01/01/1982	31/12/2023	Granted
CML 4	Consolidated Mining Lease	Prospecting and Mining Coal	02/03/1993	03/06/2033	Granted
EL 5291	Exploration Licence	Prospecting	28/04/1997	23/09/2015	Renewal Pending
EL 5292	Exploration Licence	Prospecting	28/04/1997	27/04/2015	Renewal Pending
EL 5417	Exploration Licence	Prospecting	23/12/1997	08/05/2015	Renewal Pending
EL 5418	Exploration Licence	Prospecting	23/12/1997	08/05/2017	Granted
EL 5606	Exploration Licence	Prospecting	11/08/1999	10/08/2019	Granted
EL 8175	Exploration Licence	Prospecting	23/09/2013	22/09/2018	Granted
ML 1324	Mining Lease	Prospecting and Mining Coal	19/08/1993	18/08/2014	Renewal Pending
ML 1337	Mining Lease	Prospecting	01/02/1994	09/09/2014	Renewal

Title	Mining Tenement	Purpose	Grant Date	Expiry Date	Status
		and Mining Coal			Pending
ML 1359	Mining Lease	Prospecting and Mining Coal	01/11/1994	31/10/2015	Renewal Pending
ML 1406	Mining Lease	Prospecting and Mining Coal	27/02/1997	10/02/2027	Granted
ML 1428	Mining Lease	Prospecting and Mining Coal	15/04/1998	14/04/2019	Granted
ML 1465	Mining Lease	Prospecting and Mining Coal	21/02/2000	20/02/2021	Granted
ML 1474	Mining Lease	Prospecting and Mining Coal	24/11/2000	23/11/2021	Granted
ML 1482	Mining Lease	Prospecting and Mining Coal	19/03/2001	14/04/2019	Granted
ML 1500	Mining Lease	Prospecting and Mining Coal	21/12/2001	20/12/2022	Granted
ML 1560	Mining Lease	Prospecting and Mining Coal	28/01/2005	27/01/2026	Granted
ML 1526	Mining Lease	Prospecting and Mining Coal	03/12/2002	02/12/2023	Granted (Transfer from Cumnock No. 1 Colliery Pty Limited and ICRA Cumnock Pty Ltd to Novacoal Australia Pty Limited registered on 2 December 2015)
ML 1589	Mining Lease	Prospecting and Mining Coal	02/11/2006	01/11/2027	Granted
ML 1622	Mining Lease	Prospecting and Mining Coal	22/10/2010	10/03/2027	Granted
ML 1634	Mining Lease	Prospecting and Mining Coal	31/07/2009	30/07/2030	Granted
ML 1682	Mining Lease	Prospecting and Mining Coal	16/12/2012	15/12/2033	Granted

Title	Mining Tenement	Purpose	Grant Date	Expiry Date	Status
ML 1704	Mining Lease	Mining Purposes	05/12/2014	04/12/2035	Granted
ML 1705	Mining Lease	Prospecting and Mining Coal	17/12/2014	16/12/2035	Granted
ML 1706	Mining Lease	Mining Purposes	09/12/2014	08/12/2035	Granted
ML 1707	Mining Lease	Prospecting and Mining Coal	09/12/2014	08/12/2035	Granted
ALA 52	Assessment Lease Application	Prospecting	Mining Lease Application lodged 10th September 2012		Offer of Grant – Pending Determination
MLA 468	Mining Lease Application	Mining Purposes	Mining Lease Application lodged 24th January 2014		Application Pending
MLA 488	Mining Lease Application	Mining Purposes	Mining Lease Application lodged 10th March 2015		Application Pending
MLA 489	Mining Lease Application	Mining Purposes	Mining Lease Application lodged 10th March 2015		Application Pending
MLA 490	Mining Lease Application	Mining Purposes	Mining Lease Application lodged 10th March 2015		Application Pending
MLA 495	Mining Lease Application	Mining Purposes	Mining Lease Application lodged 12th May 2015		Application Pending
MLA 496	Mining Lease Application	Mining Purposes	Mining Lease Application lodged 12th May 2015		Application Pending
MLA 501	Mining Lease Application	Mining Purposes	Mining Lease Application lodged 10th July 2015		Application Pending
MLA 520	Mining Lease Application	Mining Purposes	Mining Lease Application lodged 23rd December 2015		Application Pending

Table 5: HVO Leases and Permits

Licence No.	Description	Authority	Expiry Date
Environment Protection Licence			
EPL 640	Environment Protection Licence	EPA	N/A
Dangerous Goods / Explosives			
RR12709	Licence to Store	Workcover	06/7/2017
Radiation Licence			
RML5061121	Radiation Management Licence	EPA	05/09/2016
Aboriginal Heritage Permits			
2863	Care and Control Permit (Renewed & extended until 16 January 2016)	OEH	16/01/2016
Road Closure Permits			
538338	Road Occupancy Licences– Golden Highway	RMS	30/06/2016
	Road Closure Approval Lemington Road	Singleton Council	30/06/2016
	Road Closure Approval Comleroi Road	Singleton Council	30/04/2016

Table 6: Water Related Approvals

Licence Number	Type of License	Purpose	Legislation	Description	Renewal Date
20BL030566	Bore	Well	Part 5 Water Act 1912	East Open Cut	Perpetuity
20BL141584	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – Carrington Work Licence	Perpetuity
20BL166637	Bore	Monitoring Bore	Part 5 Water Act 1912	No Current Bores	Perpetuity
20BL167860	Bore	Excavation - Mining	Part 5 Water Act 1912	HVO North – Carrington Pit	11/05/2020

Licence Number	Type of License	Purpose	Legislation	Description	Renewal Date
20BL168820	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – Bores: CGW39, CGW45a, CGW46,CGW47, CGW47a, CGW48, CGW49, P50/38.5, ,CGW56, 4036C, 4035P, 4032P, 4034P, 4033P, 4053P, 4052P, 4051C, 4040P, 4038C, 4037P Destroyed:CGW7,CGW50, CGW57, CGW58, CGW59, CGW60, CGW61, CGW62, CGW63	Perpetuity
20BL169241	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – Bores: DM1, HF3, HF7 Destroyed DM2	Perpetuity
20BL169962	Bore	Excavation - Mining	Part 5 Water Act 1912	HVO West – West Pit Excavation	22/12/2020
20BL170000	Bore	Excavation - Mining	Part 5 Water Act 1912	HVO North – Pit Excavation	11/05/2016
20BL170010	Bore	Excavation - Mining	Part 5 Water Act 1912	HVO South – Cheshunt/Riverview Extended Excavation	26/11/2016
20BL170496	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: BZ10 (CHPZ 2A), BZ11 (CHPZ 3A), BZ18 (CHPZ 10A), BZ20 (CHPZ 12A), BZ21 (CHPZ 13D) , BZ21A (CHPZ 13A), BZ20A (CHPZ 12D), BZ11A (CHPZ 3D) Destroyed AP50/47.5, AQ52, AV50/56.5, AS50/62.5, AR55, Bunc 3, BZ25 (Bunc 12) , BZ23 (Bunc 14), BZ24 (Bunc 13),	Perpetuity

Licence Number	Type of License	Purpose	Legislation	Description	Renewal Date
20BL170497	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: BZ15 (CHPZ 7A), BZ16 (CHPZ 8D), BZ17 (CHPZ 9A), BZ19 (CHPZ 11A), BZ16A (CHPZ 8A), Bunc 46D Destroyed Bunc 39 (Shallow & Deep), Bunc 44D	Perpetuity
20BL170498	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: BZ12 (CHPZ 4A), BZ13 (CHPZ 5A), BZ14, BZ9 (CHPZ 1A), BC1, BC1a, BZ8-1, BZ8-2, BZ8-3, HG1, HG2, HG2a, HG3, S4, S6, BZ22 (CHPZ14D), BZ22A (CHPZ 14A), BZ5-1, BZ5-2 Destroyed S2, S3, S9, S11	Perpetuity
20BL171423	Bore	Monitoring Bore	Part 5 Water Act 1912	E1.5	Perpetuity
20BL171424	Bore	Monitoring Bore	Part 5 Water Act 1912	Destroyed GW9711	Perpetuity
20BL171425	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: GW9701, GW9710	Perpetuity
20BL171426	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: GW9702 Destroyed D2(WH236),	Perpetuity
20BL171427	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: C335, C630 (BFS)	Perpetuity
20BL171428	Bore	Monitoring Bore	Part 5 Water Act 1912	D807	Perpetuity
20BL171429	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: B925 (BFS), C122 (BFS), C122 (WDH)	Perpetuity
20BL171430	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: C613 (BFS), C809 (GM/WDH)	Perpetuity
20BL171431	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: B631 (BFS), B631 (WDH)	Perpetuity

Licence Number	Type of License	Purpose	Legislation	Description	Renewal Date
20BL171432	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: C130 (AFSH1), C130 (ALL), C130(BFS), C130 (WDH)	Perpetuity
20BL171433	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bore B334 (BFS)	Perpetuity
20BL171434	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: C317 (BFS), C317 (WDH)	Perpetuity
20BL171435	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: BZ3-1, BZ3-2, BZ3-3	Perpetuity
20BL171436	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: BZ4A(1), BZ4A(2), BZ4B	Perpetuity
20BL171437	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: WG1, WG2, WG3	Perpetuity
20BL171438	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – Bores: CGW5, CGW51A, CGW52, CGW53, CGW54, CGW55A, CGW53A, CGW52A, CGW54A, CGW6, CFW55, CFW57, CFW57A, CFW59, and CFW55R. Destroyed CGW1, CGW2, CGW3, CGW5, CGW8,CGW9, CGW10, CGW12, CGW13, CGW14, CGW30, CGW33, CGW34, CGW35, CGW36, CGW37, CGW38, CGW40, CGW41, CGW42, CGW43, CGW44, CFW56, CFW56A, CFW58	Perpetuity
20BL171439	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: BRN, E012	Perpetuity
20BL171492	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: C1(WJ039), GW9704, North, GWAR981	Perpetuity
20BL171681	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: Bunc 45A, Bunc 45D	Perpetuity

Licence Number	Type of License	Purpose	Legislation	Description	Renewal Date
20BL171725	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: B425 (WDH), BRS, C621 (BFS), C919 (ALL), D317 (BFS), D317(ALL), D317(WDH) Destroyed D420, D425, D621, PB02	Perpetuity
20BL171726	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: SR002, SR003, SR004, SR005, SR006, SR007	Perpetuity
20BL171727	Bore	Monitoring Bore	Part 5 Water Act 1912	SR001	Perpetuity
20BL171728	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: BZ2B, BZ1-1, BZ1-2, BZ1-3, BZ2-1, BZ2-2	Perpetuity
20BL171762	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO South – Bores: C817, D010 (BFS), D214 (BFS), D406 (BFS) (AFS), D510 (BFS), PB01 (ALL), D510 (AFS), D010 (GM), D010 (WDH), D406 (BFS) (AFS), D612 (AFS), D612 (BFS)	Perpetuity
20BL171851	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North/South – Bores: HV2, PZ1CH200, PZ2CH400, PZ3CH800, 4118P, 4119P	Perpetuity
20BL171852	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – PZ4CH1380	Perpetuity
20BL171853	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – DM3	Perpetuity
20BL171854	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – Bores: DM5, PZ6CH2450	Perpetuity
20BL171855	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – PZ5CH1800	Perpetuity
20BL171856	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – Bores: HV6, HV3, DM6, HV2 (2), 4113P, 4114P. 4116P, 4117P	Perpetuity

Licence Number	Type of License	Purpose	Legislation	Description	Renewal Date
20BL171857	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: HV4, HV4 (2) (GA3), GA3,	Perpetuity
20BL171858	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO North – DM4	Perpetuity
20BL171895	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO West – NPZ4	Perpetuity
20BL171896	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO West – NPZ2	Perpetuity
20BL171897	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO West – Bores: NPZ5, NPZ1	Perpetuity
20BL171898	Bore	Monitoring Bore	Part 5 Water Act 1912	HVO West – NPZ3	Perpetuity
20BL173392	Bore	Production Bore	Part 5 Water Act 1912	HVO South – LUG Bore	22/09/2015
20BL173065	Bore	Monitoring Bore	Part 5 Water Act 1912	HQ11	Perpetuity
20BL173062	Bore	Monitoring Bore	Part 5 Water Act 1912	RC14	Perpetuity
20BL173063	Bore	Monitoring Bore	Part 5 Water Act 1912	RC07, RC08	Perpetuity
20BL173064	Bore	Monitoring Bore	Part 5 Water Act 1912	RC06	Perpetuity
20BL173069	Bore	Monitoring Bore	Part 5 Water Act 1912	RC11	Perpetuity
20BL173589	Bore	Dewatering Bore	Part 5 Water Act 1912	HVO North – DM7 Dewatering Bore	13/10/2015*
20BL173587	Bore	Dewatering Bore	Part 5 Water Act 1912	HVO North – DM9 Dewatering Bore	13/10/2015*
20BL173588	Bore	Dewatering Bore	Part 5 Water Act 1912	HVO North – DM8 Dewatering Bore	13/10/2015*
20BL173847	Bore	Dewatering Bore	Part 5 Water Act 1912	WB15HVO01	04/11/2015*
20CA201247	Works Approval	Pumping Plant	Water Management Act 2000	Associated with WAL965	28/12/2017
20CA212713	Works Approval	Pumping Plant	Water Management Act 2000	Associated with WAL36190	30/05/2015*
20CW802613	Controlled Work	Levee	Part 8 Water Act 1912	HVO South – Barry Levee	05/09/2016
20CW802603	Controlled Work	Controlled Work	Part 8 Water Act 1912	HVO South – Hobden Gully Levee	27/03/2016
20CW802604	Controlled Work	Controlled Work	Part 8 Water Act 1912	HVO North – North Pit Levee 3	25/07/2016

Licence Number	Type of License	Purpose	Legislation	Description	Renewal Date
20CW802612	Controlled Work	Controlled Work	Part 8 Water Act 1912	HVO North – Carrington Levee 5	04/09/2016
20WA210991 (see WAL 18307) Formerly 20SL050903	Stream Diversion	Stream Diversion	Water Management Act 2000	HVO West – Parnells Creek Dam	09/01/2023
20WA211427 Formerly 20SL061290	Stream Diversion	Cutting (Diversion Drain)	Section 10 Water Act 1912	Pikes Gully Creek Stream Diversion	07/09/2023
20WA210984 (see WAL 18327) 20SL042746	Diversion Works	Industrial	Water Management Act 2000	HV Loading Point Pump Bayswater Creek	08/09/2022
20WA211428 20SL061594	Stream Diversion	Cutting (Diversion Drain)	Water Management Act 2000	HVO North – Carrington Stream Diversion	31/7/2022
20WA201238 (see WAL 962)	Diversion Works	Pumping Plant	Water Management Act 2000	HVCPP River Pump	16/03/2018
20WA201257 (see WAL 970)	Diversion Works	Pumping Plant	Water Management Act 2000	HVO South – LCPP River Pump	Perpetuity
20WA201338 (see WAL 1006)	Diversion Works	Pumping Plant	Water Management Act 2000	HVO South – LCPP River Pump	Perpetuity
20WA201501 (see WAL 1070)	Diversion Works	Pumping Plant	Water Management Act 2000	HVO South – LCPP River Pump	Perpetuity
20WA201685 (see WAL 13387)	Diversion Works	Pumping Plant	Water Management Act 2000	HVO West – "Lake Liddell" Licence	Perpetuity

*Application for renewal submitted, waiting on DPI Water

Table 7: Water Access Licence

Licence Number	Purpose	Legislation	Description	Renewal Date	Approved Extraction (ML)	Actual Extraction 2015 (ML)
20AL201237 (see WAL 962)	Water Access Licence	Water Management Act 2000	HVO North – HVCPP River Pump – Water Access Licence	Perpetuity	3,165	945*
20AL201254 (see WAL 969)	Water Access Licence	Water Management Act 2000	HVO South – Former Riverview pump	Perpetuity	39	0
20AL201256 (see WAL 970)	Water Access Licence	Water Management Act 2000	HVO South – LCPP River Pump – Water Access Licence	Perpetuity	500	0
20AL201337 (see WAL 1006)	Water Access Licence	Water Management Act 2000	HVO South – LCPP River Pump – Water Access Licence	Perpetuity	500	0
20AL201500 (see WAL 1070)	Water Access Licence	Water Management Act 2000	HVO South - LCPP River Pump – Water Access Licence	Perpetuity	500	0
20AL201684 (see WAL 13387)	Water Access Licence	Water Management Act 2000	Macquarie Generation Hunter River Pump Station	Perpetuity	20	0
20AL201895 (see WAL 13391)	Water Access Licence	Water Management Act 2000	HVO North – Alluvial Rehabilitation Irrigation.	Perpetuity	420	0
TOTAL					5,144	945

* Passive take due to pit seepage; no water pumped from Hunter River

3.1.2 Management Plans, Programmes and Strategies

Under the Project Approvals, HVO is required to develop and submit a range of environmental management plans for approval prior to implementation. Issued in 2009, the HVO South Coal Project Approval (PA06_0261) required submission of a number of monitoring programmes, strategies and some management plans, while the March 2013 modification to the HVO North Consent (DA 450-10-2003) contains a contemporary list of comprehensive management plan requirements. Where possible, the HVO South conditions, commitments and obligations have been included in the Management Plans which have been submitted for HVO North, allowing for a single plan to detail management measures which will be employed across the site. Once approved, management plans are made publically available via the Rio Tinto website (www.riotinto.com.au). The status of these management plans is shown in Table 8 and Table 9.

Table 8: Management plans and MOPs required for HVO North

Management Plan	Due Date	Date Approved
Water management plan	30/09/2013 (Extension approved until 31/12/2013)	10/07/2015
A rehabilitation management plan and an agricultural reinstatement management plan	30/09/2013	Reviewed by DP&E and DRE, updated version to be included in new HVO North MOP in 2016
Aboriginal Heritage Management Plan	30/06/2013 (Extension approved until 31/12/2013)	12/02/2014
Fire management plan	N/A	No submission required
Noise Management Plan (including Noise Monitoring Programme)	30/06/2013	25/08/2015
Blast Management Plan (including Blast Monitoring Programme)	30/09/2013	4/4/2014
Air Quality and Greenhouse Gas Management Plan (including Air Quality Monitoring Programme)	30/06/2013	12/02/2014
Environmental Management Strategy	12/12/2004 (Latest version submitted 04/02/2016)	03/02/2016
Mining Operations Plan (MOP) HVO North 2012-2018	N/A	05/06/2012
Mining Operations Plan (MOP) Newdell 2002-2009	N/A	29/07/2002
Rehabilitation management plan	30/09/2013	30/09/2013
Agricultural reinstatement management plan	30/09/2013	30/09/2013
Rehabilitation and restoration Strategy for Carrington Billabong	30/06/2007	30/06/2007
Landscape and Rehabilitation Management Strategy	30/06/2007	30/06/2007

Table 9: Management Plans and MOPs required for HVO South

Management Plan	Due Date	Date Approved
River Red Gum Restoration Strategy	24/03/2010	24/03/2010
Rehabilitation and Landscape Management Plan; including • Rehabilitation and Biodiversity Management Plan; • Final Void Management Plan and • Mine Closure Plan	24/03/2010	24/03/2010
Amenity Management Plan for Hunter Valley Glider Club facilities (Blast Training Procedure HVGC)	6 months prior to mining in Riverview South East Extension area	22/01/2013
Water management plan	30/09/2013 (Extension approved until 31/12/2013)	10/07/2015
Aboriginal Heritage Management Plan	30/06/2013 (Extension approved until 31/12/2013)	12/02/2014
Fire management plan	N/A	No submission required
Noise Management Plan (including Noise Monitoring Programme)	30/06/2013	25/08/2015
Blast Management Plan (including Blast Monitoring Programme)	30/09/2013	4/04/2014
Air Quality and Greenhouse Gas Management Plan (including Air Quality Monitoring Programme)	30/06/2013	12/02/2014
Environmental Management Strategy	24/09/2009 (Latest version submitted 04/02/2016)	03/02/2016
Mining Operations Plan (MOP) HVO South 2015-2018	N/A	17/12/2015

4 OPERATIONS SUMMARY

4.1 Mining

Areas to be mined are geologically modelled, a mine plan is formed and the relevant mining locations are surveyed prior to mining. Figure 2 illustrates the mining process. HVO have no active underground workings.

No changes were made to the mining method during the reporting period. Mining progress deviated slightly from the schedule of the MOPs as a result of normal variations in productivity and utilisation.

The mining equipment fleet employed to carry out mining operations at HVO is detailed in Table 10, along with the fleet transformation from 2014 to 2016 predictions. Changes in the data appear in **bold**.

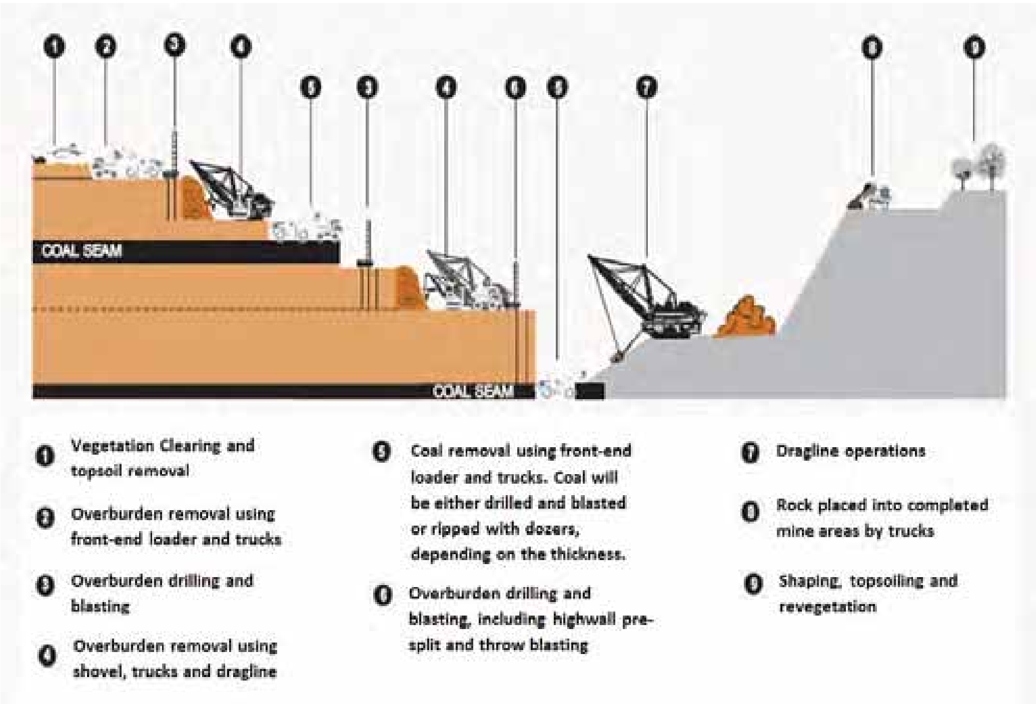


Figure 2: Mining Schematic

Table 10: HVO Equipment Used 2014-2016

Equipment Type	Number Used in 2014	Number Used in 2015	Forecast numbers in 2016
Scrapers	2	2	2
Drills	10	**9**	9
Draglines	2	2	2
Shovels	4	4	**4.5**
Excavators	7	7	**7.5**
Trucks	**85**	**87**	**94**
Loaders	7	7	7
Service Trucks	**5**	5	5
Track Dozers	33	**30**	**33**
Rubber Tyre Dozers	5	5	5
Graders	**11**	11	11
Surface Miner*	**1**	1	0
Water Trucks	**10**	10	10
Floats	1	1	1
Cable Reeler	**1**	1	1
Cable Tractors	**5**	5	5
Total	189	187	197

*In 2014, HVO commenced a trial of a surface miner. At this time the surface miner will not be utilised in 2016

4.1.1 Mineral Processing

Coal is transported to one of two CHPPs, where it is crushed to size and processed to remove impurities. Processing produces saleable coal, along with coarse and fine reject materials. Coarse rejects are disposed of in pit, and fine rejects are placed in a tailings dam, according to commitments outlined in the MOP. Each CHPP site has storage facilities for processed (saleable) and unprocessed (ROM) coal. The capacity of each site is listed in Table 11. No changes or additions were made to process or facilities during the reporting period.

Table 11: Stockpile Capacities

Location	ROM stockpile(t)	Saleable stockpile (t)
Hunter Valley CHPP	176,000	29,700
West CHPP	15,000	30,000
Newdell CHPP	0	450,000

Processed, or product coal is transported to one of the two loading points via conveyor belt or road, detailed in Table 12. The coal from HVCHPP is transported to the Hunter Valley Load Point (HVLP) by means of overland conveyor whereas coal from West CHPP (Howick) is trucked to Newdell Load Point. After the coal has reached either HVLP or the Newdell Load Point, it is transported to Newcastle by rail.

Table 12: Methods of Coal Transportation

Category of Transport	Quantity (million tonnes)
Coal transported from the site via trains	13.01
Amount of coal received from Hunter Valley Operations South of the Hunter River	10.74
Amount of coal hauled by road to the Hunter Valley Loading Point	Nil
Coal hauled by road to the Newdell Load Point	1.822
Amount of coal hauled by road from the Newdell Loading Point to the Ravensworth Coal Terminal	Nil
Amount of coal hauled by road from the Hunter Valley Loading Point to the Ravensworth Coal Terminal	Nil
Number of coal haulage truck movements generated by the development. (includes -coal hauled to stockpile, coal hauled to bins, coal hauled from stockpile to bins)	46,724

4.1.2 Production statistics

Project approvals allow for the extraction of up to 22 million ROM tonnes from operations north of the Hunter River and 16 million ROM tonnes from operations south of the Hunter River. A summary of production and waste at HVO during 2015 in comparison to previous years is provided in Table 13.

Product coal includes low-ash, semi-soft and steaming coals. During 2015, total product coal decreased compared to 2014 production. Table 14 outlines the tonnages produced by each CHPP compared to Project Approval (PA) limits.

Table 13: Summary of Production and Waste at HVO in 2015

	HVO North MOP 2015	HVO South MOP 2015	Reporting Period 2015	Reporting Period 2014	Forecast for 2016
Prime Waste (Mbcm)	48.6	75.1	104.34	93.4	115.57
ROM Coal (Mt) (mined)	8.3	15.0	17.16	18	19.2
Coarse Reject (Mt)	1.8	2.8	2.7	2.8	3.4
Fine Reject-Tailings (Mt)	0.8	1.2	1.1	1.2	1.2
Product (Mt)	5.7	11.0	13.01	13.91	14.54

Table 14: Production Statistics and Correlating Project Approval Limits

Product Coal	Project Approval limits (mtpa)	2015 (Mt)	2014 (Mt)	Forecast for 2016
Hunter Valley CHPP	20	11.25	11.66	11.86
Howick CHPP	6	1.76	2.25	2.68
Total HVO Product Coal	26	13.01	13.91	14.54

4.1.3 Summary of Changes (developments, equipment upgrades)

No land was acquired during 2015 in relation to the existing Project Approvals.

Consistent with the MOP and the EA's, additional machinery was used when compared to 2014; details are outlined in Table 10.

During 2016, mining will also involve one small satellite pit: the Glider Pit is located to the east of the existing Riverview Void and will be mined until late-2016.

5 ACTIONS REQUIRED FROM PREVIOUS ANNUAL REVIEW

The DRE and DP&E both conducted an annual inspection of HVO on the 26 June 2015 to review mining activities as reported in the 2014 Annual Environmental Review. Both Departments were generally satisfied with the contents of the report; however a number of actions were identified as part of the inspection and review of the document. The actions and responses are shown in Table 15 and Table 16.

Table 15: Response to actions from DRE 2014 Annual Review Inspection

Issue/Observation	Action	Response
Tailings Management	DRE encourage active management to minimise standing surface water on tailings facilities. Report on management practices in the next AEMR	Status of decant pump infrastructure on HVO active and inactive TSF's included in Section 8.6 Tailings Management.
Riverview Void Maintenance	Continue to implement the maintenance program to repair gully erosion and contour banks	At the end of 2015, approximately 55% of the Riverview Void slope maintenance had been completed. The remaining section of eroded slope will be repaired during 2016.
Performance Criteria – Native Vegetation	Develop a Monitoring Program for native vegetation communities, including analogue and rehabilitated mine sites.	Monitoring program for native vegetation rehabilitation commenced in 2015. Permanent monitoring transects established for 12 reference sites and 19 HVO rehabilitation sites. Monitoring report (prepared by Niche Environment and Heritage) included in Appendix 5.
Ecosystem and Landuse Establishment – Species Specific Habitat	DRE encourage the development and implementation of a Habitat Augmentation Plan with performance measures for nesting structures and woody debris/rock piles	Performance criteria included in HVO North MOP for habitat augmentation in rehabilitation areas. Guidelines for habitat augmentation in rehabilitation areas will be developed during 2016.
Appendix 6 – Rehabilitation and Disturbance Summary Maps	DRE encourage HVO to incorporate additional information regarding landform establishment(slope, drainage, substrate material characterisation, morphology, aspect)	Additional information included in Appendix 4

Table 16: Responses to Actions from DP&E 2014 Annual Review Inspection

Issue / Observation	Response
The Department notes that the Annual Review document was completed generally to a very high standard. However in aid of review to future documents it would be appreciated if commentary regarding visual amenity and lighting be directed toward more local considerations.	Noted and amended context of visual amenity in this report
It is noted in the period of the Annual Review that discharge occurred into the Wollombi Brook from an event which occurred on 9th October 2014.	A number of actions have been undertaken to mitigate a reoccurrence of this event. These included but are not limited to a full survey and modelling of pipeline, resulting in upgrades to pipe infrastructure and operating protocols and; installation of an automated leak detection system, which is remotely monitored and operated.
During the inspection the Department discovered a broken pipe discharging sediment laden black coloured water. This water was fortuitously caught by the Hunter Valley Loadpoint sump and did not leave site,	Immediately after the site inspection the Hunter Valley Load Point pipeline clamp joints were replaced with poly welded joins. Daily Environmental Inspection checklists were reviewed to ensure this area was being captured.
During the inspection of the Hunter River Crossing a section of the double sleeving of one of the raw water pipes which crosses the Hunter River had been disconnected or broken. Given dot point 2 and 3 and this issue, the Department requests that a review of Surface Water Management Plan be undertaken to include details of inspections and maintenance of the raw water and tailings reticulation network by 31st October 2015.	Immediately after the site inspection the steel band clamp on the double sleeving at the Hunter River Bridge crossing was reconnected and reinforced with a poly welded strap. A bund has also been constructed as tertiary containment to direct any potential leaks from the double sleeved pipeline into the north east sediment trap at the bridge. Daily Environmental Inspection checklists were reviewed to ensure this area was being captured.
During the inspection it was observed that a large amount of mud and sediment had accumulated on the Hunter River Bridge. On further observation it was noted that this material was leaking through the Jersey barrier through gaps and depositing outside of the bridge. It is suspected that this sediment material is entering the Hunter River and therefore the Department requests that a permanent, practical and feasible method to prevent this material coming through the jersey barrier is developed and implemented by 31st December 2015.	HVO have undertaken a comprehensive clean of the Hunter River Bridge deck both inside and outside of the Jersey barrier. It's understood that much of the material accumulated was remnant from prior to completion of the sediment trap upgrades. Now that the sediment traps on both the north and south approaches of the bridge are fully functional HVO will observe the new cleaned bridge deck during and after rain periods if further action is required.
Efforts in the design and construction of the southern sediment catchment drains at the Hunter River Crossing are noted by the Department.	Noted, no action required.

6 ENVIRONMENTAL PERFORMANCE

6.1 Meteorological data

The collection of meteorological data is carried out to assist in day to day operational decisions, planning, environmental management and to maintain a historic record. The meteorological (weather) stations record wind speed, wind direction, temperature, humidity, solar radiation and rainfall. HVO operates two real time weather stations; the HVO Corporate Meteorological Station and the Cheshunt Meteorological Station. Data is publically available via the Monthly Environmental Reports published on the Rio Tinto website (www.riotinto.com.au).

6.2 Noise

6.2.1 Management

Mining activities are undertaken at HVO in a manner so as to ensure adverse noise impacts are minimised, and to ensure compliance with permissible noise limits at nearby private residences. A combination of both proactive and reactive control mechanisms are employed to ensure effective management of noise emissions.

6.2.2 Sound Attenuation of Heavy Equipment

During 2015, four Komatsu 830E-DC haul trucks were retrofitted with attenuated mufflers. On average, the installation of the attenuation resulted in a significant sound reduction of 5dB(A) and 9dB(L), representing a halving of the sound energy from the engine exhaust.

During 2016, HVO is scheduled to complete fitment of full sound attenuation kits (to achieve 115dB(A)) to a further six Komatsu 830E-AC units. At the time of reporting, this is planned for completion during H2 2016, at an approximate cost of $800k.

6.2.3 Real Time Noise Management

HVO operates a network of directional real-time noise monitors, used to ensure noise emissions remain below statutory limits and to minimise community impact. The real-time system generates alarms when elevated noise is measured, triggering the implementation of reactive controls to reduce noise levels.

During 2015, the HVO Mine Monitoring and Control Team received and responded to 1,913 noise alarms, recording a total of 2,025 hours of equipment stoppage in direct response to real-time alerts (Figure 3).

The noise monitoring network was improved through the purchase of an Environmental Noise Compass (ENC) unit, installed in the Jerrys Plains area during November 2015. The ENC utilises a 26 microphone array and conventional beamforming techniques (borrowed from military / submarine applications) to resolve the source direction of measured noise in real-time. The ENC will replace the existing Jerrys Plains BarnOwl monitor, and will be integrated into the noise management system in 2016.

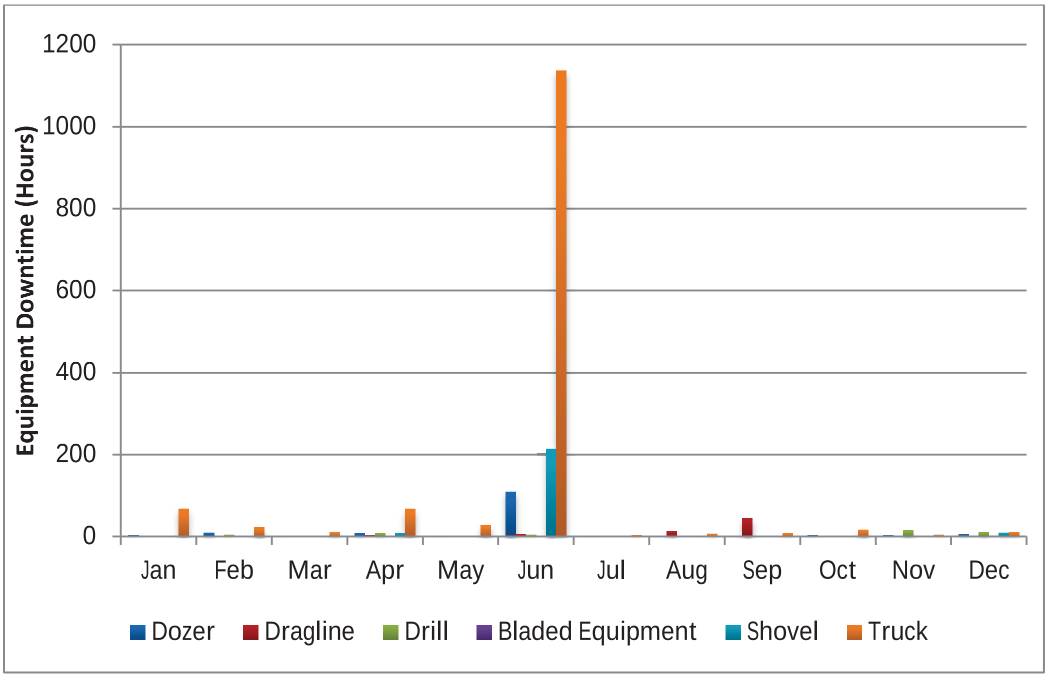


Figure 3: Environmental delays due to noise 2015

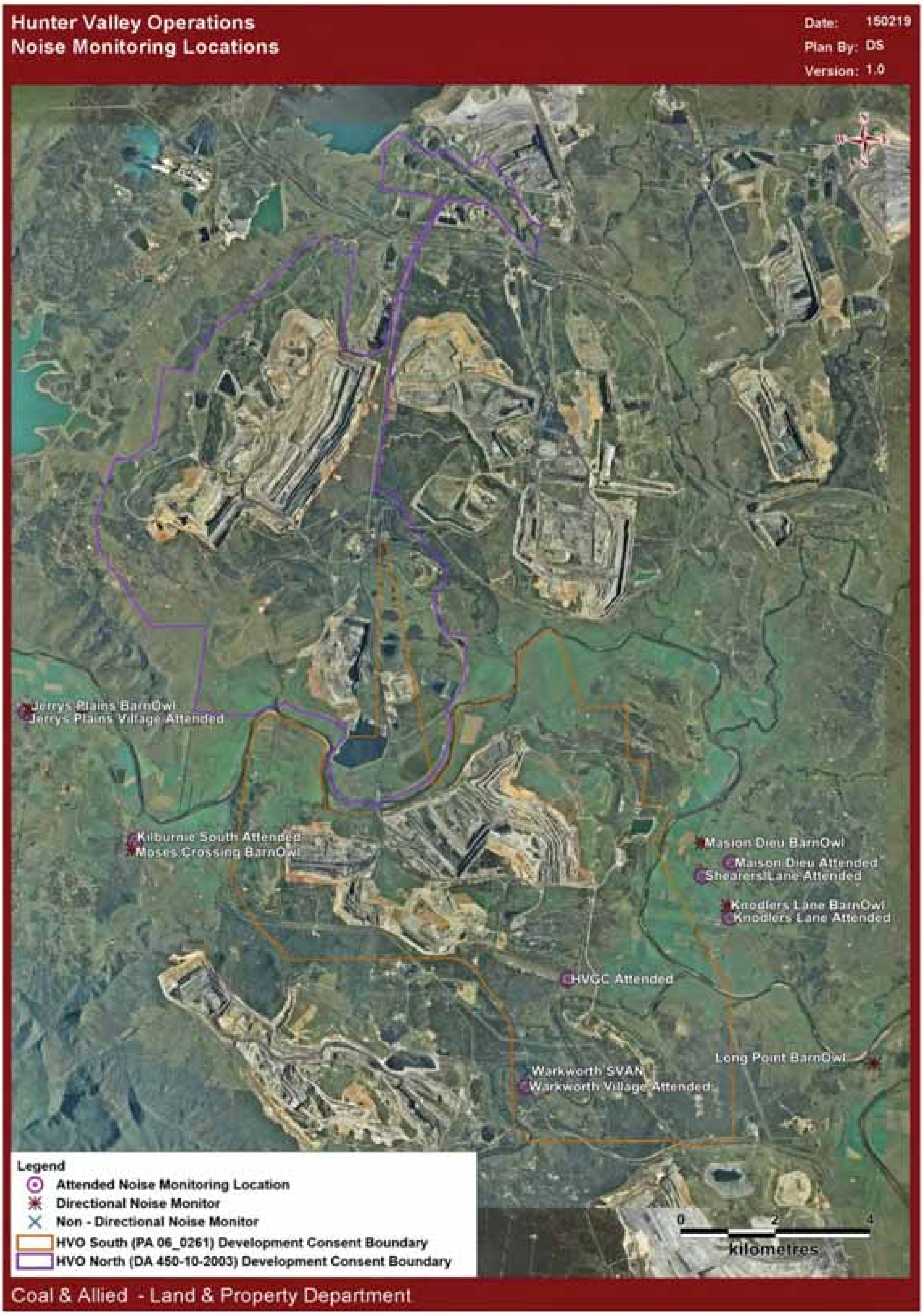


Figure 4: HVO Attended Noise Monitoring Network

6.2.4 Operational Noise Performance

To assess compliance with the relevant Project Approval noise criteria, HVO engages Global Acoustics to undertake routine compliance monitoring at nearby private residences (Figure 4), in accordance with the HVO Noise Management Plan. Monitoring is undertaken at a frequency of one night per month so as to ensure that noise impacts are adequately assessed under a range of meteorological conditions throughout the year.

A total of 107 measurements were taken during 2015. Each measurement involves an assessment of HVO mine noise against the various LAeq and LA1, 1min noise criteria in place under the HVO North and South Approvals (a total of 504 assessments). HVO reported three measurements which exceeded an applicable noise criterion during the reporting period, described further herein. A summary of noise monitoring results are presented in Table 17. Full details for all noise assessments completed can be found in the Hunter Valley Operations Monthly Environmental Monitoring Report, published on the Rio Tinto website.

6.2.5 Noise Non-compliances

See Section 11 of the report for non-compliance details.

6.2.6 Comparison to previous years' results

Table 17: Comparison of 2015 noise monitoring results against previous years.

Year	Number of measurements	Number of measurements which exceeded allowable noise limits by 2dB or greater (under applicable meteorological conditions)*	Number of non-compliances*
2015	107	3	2
2014	75	2	0
2013	85	5	2
2012	75	4	1
2011	95	7	5
2010	114	7	2
2009	71	3	1

* The Industrial Noise Policy allows for the measured result to be less than or equal to 2 dB above the applicable noise limit without constituting a non-compliance. A non-compliance is therefore classed as a result greater than 2 dB above the applicable noise limit.

6.2.7 Comparison to EIS Predictions

Table 18 and Table 19 shows comparisons between 2015 L_{Aeq} attended noise monitoring results and the predictions made in the HVO West Pit Extension and Minor Modifications EIS (2003) and the HVO South Coal Project Environmental Assessment (2006).

Comparisons against the predicted noise levels in the HVO Carrington West Wing EA (2010) have not been made in this years' Annual Review, as mining activity in the Carrington Pit area was minimal during the reporting period.

Comparisons against the predicted noise levels in the HVO West Pit Extension and Minor Modifications EIS (2003) have been made against the modelled scenario for Year 14 of the development (Table 5.2 of Part J – Hunter Valley Operations West Pit Extension and Minor Modifications Technical Reports Part 3).

Comparisons against the predicted noise levels in the HVO South Coal Project Environmental Assessment have been made against Mitigated Scenario B2 (indicative of mining operations in 2014), (Table 5.4 of Annexure H – Hunter Valley Operations South Coal Project Approval Environmental Assessment Report Volume 2). Where there are multiple predicted noise levels under scenario B2 (under different operating conditions), the comparison has been made against the lowest predicted noise level.

Comparisons have been made by averaging the results (where measureable) of the 2015 attended surveys conducted during each month (presented on a per quarter basis), and comparing directly with the predicted noise level at each monitoring location. The use of averaged results is considered most appropriate so as to provide an annualised comparison against the EA predictions, taking account of meteorological conditions experienced throughout the year. Where attended monitoring has determined HVO to be 'inaudible' or 'not measurable' during any of the surveys, a conservative estimate of 25dB has been used to ensure a valid comparison is made.

Comparison of measured results against the modelled predictions for Year 14 in the HVO West Pit EIS (2003) demonstrates noise levels equal to or lower than predicted at all monitoring locations.

Table 18: Comparison of 2015 monitoring against HVO North (year 14, West Pit EIS, 2003) - Night Period

Location	Units	EIS Prediction (INP)	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Knodlers Lane	dB(A)	27	Inaudible	Inaudible	Inaudible	Inaudible
Maison Dieu	dB(A)	26	Inaudible	25.7	Inaudible	Inaudible
Kilburnie South	dB(A)	34	33.7	28.3	29	26.7
Jerrys Plains	dB(A)	<35	32.7	31	30.2	28
Jerrys Plains East	dB(A)	38	NA	NA	Inaudible	26.7
Warkworth Village	dB(A)	<35	Inaudible	Inaudible	Inaudible	NA

* Where a '<' reading has been provided, this indicates that the highest recorded value at that location was less than this number. This is generally due to inability to ascertain a more accurate reading due to another dominant noise source, or if the audible noise was not constant during the recording period.

Comparison of HVO South Pit area data measured through routine compliance assessment indicates good correlation with predicted noise levels for all receptors.

Table 19: Comparison of 2015 monitoring against HVO South (South Coal Project EA, 2006) - Scenario B2 (2014) - Night Period

Location	Units	EIS Prediction (INP)	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Knodlers Lane	dB(A)	37	34	25	35	Inaudible
Maison Dieu	dB(A)	39	32.5	27	37	Inaudible
Shearers Lane	dB(A)	39	36	36	39	Inaudible
Kilburnie South	dB(A)	35	32.7	32	35	32
Jerrys Plains	dB(A)	28	Inaudible	28	26.3	26.3
Jerrys Plains East	dB(A)	28	NA	NA	NA	28.3
Warkworth Village	dB(A)	36	29	32	<35	NA

6.3 Blasting

6.3.1 Blasting Management

The objective of blasting operations is to ensure that optimal fragmentation is obtained whilst minimising dust and fume generation, adhering to safety standards and conforming to approvals criteria for vibration and overpressure.

During 2015, HVO operated a network of Dynamasters DV6 R4 and Datamasters Version 6 (V6) blast monitors up until 1 April 2015, at which time these units where replaced with Benchmark Monitoring's' Kaboom Blast Monitoring System. HVO achieved 100% blast data capture during 2015. These are located at or in close proximity to nearby privately owned residences and function as regulatory compliance monitors as shown in Figure 5. These monitors are located at:

- Jerrys Plains Village;
- Warkworth;
- Maison Dieu;
- Moses Crossing; and
- Knodlers Lane

Figure 5: Blast Monitoring Network

6.3.2 Blasting Performance

During the reporting period 304 blast events were initiated at HVO. One blast event on 17th July 2015 recorded an airblast overpressure result of 120.55dB(L), exceeding the HVO South Airblast Overpressure criterion of 120.0 dB(L). HVO complied with all other blasting related consent and licence conditions during the reporting period. Airblast Overpressure and Ground Vibration results for all blasts fired during the reporting period are displayed in Figure 6 to Figure 10.

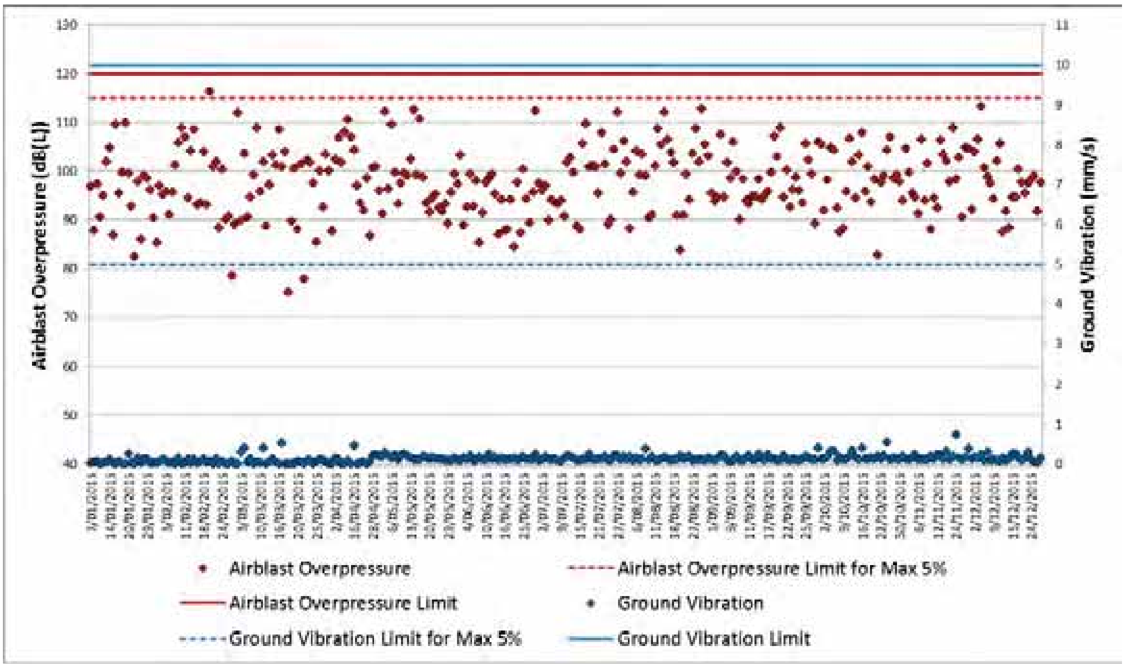


Figure 6: Jerrys Plains Blast Monitoring Results 2015

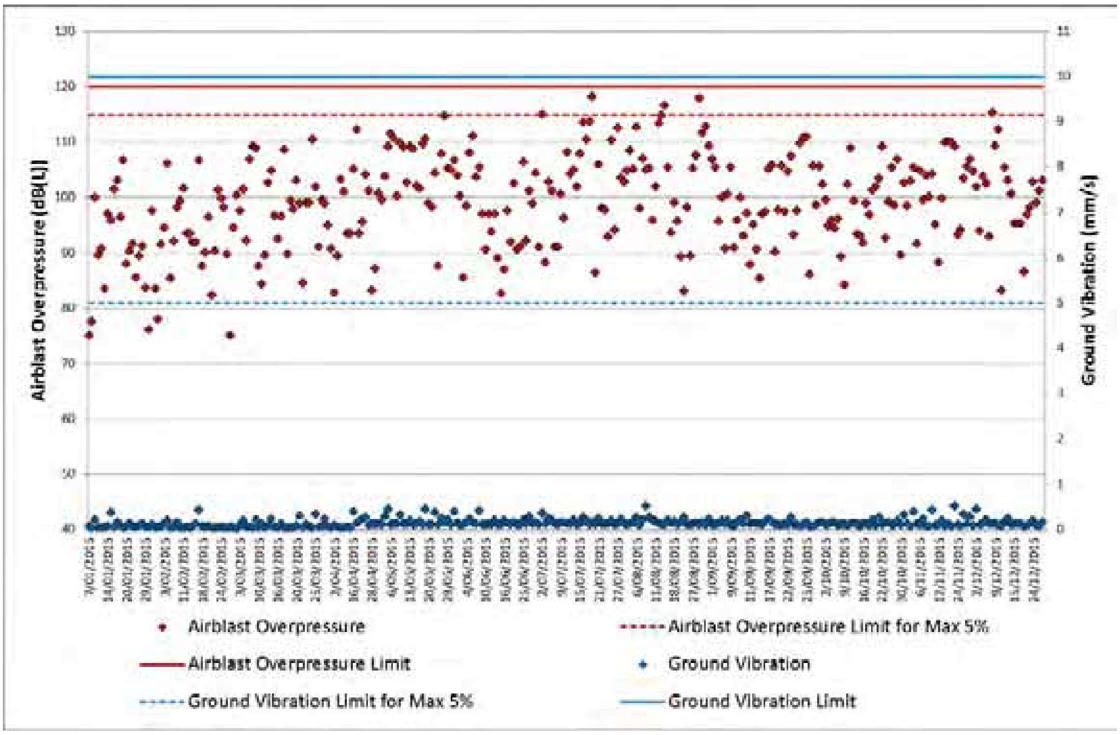


Figure 7: Knodlers Lane Blast Monitoring Results 2015

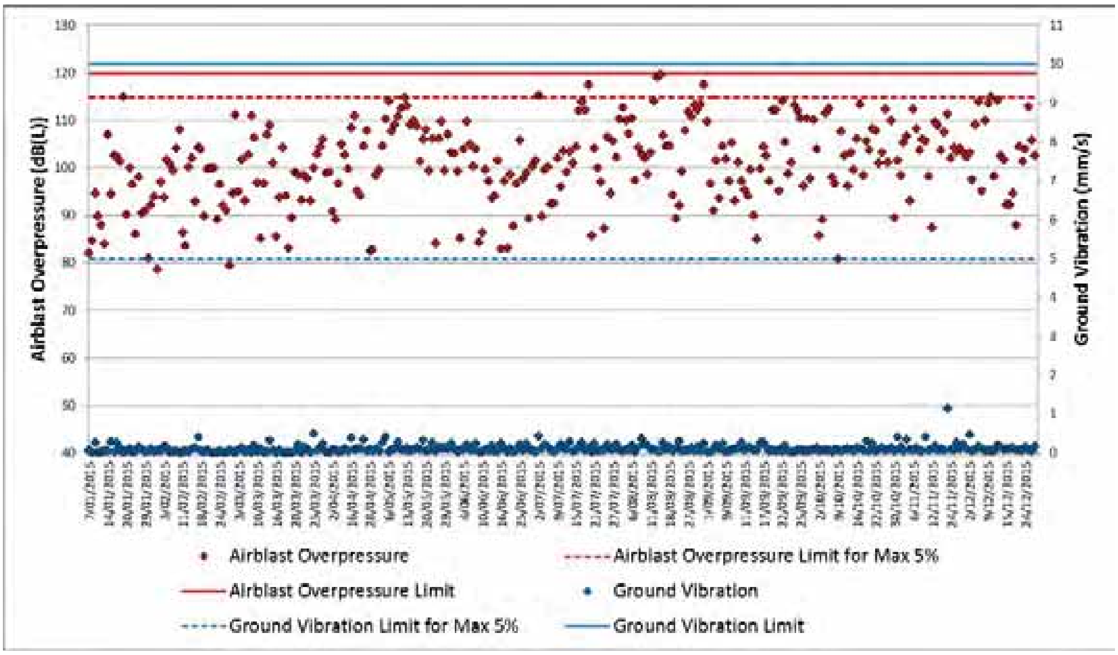


Figure 8: Maison Dieu Blast Monitoring Results 2015

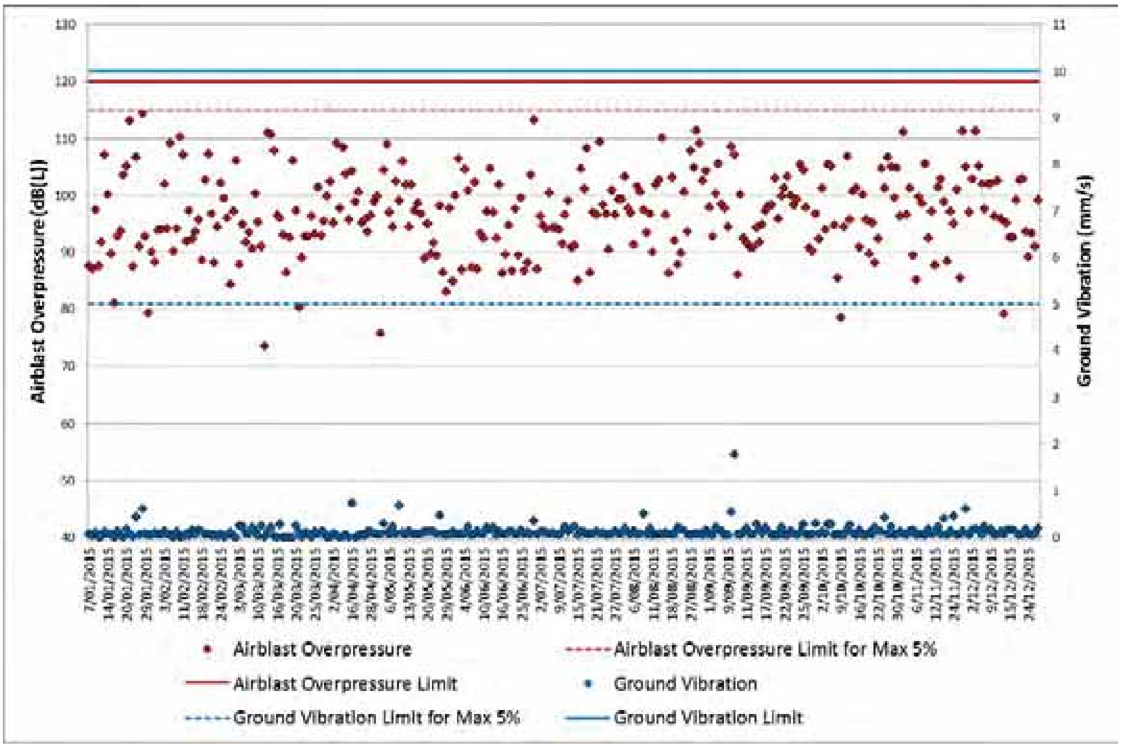


Figure 9: Moses Crossing Blast Monitoring Results 2015

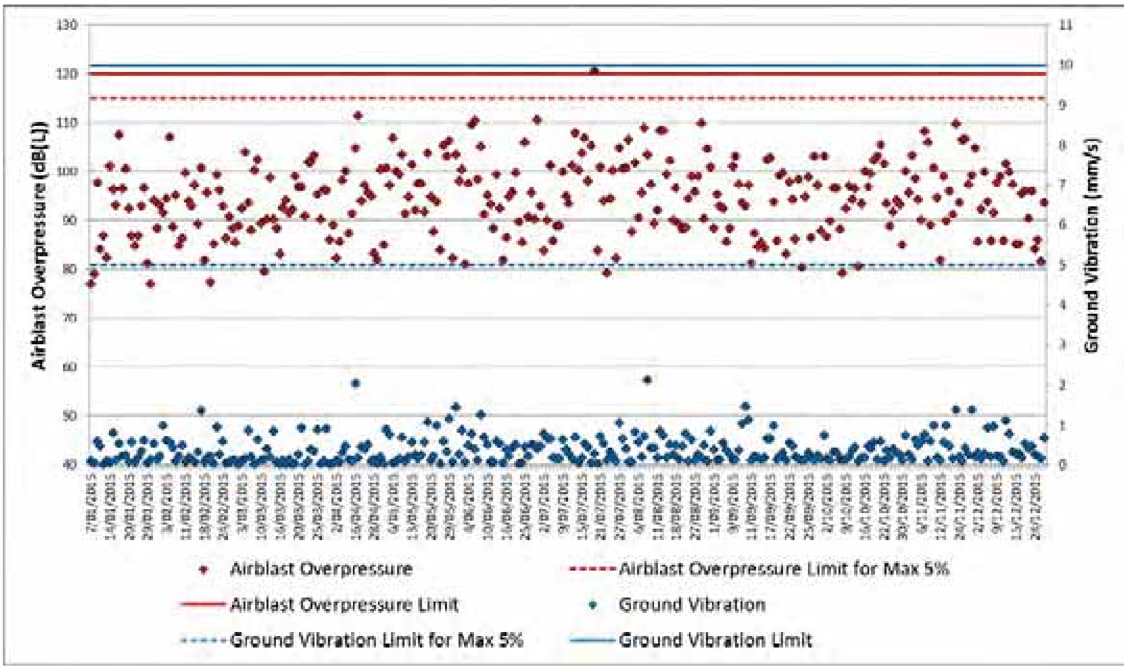


Figure 10: Warkworth Blast Monitoring Results 2015

6.3.3 Blast fume management

HVO operates a Post Blast Fume Generation Mitigation and Management Plan. This document outlines the practices to be utilised to reduce the risk of generation of post blast fume, and reduce potential offsite impact from any fume which may be produced. This includes risk assessment of the likelihood of fume production, specialised blasting design, appropriate product selection, on-bench water management, implementation of fume management zones and use existing blasting permissions to identify likely path of any fume which may be produced.

All blasts are observed for fume and any fume produced is ranked according to the Australian Explosive Industry & Safety Group (AEISG) Scale.

One category 4 fume event and one category 3 fume event were recorded in 2015 and notified to DP&E. The category 4 fume event dissipated within the HVO South consent area. The level 3 fume event left the site as a degraded fume of Level 1, dissipating at height over neighbouring mine owned land. Zero category 5 events were recorded. Fume rankings for shots fired during 2015 and comparison to previous years is provided in Table 20.

Table 20: Visible blast fume rankings according to the AEISG colour scale

AEISG Ranking	2015	2014	2013
0	310	245	247
1	37	40	50
2	17	17	20
3	1	4	0
4	1	0	0
5	0	0	0
Total*	366	306	317

* Where a number of individual blasts were fired as a blast event, fume was assessed for each individual blast pattern rather than for the event as a whole.

6.3.4 Blasting Non-compliances during the Reporting Period

See section 11.2

6.4 Air Quality

6.4.1 Air Quality Management

Air quality management initiatives are implemented at HVO to ensure that:

- air quality impacts on surrounding residents are minimised;
- all statutory requirements are adhered to; and
- local community and regulators are kept informed through prompt and effective response to issues and complaints.

Air quality control mechanisms employed at HVO are described in detail in the Hunter Valley Operations Air Quality and Greenhouse Gas Management Plan, publically available via the Rio Tinto website. Figure 13 shows the air quality monitoring network at HVO.

6.4.2 Air Quality Performance

6.4.2.1 Real Time Air Quality Management

HVO's real time air quality monitoring stations continuously log information and transmit data to a central database, generating alarms when particulate matter levels exceed internal trigger limits.

A total of 429 real time alarms for air quality and wind conditions were received and acknowledged during 2015. In response, 3,835 hours of equipment downtime was recorded due to air quality management. The detailed breakdown of air quality related equipment stoppages (per month, per equipment type) presented in Figure 11 illustrates the prevalence of stoppages during the warmer months, generally associated with elevated winds.

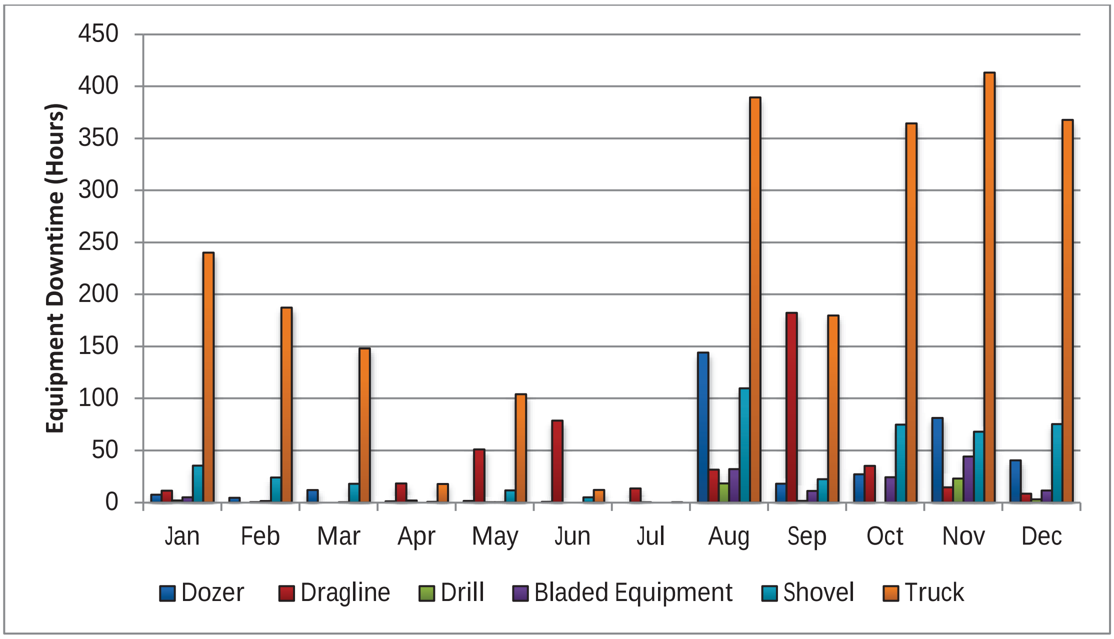


Figure 11: Equipment Downtime Hours for Air Quality Management 2015

6.4.2.2 Temporary Stabilisation

Aerial Seeding was undertaken in October 2015 by a fixed wing aircraft to provide temporary cover to areas exposed to wind generated dust and erosion at HVO. Waste dumps and exposed areas were selected for seeding if they were not planned to be disturbed within six months. The 199ha of area seeded included waste dumps ahead of mining disturbance (Figure 12). All areas were seeded using an exotic pasture and legume mix suitable for spring sowing. A starter fertiliser was mixed with the seed prior to loading to provide sufficient nutrients for plant growth.

Figure 12: Areas Aerial Seeded in 2015

6.4.2.3 Air Quality Monitoring

Air quality monitoring at HVO is undertaken in accordance with the HVO Air Quality Monitoring Programme (available via the Rio Tinto website http://www.riotinto.com/documents/HVOAirQualityandGreenhouseGasMgmtPlan.pdf), comprising an extensive network of monitoring equipment which is utilised to assess performance against the relevant conditions of HVO's approvals. Air quality monitoring locations are shown in Figure 13. During 2015, HVO complied with all short term and annual average air quality criteria. Air quality compliance criteria are shown in Table 21 and Table 22, along with a summary of HVO's performance against the criteria. HVO currently operates under two separate Planning Approvals (DA450-10-2003 – HVO North, and PA 06-0261 – HVO South). With the exception of the percentile frequency of short term PM_{10} non-compliance allowable under the HVO South Approval (Table 12 in Schedule 3, Condition 20 of PA 06_0261), the air quality criteria are identical in both approvals. As such it should be noted that the following compliance assessment has been undertaken on a 'whole of HVO site' basis, rather than individually assessing the contribution of each approval area to the measured results.

Air quality monitoring data is made publically available through the HVO Monthly Environmental Monitoring Report, which can be viewed on the Rio Tinto website.

Figure 13: Air Quality Monitoring Locations 2015

Table 21: Air quality impact assessment criteria and 2015 compliance assessment (HVO North DA 450-10-2003 and HVO South PA 06_0261)

Pollutant	Criterion	Averaging Period	Compliance
Deposited Dust	4 g/m^2/month	Maximum total deposited dust level	100%
	2 g/m^2/month	Maximum increase in deposited dust level	100%
Total Suspended Particulate matter (TSP)	90 $\mu g/m^3$	Long Term (Annual)	100%
Particulate matter <10µm (PM_{10})	30 $\mu g/m^3$	Long Term (Annual)	100%
	50 $\mu g/m^3$	Short Term (24 hour)	100%

Table 22: Air quality land acquisition criteria and 2015 compliance assessment (HVO North DA 450-10-2003 and HVO South PA 06_0261)

Pollutant	Criterion	Averaging Period	Compliance
Deposited Dust	4 g/m^2/month	Maximum total deposited dust level	100%
	2 g/m^2/month	Maximum increase in deposited dust level	100%
Total Suspended Particulate matter (TSP)	90 $\mu g/m^3$	Long Term (Annual)	100%
Particulate matter <10µm (PM_{10})	30 $\mu g/m^3$	Long Term (Annual)	100%
	150 $\mu g/m^3$ [a]	Short Term (24 hour)	100%
	50 $\mu g/m^3$ [b]	Short Term (24 hour)	100%

[a] – Total impact (i.e. incremental increase in concentrations due to the development plus background concentrations due to all other sources);
[b] – Incremental impact (i.e. incremental increase in concentrations due to the development on its own)

6.4.2.4 Deposited Dust

Deposited dust is monitored at nine locations on privately-owned land, in accordance with AS3580.10.1 (2003). The annual average insoluble matter deposition rates in 2015 compared with the depositional dust impact assessment criterion and previous years' data are shown in Figure 14. During 2015 all annual average insoluble matter deposition rates were compliant with the long-term impact assessment and land acquisition criteria. All monitoring locations also demonstrated compliance with the maximum allowable insoluble solids increase criteria of 2g/m^2/month (Figure 15).

During 2015 monthly dust deposition rates equal to or greater than the long-term impact assessment criteria of 4g/m^2/month were recorded at number of sites. Where field observations denote a sample as contaminated (typically with insects, bird droppings or vegetation), the results are excluded from Annual Average compliance assessment. Meteorological conditions and the results of nearby monitors for the sampling period are also considered when determining HVO's level of contribution to any elevated result. Details of excluded results are presented in the relevant HVO Monthly Environmental Monitoring Report.

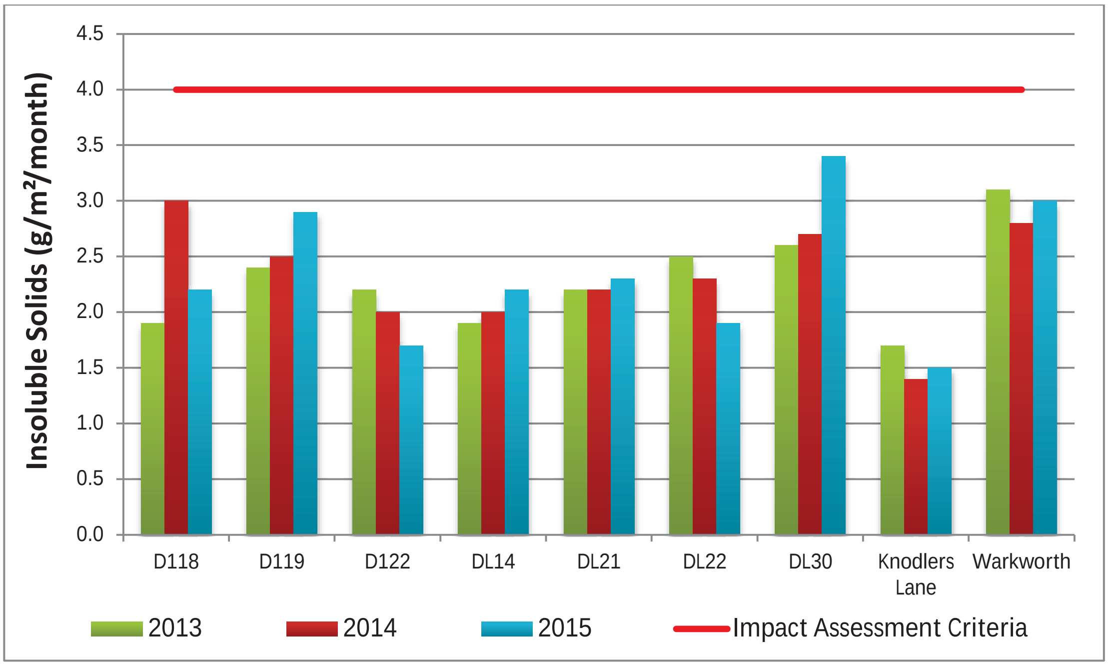


Figure 14: Annual average insoluble matter deposition rates 2013-2015

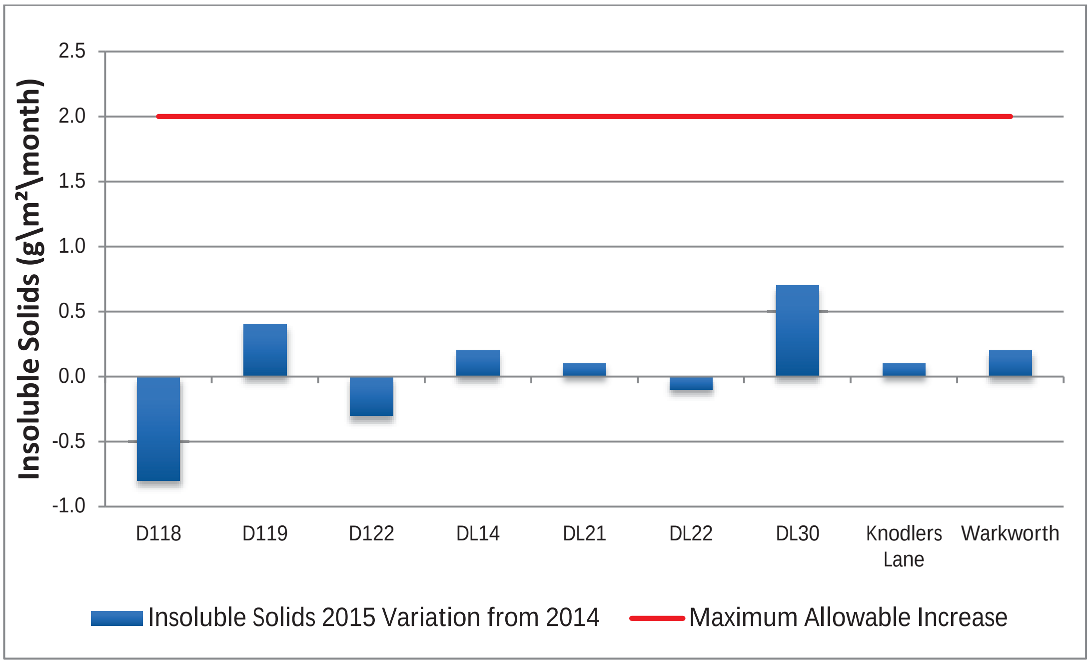


Figure 15: Annual average total insoluble solids variation, 2015 from 2014

6.4.2.5 Total Suspended Particulates (TSP)

Total Suspended Particulates (TSP) are measured at five locations on privately owned land in accordance with AS3580.9.3 (2003). Annual average TSP concentrations recorded in 2015 compared with the long term impact assessment criterion and previous years' data, are shown in Figure 16. During 2015 all annual average results were compliant with the impact assessment and land acquisition criteria.

The annual average TSP concentrations recorded in 2015 are generally consistent with those during previous years with the exception of Kilburnie South and Long Point which recorded increases on the 2014 TSP Annual Average of 2.5 $\mu g/m^3$ and 6.2 $\mu g/m^3$ respectively.

The annual average result recorded at Kilburnie South is similar to the result recorded in 2012. It is noted that the annual average PM_{10} recorded at this location displayed the inverse trend (a reduction of 2.3$\mu g/m^3$). Further, it is generally recognised that a PM_{10}: TSP relationship of approximately 40% should be expected in most monitoring contexts. The 2015 results at Kilburnie South return a relationship of 27%. This low result could be explained in two ways: 1. Monitor error or malfunction, or 2. Influence of localised sources such as livestock or vehicle movements. Regular calibration and inspection of the units has not identified any issues that would support (1) above, however livestock have been noted in the vicinity of the monitor, and could explain the increase in TSP recorded in 2015.

The paucity of data from the Long Point TSP monitor makes meaningful comparison difficult (commissioned in 2014). As the monitor is located further away from HVO than other monitors (Maison Dieu, Knodlers Lane and Warkworth) it is unlikely that the measured increases are a direct result of HVO activity. It is noted that the PM_{10} data recorded at the Long Point monitoring location did not follow the same trend (reduction of 0.4$\mu g/m^3$).

TSP concentrations at Knodlers Lane reduced by 9.9$\mu g/m^3$, when compared to results recorded in 2014, with a long term average of 56.1$\mu g/m^3$ at this location; Maison Dieu and Warkworth recorded similar trends.

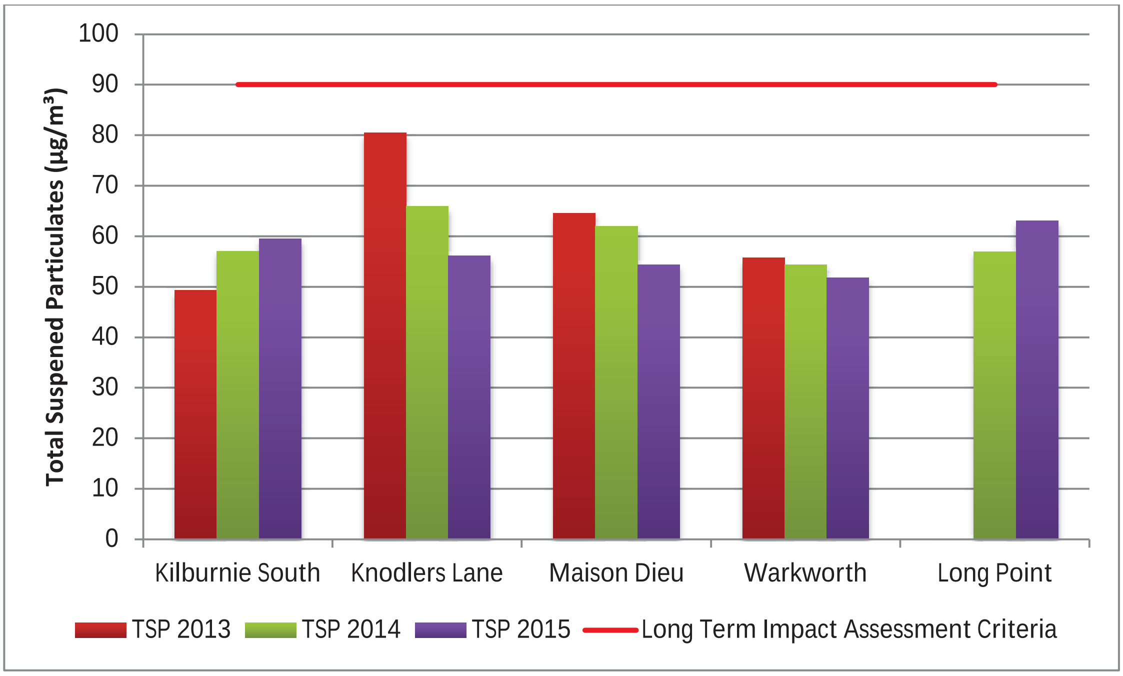


Figure 16: Annual average TSP concentrations 2013 to 2015

Note: the Long Point monitor was installed in late 2013.

6.4.2.6 Particulate Matter <10µm (PM_{10})

Compliance assessment for Particulate Matter <10µm (PM_{10}) is measured at five locations on privately owned land in accordance with AS3580.9.6 (2003). During 2015 all short term and annual average results were compliant with the impact assessment and land acquisition criteria.

Routine monitoring of PM_{10} at the Hunter Valley Glider Club (HVGC) commenced on 24th November 2014 in accordance with the HVGC Amenity Management Plan, and following consultation with the HVGC.

6.4.2.7 Short term PM_{10} impact assessment criteria

Monitoring results for 2015 PM_{10} (24 hour) collected through the High Volume Air Sampler monitoring regime compared against the short term impact assessment criteria is shown in Figure 17. All 24hr average results recorded by HVO's surrounding network of TEOM monitors are presented on a quarterly basis in Figure 18 to Figure 21.

On 13th November a localised storm caused damage to the Maison Dieu monitoring compound, shifting the hut off its footings. The TEOM was damaged and consequently was offline between the 13th and 20th November.

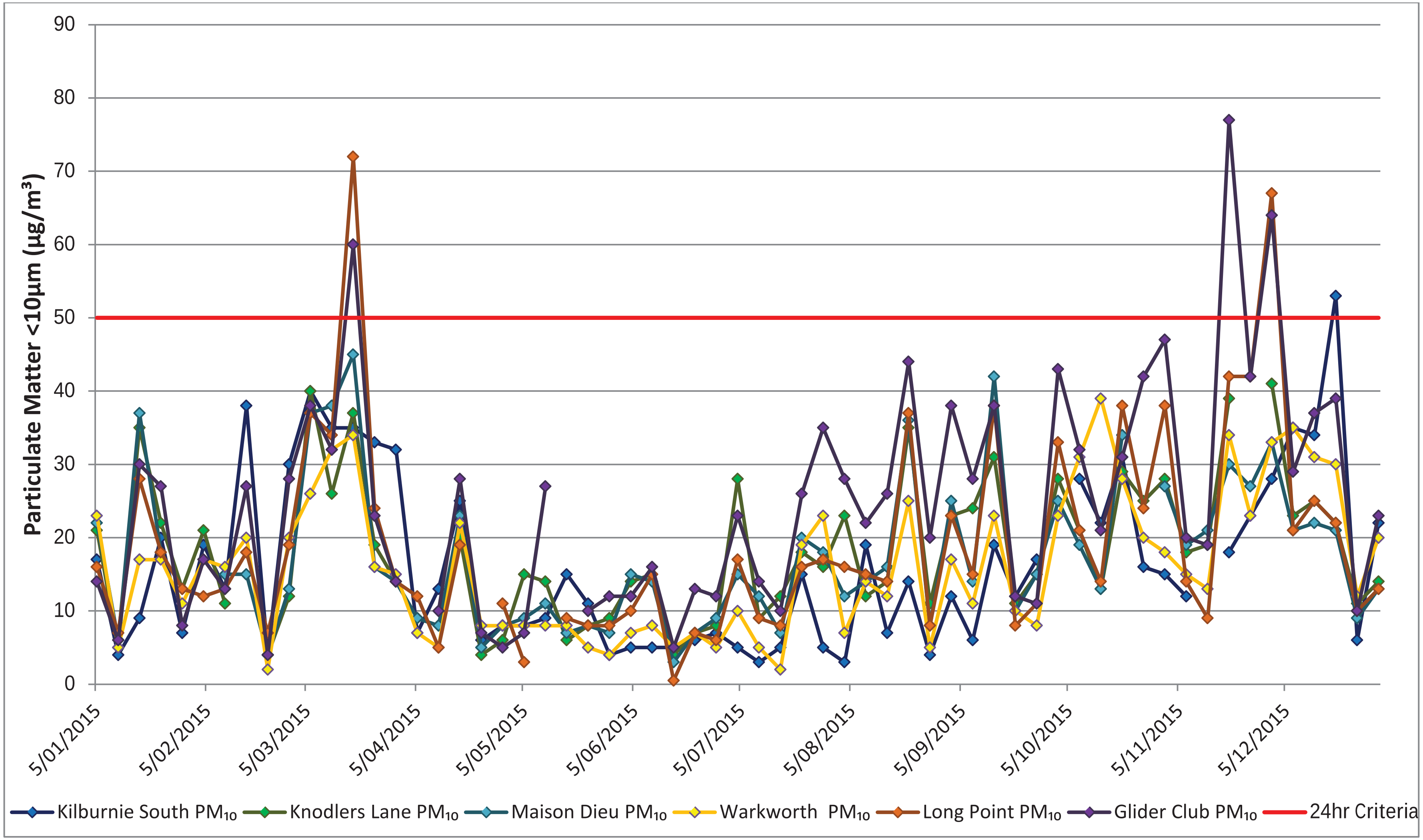


Figure 17: 2015 PM_{10} Results (measured through (HVAS) network)

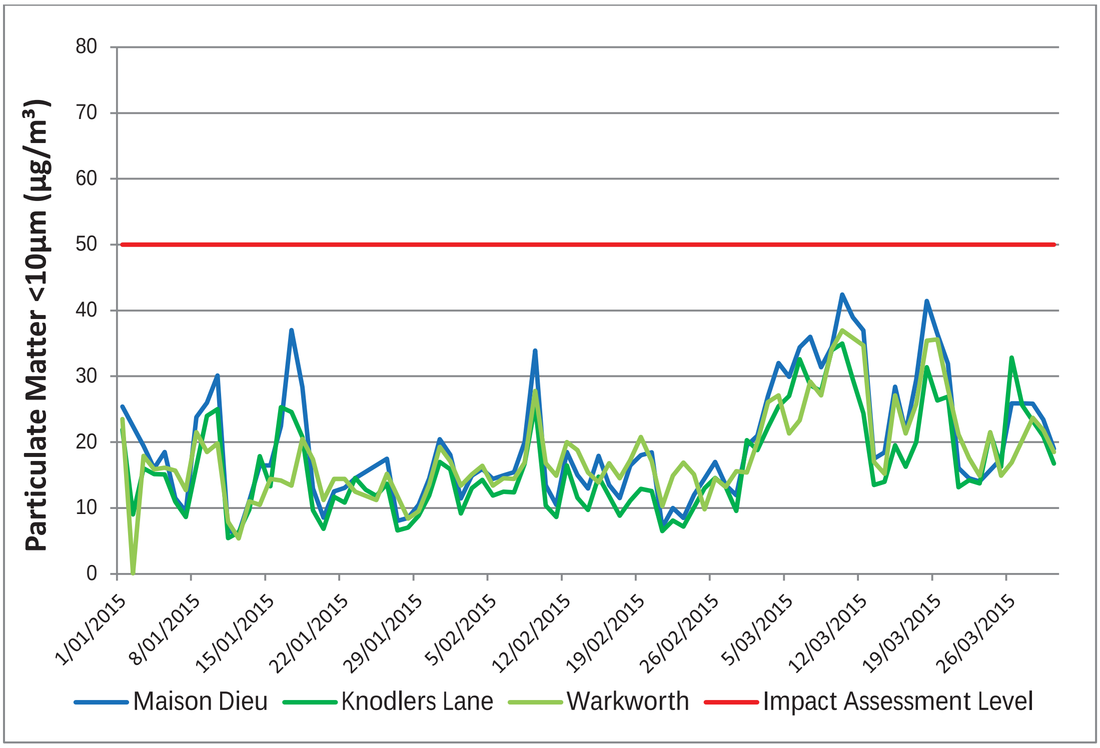


Figure 18: 24hr average PM_{10} (real time monitors) - Quarter One 2015

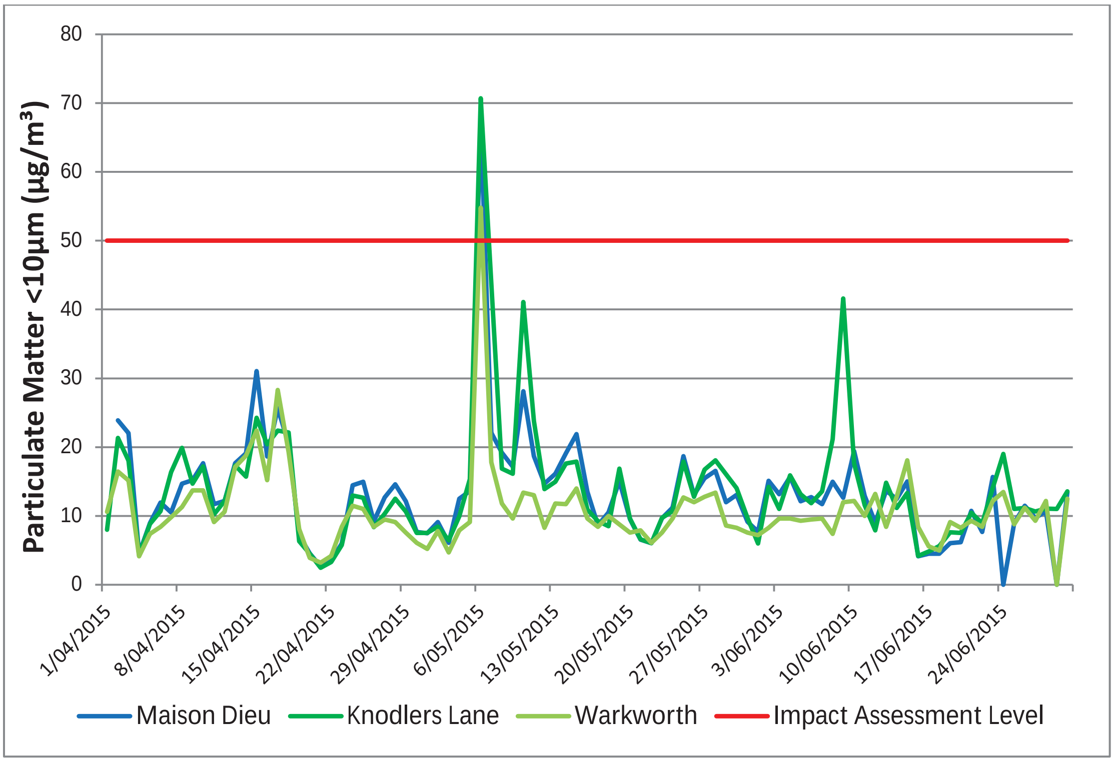


Figure 19: 24hr average PM_{10} (real time monitors) - Quarter Two 2015

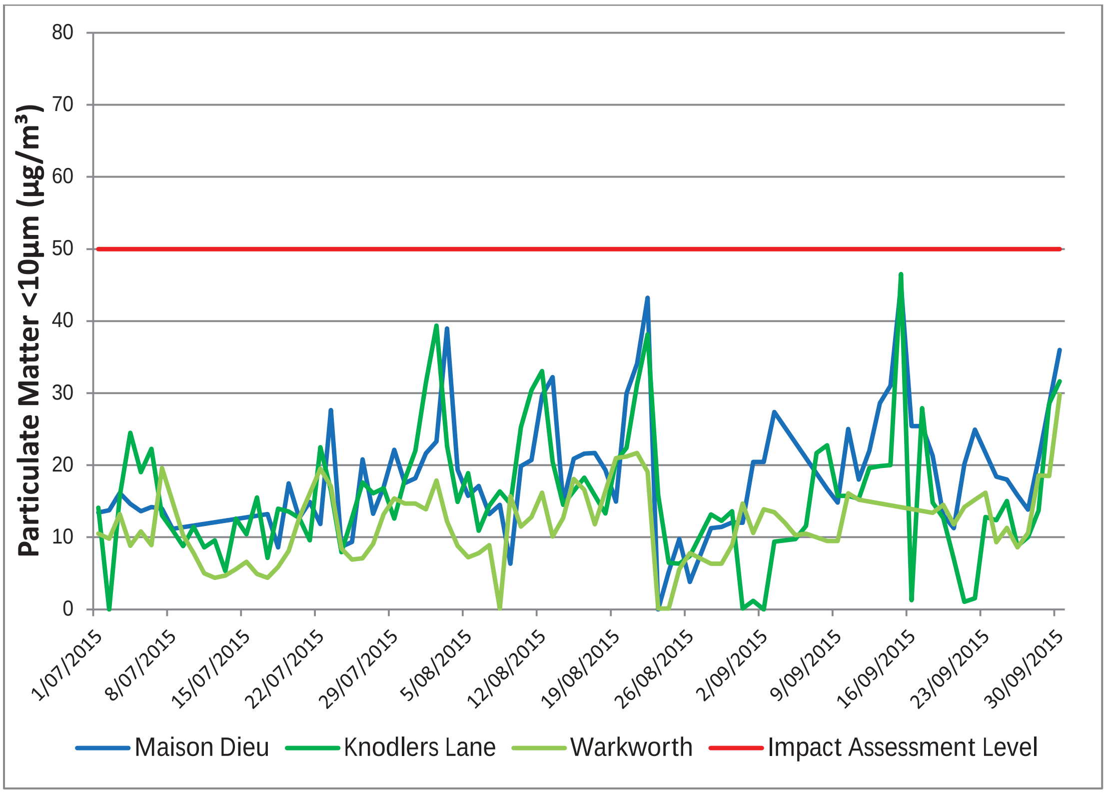


Figure 20: 24hr average PM_{10} (real time monitors) - Quarter Three 2015

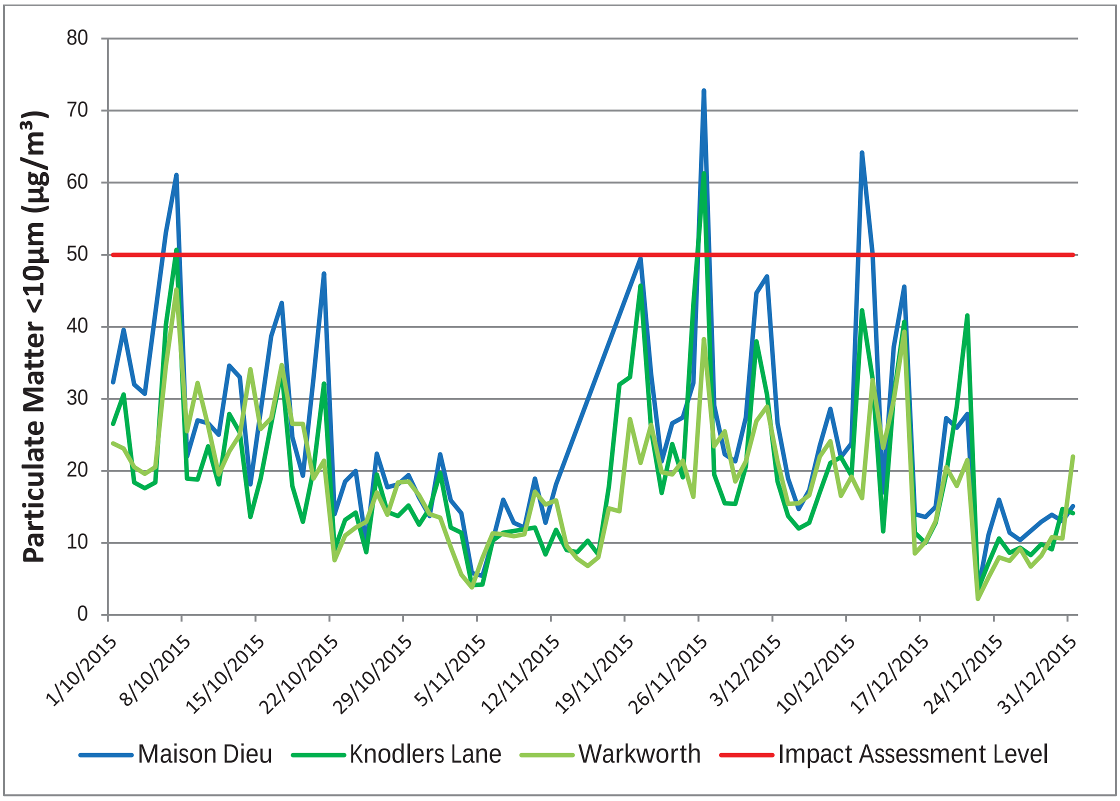


Figure 21: 24hr average PM_{10} (real time monitors) - Quarter Four 2015

Six High Volume Air Sampler measurements and nine TEOM PM_{10} measurements exceeded the 24hr impact assessment criteria during the reporting period. Each was investigated to determine the level of contribution from HVO activities to the elevated result (Table 23). For each measurement, it was determined that HVO was not the predominant contributor hence compliant with the impact assessment criteria. DP&E were notified at the time of each exceedance, with follow-up notifications to confirm the outcome of the investigation undertaken. No further requests were received from the Department in relation to these events.

Table 23: 24 hour PM_{10} investigations – 2015

Date	Site	24hr result ($\mu g/m^3$)	Estimated contribution from HVO ($\mu g/m^3$)	Discussion
18/03/2015	HVGC PM_{10} (HVAS)	60	<30	The HVGC Secretary has confirmed that the Club was not in use on the 18th March, thus HVO South Air Quality criteria are not applicable on this day.
	Long Point PM_{10} (HVAS)	72	6.5	A consultant was engaged to investigate PM_{10} exceedances. Investigation concluded that the result is out of step with nearby monitors, and likely due to localised sources unrelated to HVO. Maximum potential HVO contribution to the result is estimated at approximately 6.5$\mu g/m^3$ (9% of the measured result).
06/05/2015	Maison Dieu PM_{10} (TEOM)	67.5	14	Elevated results are a consequence of a large dust storm which originated from the Victorian Mallee and South-West NSW, resulting in exceedances at 38 of 43 EPA PM_{10} monitoring locations across NSW.
06/05/2015	Knodlers Lane PM_{10} (TEOM)	70.7	10	
06/05/2015	Warkworth PM_{10} (TEOM)	54.8	15.2	
06/10/2015	Maison Dieu PM_{10} (TEOM)	55.1	32.3	An internal investigation determined that the maximum potential contribution to be less than the measured result. As the calculated contribution was less than 50$\mu g/m^3$ or less than 75% of the measured result HVO operations are not considered to be a significant contributor to the results described in the HVO Air Quality and Greenhouse Gas Management Plan.
07/10/2015	Maison Dieu PM_{10} (TEOM)	50.7	15.9	
07/10/2015	Knodlers Lane PM_{10} (TEOM)	61.1	26.7	
19/11/2015	HVGC PM_{10} (HVAS)	77	56.5	The HVGC Secretary has confirmed that the Club was not in use on the 25th November, thus HVO South Air Quality criteria are not applicable on this day.

26/11/2015	Maison Dieu PM_{10} (TEOM)	77.1	-	This was an extreme weather day with high regional dust shed and high winds. HVO Operations ceased between 11:05am to 9:00pm. NSW Department of Planning and Environment were notified of measured results and actions taken on the day to manage air quality, and did not request any further investigation be undertaken.
26/11/2015	Knodlers Lane PM_{10} (TEOM)	61.5	-	
01/12/2015	HVGC PM_{10} (HVAS)	64	33	The HVGC Secretary has confirmed that the Club was not in use on the 25th November, thus HVO South Air Quality criteria are not applicable on this day.
01/12/2015	Long Point PM_{10} (HVAS)	67	36	An internal investigation determined that the maximum potential contribution to be less than the measured result. As the calculated contribution was less than 50µg/m³ or less than 75% of the measured result HVO operations are not considered to be a significant contributor to the results described in the HVO Air Quality and Greenhouse Gas Management Plan.
11/12/2015	Maison Dieu PM_{10} (TEOM)	52.6	30.1	
19/12/2015	Kilburnie South PM_{10} (HVAS)	53	12	An internal investigation has determined that it is unlikely that HVO has contributed to the measured result. Based on results from downstream and regional PM_{10} monitors on the day it is likely that a local source was contributing to the measured result.

6.4.2.8 Long term PM_{10} impact assessment criteria

Annual average PM_{10} concentrations recorded at the six monitoring locations in 2015, compared with the long term PM_{10} impact assessment criterion and previous years' data, are shown on Figure 22. During 2015 all annual average PM_{10} concentrations recorded on privately owned land were compliant with the assessment criterion, and are consistent with annual average results measured in recent years.

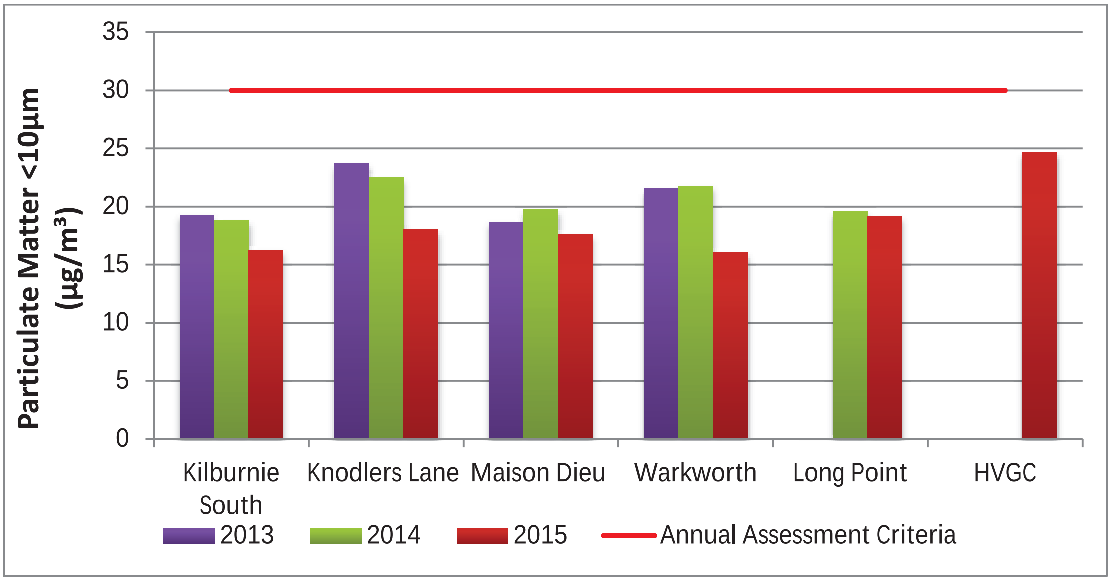


Figure 22: Annual average HVAS PM_{10} results 2013 to 2015

6.4.3 Comparison of 2015 Air Quality data against EA predictions

Table 24 to Table 26 show a comparison between 2015 air quality data and the predictions made in the HVO South Environmental Assessment 2008 (EA). Comparisons have been made against the predictions listed in the EA for the nearest private residence to each monitoring location.

Annual average PM_{10} measurements in 2015 are either below or consistent with predicted levels for all monitoring locations. Comparison of 2015 maximum 24hr PM_{10} values against the predicted maximum values returned results either below or consistent with the predicted worst case results for the Maison Dieu and Knodlers Lane, Long Point, Warkworth and HVGC monitoring locations. It should be noted that the worst case 24hr PM_{10} predictions refer to maximum concentrations generated by HVO South alone, while the measurements provided in Table 24 include PM_{10} concentrations due to HVO South and all other sources. Refer to Table 23 for estimates of HVO contribution to measured exceedances of 24hr PM_{10} criteria during 2015.

TSP Annual Averages exceeded modelled predictions in 2015 at all monitoring locations with the exception of Knodlers Lane and Warkworth. Section 9.1 of the HVO South Coal Project Air Quality Assessment (Holmes Air Sciences), notes that TSP concentrations are significantly under predicted. This is due to the fact that local dust sources (such as dust from local roads, stock movements and agricultural activity) have not been considered in the model.

Table 27 and Table 28 detail comparisons between 2015 air quality monitoring results and the modelled predictions from the 2010 HVO North Carrington West Wing Air Quality Impact Assessment. Predictions have been sourced from modelled scenarios of Year One of the Carrington West Wing development. It should be noted that while Approval has been granted for the commencement of that project, works have not yet commenced.

Comparison of measured PM_{10} with modelled predictions demonstrates close alignment for all monitoring locations; however TSP measurements have exceeded predictions in a similar fashion to the comparison undertaken for HVO South. Given that the TSP fraction settles out of suspension faster than PM_{10} (and thus much closer to the operation), it is not reasonable to suggest that nearby private residences are being impacted by mine-generated TSP to a greater degree than by PM_{10}, on the basis of measured data exceeding the predictions. Rather, the data suggests the assumptions in the model relating to extraneous dust sources are under predicting total TSP levels which are experienced at receptors.

Regardless of correlation with the modelled predictions, TSP levels measured remain well below the impact assessment criteria of 90μg/m³ and have been relatively stable in recent years (Figure 16).

Table 24: 2015 PM_{10} annual average results compared against cumulative predictions for 2014 and 2019 (HVO South Environmental Assessment)

Site (EA receptor)	Short Term (24hr) criteria			Long Term (annual average) criteria		
	Predicted maximum 24hr PM_{10} due to HVO South alone (μg/m³)		2015 maximum 24hr PM_{10} result (μg/m³)	Predicted PM_{10} annual averages (μg/m³)		2015 PM_{10} annual average (μg/m³)
	2014	2019		2014	2019	
Maison Dieu (47)	81.9	49.4	45	19.7	17.2	17.6
Warkworth (43)	50.8	29	39	32.9	24.8	16.1
Kilburnie South (4)	40.9	16.6	53	16.7	13.7	16.3
Knodlers Lane (32)	138	26.1	41	33.1	23	18.1
Long Point*	50-90	30-50	72	10-30	10-30	19.2
HVGC**	90-200	50-90	77	10-30	10-30	24.7

**No receptor identified in EIS (2008). Estimate has been made based on contours presented in the EIS.*

***No receptor identified in EIS (2008). The HVGC has entered into an Amenity Management Plan with Hunter Valley Operations.*

Table 25: HVO South Project Environmental Assessment cumulative predictions for 2014 and 2019 against 2015 TSP annual averages

Site (EA receptor)	Long Term (annual average) TSP Criteria		
	2014 prediction (μg/m³)	2019 prediction (μg/m³)	2015 annual average (μg/m³)
Maison Dieu (47)	44.0	22.2	54.4
Warkworth (43)	60.1	29.8	51.8
Kilburnie South (4)	40.4	18.7	59.5
Knodlers Lane (32)	61.0	28.0	56.1
Long Point*	0-50	30-50	63.1

**No receptor identified in EIS (2008). Estimate has been made based on contours presented in the EIS.*

Table 26: HVO South Environmental Assessment cumulative predictions for 2014 and 2019 against 2015 Depositional Dust annual averages

Site (representative receptor ID)	Units (Insoluble Solids)	Assessment Criteria	2014 Depositional Dust – EA Predictions Annual Averages	2019 Depositional Dust – EA Predictions Annual Averages	2015 Depositional Dust – Actual Annual Average
D118 (Kilburnie Sth) (4)	g/m^2/month	4	0.8	1.1	2.2
D119 (Jerry's Plains) (13)	g/m^2/month	4	0.7	1.1	2.9
DL14 (Maison Dieu) (47)	g/m^2/month	4	1.0	1.3	2.2
DL21 (32)	g/m^2/month	4	2.0	1.9	2.3
DL22 (16)	g/m^2/month	4	2.2	1.9	1.9
Knodlers Lane (24/34)	g/m^2/month	4	1.5	1.6	1.5
Warkworth (43)	g/m^2/month	4	1.7	1.6	3.0

Table 27: 2015 PM_{10} annual average results compared against cumulative predictions for Year One (CWW) - HVO North Environmental Assessment

Site (EA receptor)	Long Term (annual average) criteria	
	Predicted PM_{10} annual average ($\mu g/m^3$)	2015 PM_{10} annual average ($\mu g/m^3$)
Maison Dieu (6)	19.1	17.6
Warkworth (39)	20.8	16.1
Kilburnie South (4)	19.7	16.3

*no modelled predictions for the Long Point area

Table 28: 2015 TSP Annual Average results compared against cumulative predictions for Year One (CWW) - HVO North Environmental Assessment

Site (EA receptor)	Long Term (annual average) criteria	
	Predicted TSP annual average ($\mu g/m^3$)	2015 TSP annual average ($\mu g/m^3$)
Maison Dieu (6)	44.7	54.4
Warkworth (39)	46.6	51.8
Kilburnie South (4)	45.2	59.5

*no modelled predictions for the Long Point area

6.4.4 Air Quality Non-compliances during the Reporting Period

HVO complied with all air quality criteria during 2015.

6.5 Heritage Summary

6.5.1 Management and community consultation

Aboriginal cultural heritage is managed under the provisions of separate Aboriginal Cultural Heritage Management Plans (ACHMP) approved for these development consents. At HVO North, where mining or associated development activities may impact Aboriginal cultural heritage sites an Aboriginal Heritage Impact Permit (AHIP) must also be sought from the OEH under Part 6 of the *National Parks and Wildlife Act 1974* (NPW Act) on the basis of the management requirements established through the ACHMP process. The HVO South ACHMP area was approved as a State Significant Development which excludes the requirement for obtaining AHIPs prior to implementing cultural heritage management measures authorised under the provisions of the ACHMP.

The Coal & Allied Upper Hunter Valley Aboriginal Cultural Heritage Working Group (CHWG) is the primary forum for Aboriginal community consultation on matters pertaining to cultural heritage. The CHWG is comprised of representatives from Rio Tinto Coal Australia and Registered Aboriginal Parties (RAPs) from Upper Hunter Valley Aboriginal native title and community groups, corporations and individuals. The CHWG met and discussed cultural heritage management matters associated with HVO on four occasions during 2015: on 4th June, 3rd September, 19th November and 18th December.

Aboriginal cultural heritage at HVO is managed in consultation with the RAPs through the CHWG in accordance with the ACHMPs, development consent conditions, Rio Tinto Cultural Heritage Management Standard and the RTCA Cultural Heritage Management System (CHMS) Work Procedures. The RTCA CHMS combines several elements to protect, manage and mitigate cultural heritage at HVO, including:

- Ongoing consultation and involvement of the local Aboriginal community in all matters pertaining to Aboriginal cultural heritage management;
- Compliance with existing ACHMP's and Development Consent conditions;
- A cultural heritage Geographic Information System (GIS) and Cultural Heritage Zone Plan (CHZP) incorporating cultural heritage spatial and aspatial data (site location, description, assessments, date recorded, associated reports, management provisions and various other details to assist with the management of sites);
- A Ground Disturbance Permit (GDP) system for the assessment and approval of ground disturbing activities to ensure these activities do not disturb cultural heritage places;
- Limit of Disturbance Boundary (LODB) procedures to demarcate approved disturbance areas and delineate areas not to be disturbed;
- Ongoing cultural heritage site inspections, monitoring and auditing along with regular compliance inspections of development works;
- Protective management measures such as fencing/barricading sites to avoid disturbance, protective buffer zones, cultural heritage off-set areas; and
- Communicating cultural heritage issues and site awareness to personnel via internal electronic and face to face processes.

In consultation with the CHWG and OEH, Coal & Allied established the Hunter Valley Services Cultural Heritage Storage Facility (CHSF) at Hunter Valley Services. The CHSF is a combined office and storage shed, with an adjacent sea container, fitted out to allow safe and secure storage of cultural materials such as stone artefacts and scarred trees. It is a central repository for all materials collected during community collection and salvage activities on all Coal & Allied mines and lands in the Hunter Valley including HVO.

6.5.2 Aboriginal Archaeological and Cultural Heritage Investigations

Under the provisions of both the HVO South and HVO North ACHMPs, an ACHMP Compliance Inspection was conducted within both ACHMP areas during 2015. The purpose of the ACHMP compliance inspection is to provide the RAPs with:

- the opportunity to visit mine operations and mine areas to inspect operational compliance with ACHMP provisions and GDP procedures;
- to inspect and monitor the condition and management of sites; and
- to review the effectiveness and performance of the ACHMP provisions in the management of cultural heritage at the mine.

This compliance inspection was conducted by RAPs nominated by the CHWG and assisted by RTCA/Coal & Allied personnel. The 2015 HVO South and North compliance inspection was conducted over three days in March, with 115 Aboriginal cultural heritage sites inspected. The inspection found that all sites have been managed in conformance with the ACHMP requirements.

In addition to the ACHMP compliance inspections a scarred tree verification and condition inspection program was also undertaken during July 2015. This inspection was conducted within the HVO South ACHMP area in accordance with the relevant provisions of the ACHMP. This program involved the verification inspection of eight potential culturally scarred trees and a condition inspection of a further six previously verified culturally scarred trees. The inspection found that all the scarred trees have been managed in conformance with the ACHMP requirements.

The results of the compliance and verification inspections were reported to the RAPs at CHWG meetings held on 4th June and 3rd September respectively.

In November and December 2015, a ten day fieldwork program was conducted at HVO North to inform the development of a proposed AHIP application for the Mitchell Pit Area. This work program consisted of a five day test pitting program of previously identified potential archaeological deposits plus a five day pedestrian field assessment aimed at confirming that the existing Aboriginal cultural heritage dataset is still suitably current and accurate and has not been substantially affected by various taphonomic processes that could alter the form and distribution of this record. These works were conducted in accordance both with the HVO North ACHMP and the OEH Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales (2010). The fieldwork results will inform the drafting of Aboriginal Cultural Heritage Assessment Report for the AHIP application to be submitted during 2016.

6.5.3 Audits and Incidents

During the reporting period there were 57 GDPs assessed for cultural heritage management considerations with regard to mining development disturbance activities at HVO. In all cases the ground disturbance works were conducted on an Aboriginal cultural heritage sites avoidance basis so that no extant sites were impacted by these activities. There were no incidents nor any unauthorised disturbance caused to cultural heritage sites at HVO during 2015.

Coal & Allied has continued a comprehensive desk top review and ground-truthing audit of all Aboriginal cultural heritage sites located on Coal & Allied lands, including HVO leases. The purpose of the process is to confirm or revise and update the Aboriginal sites data held in the OEH Aboriginal Heritage Information Management System (AHIMS) sites database. Coal & Allied and OEH agree that there are inconsistencies between the AHIMS data and ground truthed data verified by Coal & Allied. These inconsistencies generally relate to errors in historical site location recording conducted over the last 20 years resulting in incorrect information being recorded in the AHIMS database.

6.5.4 Historic Heritage - Management and community consultation

The Stage One Chain of Ponds Inn Stabilisation Program commenced in November 2014 and was completed in May 2015. These works are being conducted under an approval granted by the Heritage Council of NSW & pursuant to Section 63 of the *NSW Heritage Act 1977*. These initial works aim to provide immediate structural integrity to the buildings to ensure their continued stability and safety in the medium term.

Temporary timber propping and support structures were installed in the main Inn building to provide additional structural support during periods of increased vibrations associated with blasting activities at the adjacent Liddell Coal Operations open cut mine (LCO). These measures were implemented in conformance with the Chain of Ponds Inn Conservation Management Plan and the LCO Blast Management Plan. A program of ongoing blast vibration monitoring and targeted visual inspections of the Chain of Ponds buildings was conducted throughout 2015.

In 2012 Coal & Allied established the Community Heritage Advisory Group (CHAG) as a community consultation forum for all matters pertaining to management of historic (non-Indigenous) heritage located on Coal & Allied lands. The CHAG is comprised of community representatives with particular knowledge and interests in historic heritage of the region such as historical groups, individuals and local government. Coal & Allied provided the CHAG with an annual Historic Heritage Management newsletter, also made available to the general community, which included information on the Chain of Ponds Inn stabilisation work and historic archaeological investigations associated with HVO.

6.6 Greenhouse Gas and Energy Management

During 2015, HVO continued to comply with Australian Government legislation for Greenhouse reporting. Under NGER, Rio Tinto is required to report its annual greenhouse gas emissions, energy use and energy production. Results of Rio Tinto's greenhouse gas and energy information are publicly available online at http://www.cleanenergyregulator.gov.au/NGER/Published-information/Reported-greenhouse-and-energy-information-by-year/greenhouse-and-energy-information-2014-15?Paged=TRUE&p_ID=704&View=%7bA647DA98-99D0-4F15-970F-89B3C1713526%7d&PageFirstRow=301

RTCA continues to invest in research and development initiatives to find ways to reduce greenhouse gas emissions throughout the coal chain, with focus on;

- Research to identify new technologies;
- Technology upgrades to improve the way coal is burned; and
- Supporting a policy environment to enable the deployment of low emissions coal technologies.

A summary of greenhouse gas emissions for HVO including fugitive coal seam gas emissions and land management emissions in comparison to 2014 values is displayed in Table 29 below.

Table 29: Total Greenhouse Gas Emissions

Hunter Valley Operations Greenhouse Gas Emissions	2014	2015
Electricity (tCO_2-e)	125,541	119,220
Diesel and other fuels (tCO_2-e)	322,792	332,508
Coal Seam Gas (tCO_2-e)	130,882	115,012*
Other Process Emissions (tCO_2-e)	78	88
Land Management (tCO_2-e)	2,384	7,050
Total Site (tCO_2-e)	581,675	573,877

* Fugitive (Coal Seam Gas) emissions may be updated after the reporting period on occasion following revision to emission factors.

6.7 Waste and Hazard Management

6.7.1 Management

Current licenses exist for the storage of dangerous goods and explosive materials at HVO. These are listed in Table 5.

Inventories of hazardous materials and Safety Data Sheets (SDS) are available through the Occupational Health and Safety department and the ChemAlert system. HVO manages hazardous materials through the ChemAlert system whereby all chemicals used on site are registered in a central database. This database contains all information contained in the SDS and can be accessed at any computer terminal within the operation to provide guidance on storage, use and disposal.

Oil water separators on site are managed with existing infrastructure, plus additional management as required. This can include removal of product using a vacuum pump, or deployment of absorbent booms to collect any free product. The wash bay at the North and South workshop and truck wash was managed in this manner in 2015 to supplement the oil water separator.

6.7.2 Waste and Hazard Management Performance

6.7.2.1 Non-Hazardous Wastes

The management of waste generated on the site is undertaken in accordance with Coal & Allied's Total Waste Management System, local ordinances and within existing regulatory guidelines. Waste rubbish not suitable for recycling is disposed of at the Singleton Council's landfill. HVO only uses waste management firms licensed by the NSW EPA.

All wastes leaving the site are tracked and recorded. Regulated wastes are tracked and reported in accordance with regulatory requirements. Figure 23 and Figure 24 depict the waste statistics at HVO. This information is used by HVO personnel to identify areas of improvements and track performance against targets.

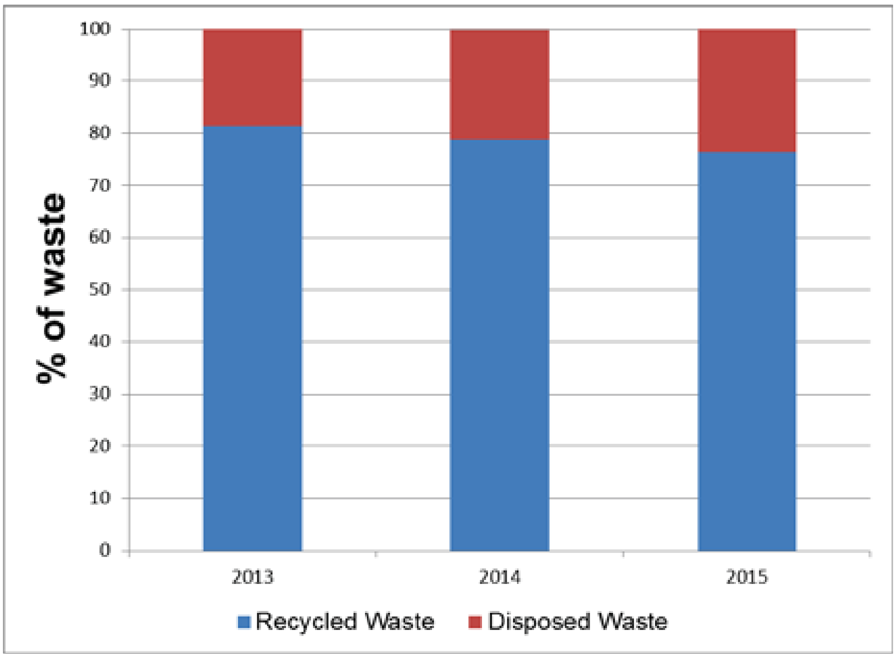


Figure 23: HVO waste streams trend 2013- 2015

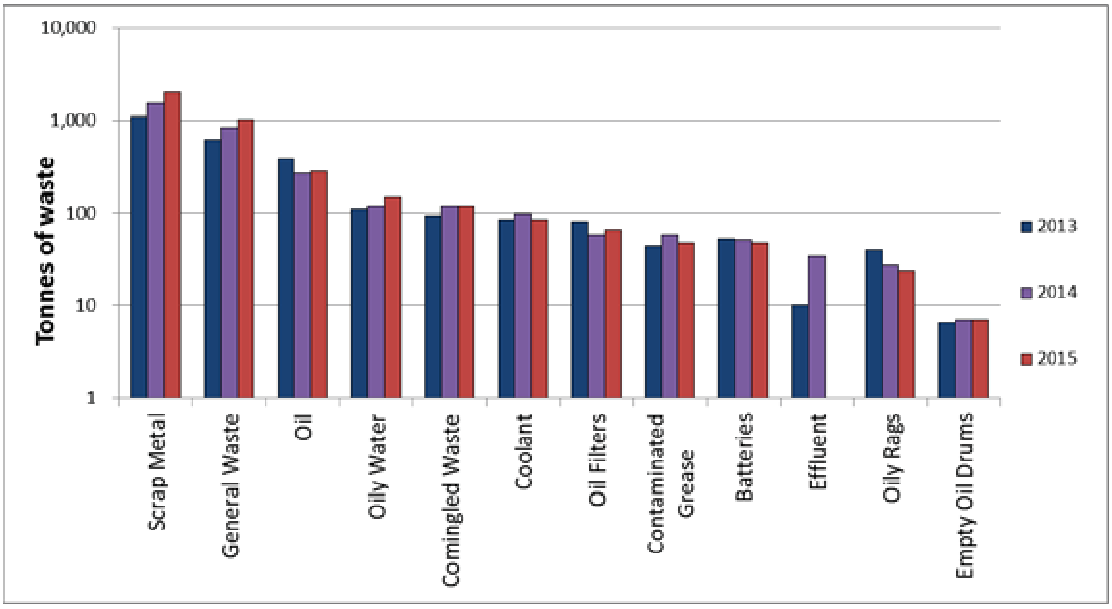


Figure 24: Waste disposed off-site from HVO activities from 2013 to 2015

6.7.2.2 Recycling

HVO has continued to have a focus on training and reinforcing the principles of a good waste management across the site including recycling. In 2015 just over 23.5 per cent of non-mineral waste material generated at HVO was disposed to licensed offsite landfill facilities. A recycling result of 76.5 per cent was achieved in 2015, as shown in Figure 23. HVO will explore opportunities to continue to improve recycling rates in 2016.

6.7.2.3 Sewage Treatment/Disposal

The sewage treatment and disposal facilities at Coal & Allied's operations consist of packaged sewage treatment plants which treat, disinfect and re-use the treated effluent on-site. The remaining effluent from some septic systems that can't be treated on site is sent to approved facilities for disposal.

HVO currently has 19 on-site sewerage management systems, of which six are located in-pit, a further six are associated with CHPP's and the remaining seven systems are located at infrastructure associated with mining and administration. Two of the 19 systems are large scale systems that service up to four sub-systems.

6.7.2.4 Hydrocarbons

In 2015 HVO used 324kL of waste oil in blasting as a replacement for diesel. Another 837kL was taken offsite to be refined into a base oil for reuse in new oil products. Other hydrocarbons recycled via a licensed waste hydrocarbon disposal company include approximately 47 tonnes of grease.

6.7.2.5 Fuel Containment

The HVO fuel storage systems are located at several sites across HVO including:

- Hunter Valley Store area at the main workshop facility;
- West Pit Workshop service area; and
- Southern Facilities.

HVO also has three in-pit fuel tanker locations. Each of these facilities is bunded to contain the leaks and spills from the fuel being stored. Existing in-pit fuel tankers were replaced with new double skin tanks during 2009 to improve containment of fuel on site. Since 2014, new facilities have been constructed with a synthetic clay liner to reduce potential contamination.

6.7.2.6 Oil and Grease Containment and Disposal

Bulk oil and grease is stored at the Hunter Valley Store. The bulk oils and grease storage facilities are part of the fuel storage facility that complies with Australian Standard 1940.

6.7.2.7 Hydrocarbon Management and Performance

Management of hydrocarbon contaminated soil is ongoing at HVO. The current technique employs the use of bioremediation areas that are maintained and operated in accordance with Coal & Allied procedures.

Contaminated soil is taken to one of the bioremediation areas and placed in cells based on the time of contamination. To maximise air circulation, contaminated soil is spread out in windrows of no more than approximately 300 mm in height and approximately a grader width at the base.

Windrows are oriented north south to achieve maximum exposure to sunlight. The windrows are tined by a grader or equivalent on regular intervals in order to provide aeration for the microbes.

Soil in the treatment area is sampled and tested on a regular basis until total hydrocarbon levels are below relevant government guidelines. Soil meeting these criteria is then removed and disposed of in the spoil dump.

6.7.2.8 Waste and Hazard Management Non-compliances during reporting period

There were no externally reportable incidents related to waste or hazard management during the reporting period.

7 WATER MANAGEMENT

7.1 Water Balance

7.1.1 Water Management

HVO manages surface and ground water according to three main objectives:

- Fresh water usage is minimised;
- Impacts on the environment and HVO neighbours are minimised; and
- Interference to mining production is minimal.

This is achieved by:

- Minimising freshwater use from the Hunter River;
- Preferentially using mine water for coal preparation and dust suppression;
- An emphasis on control of water quality and quantity at the source;
- Segregating waters of different quality where practical;
- Recycling on-site water;
- Ongoing maintenance and review of the system; and
- Disposing of water to the environment in accordance with statutes and regulations.

Plans showing the layout of all water management structures and key pipelines are shown in Figure 25 to Figure 27. The HVO Water Management Plan contains further detail on management practices and is available on Rio Tinto Coal Australia's website.

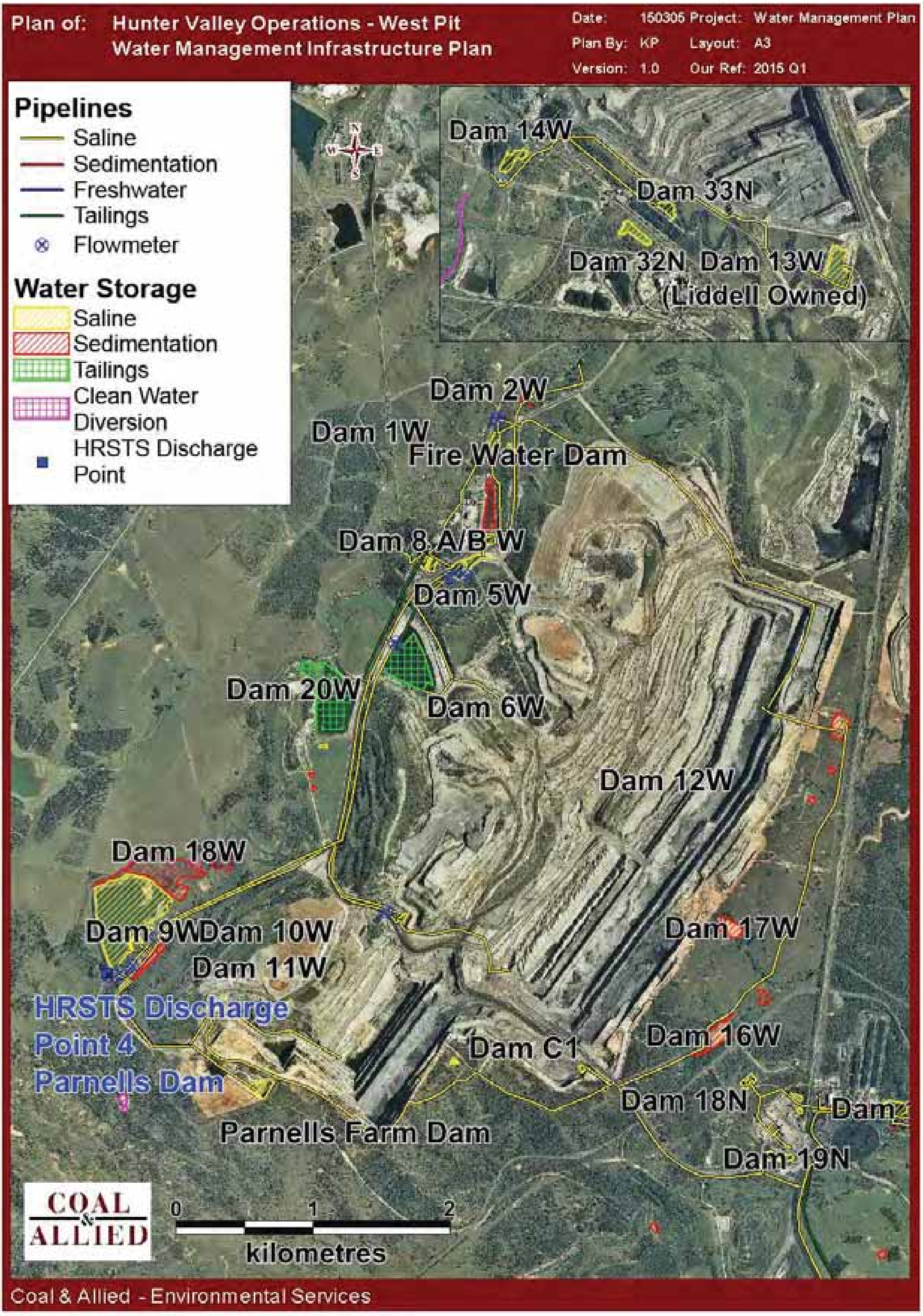


Figure 25: West Pit water management infrastructure

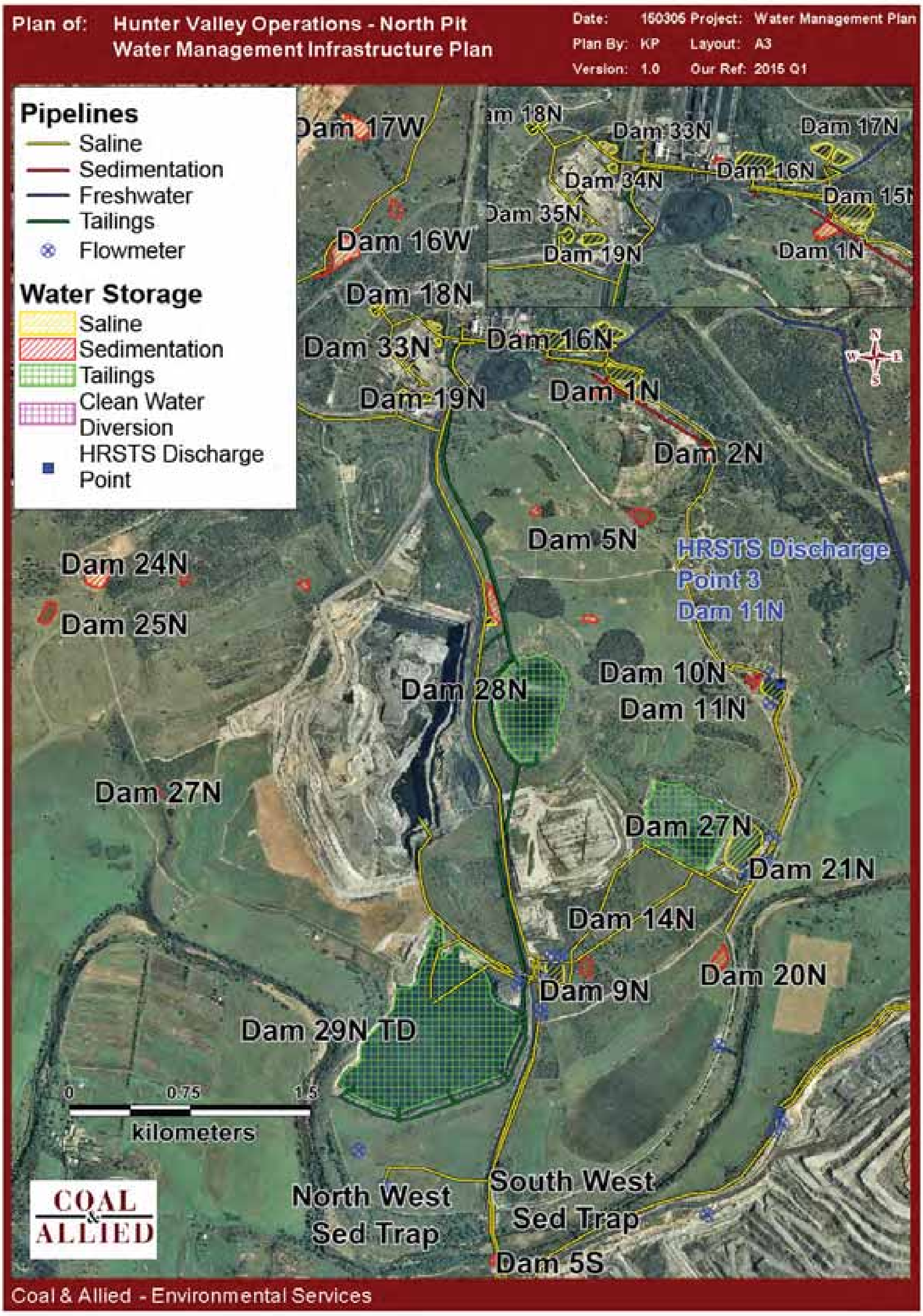


Figure 26: North Pit water management infrastructure

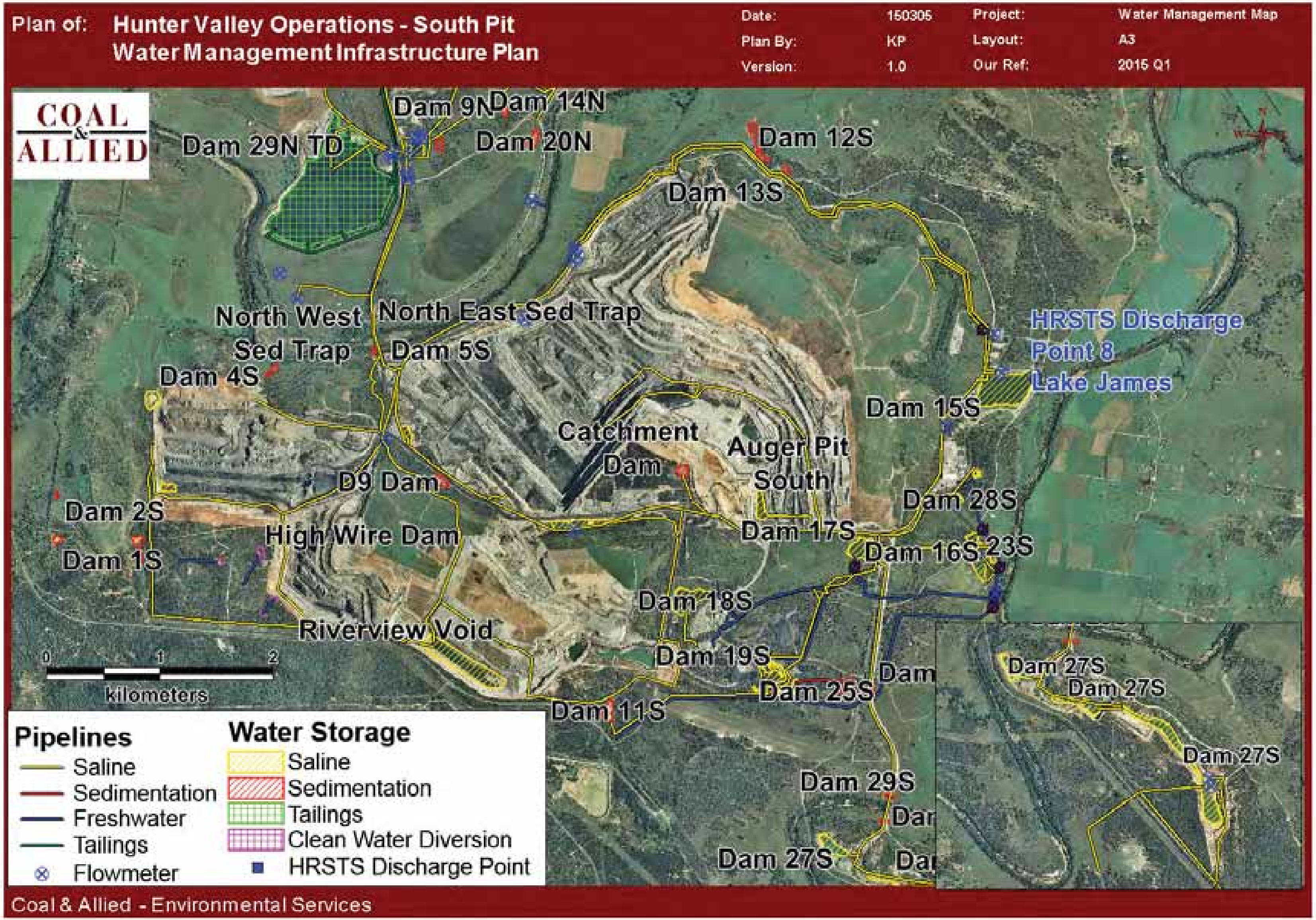


Figure 27: South Pit water management infrastructure

7.1.2 Water Performance

7.1.2.1 Water Balance

The 2015 static water balance for HVO is presented in Table 30 and a simplified schematic of this balance is included as Figure 28. The water balance is for a coal production rate of 17.16 million tonnes per year ROM and 13.01 million tonnes per year of product. Rainfall runoff was a larger contributor to inputs compared to 2014, due to higher rainfall received. Outputs were broadly consistent with the 2014 reporting period. A salt flux schematic is shown in Figure 29.

Water balance results for 2015 were greater than 2014, primarily due to increased rainfall runoff and subsequent evaporation.

Table 30: 2015 HVO Water Balance

Water Stream	Volume (ML)
Inputs	
Fresh Water (potable)	27 (<1%)
Groundwater	968 (9%)
Rainfall Runoff	8,225 (77%)
Recycled to CHPP from Tails & Storage (not included in total)	3,630
Imported (Liddell)	10 (<1%)
Water from ROM Coal	1,469 (14%)
Total Inputs	**10,699**
Outputs	
Dust Suppression	2,638 (27%)
Evaporation - Mine Water & Tailings Dams	2,100 (21%)
Entrained in Process Waste	1,930 (19%)
Discharged (HRSTS)	497 (5%)
Vehicle Wash-down	255 (3%)
Miscellaneous Industrial Use	350 (4%)
Water in Coarse Reject	892 (9%)
Water in Product Coal	1,237 (12%)
Total Outputs	**9,899**
Change in Pit Storage (increase)	**800**

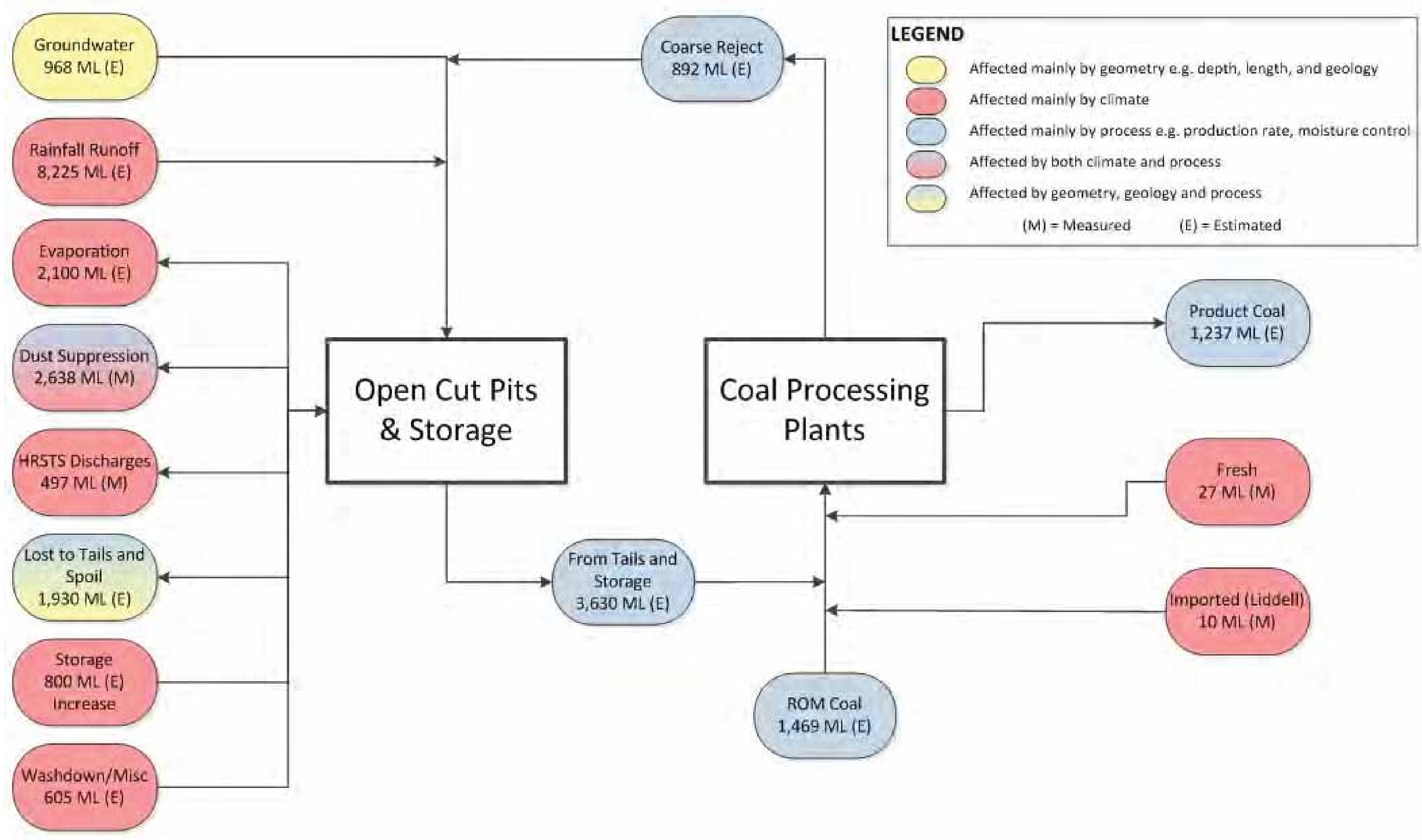


Figure 28: HVO water balance schematic diagram

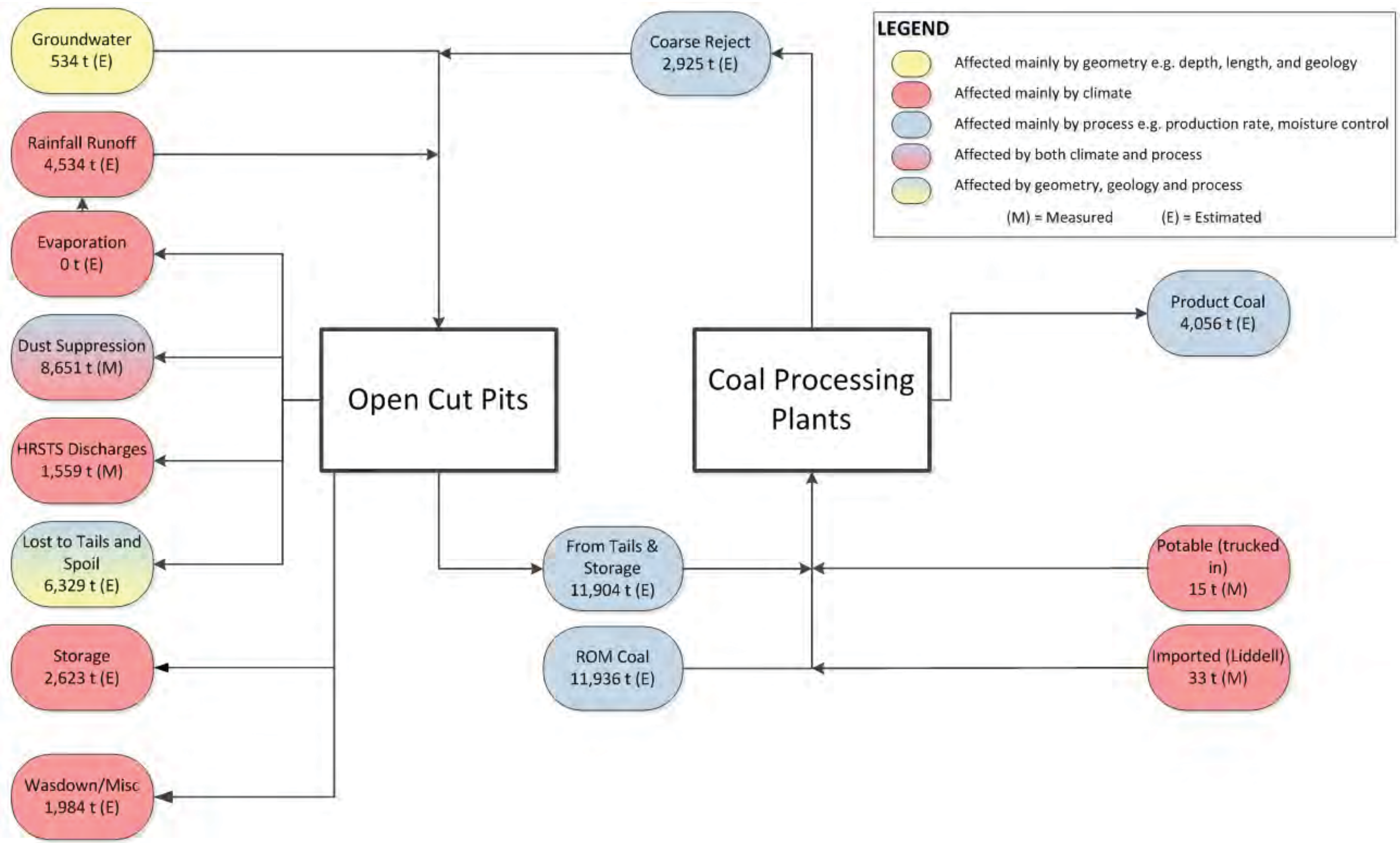


Figure 29: HVO Salt balance schematic diagram

7.1.2.2 Water Inputs

A total of 813.6 mm of rainfall was recorded at HVO in 2015 producing an estimated 8,225 ML of runoff from approximately 6,083 ha of developed, disturbed and mining catchments. Water falling on undisturbed clean water catchments is diverted off site into natural systems where possible. Rainfall runoff was the largest input to the site mine water balance in 2015.

Pit inflows are calculated for HVO North and HVO South on an annual basis; refer to Appendix 2. Figure 30 shows the lands licenced as part of the groundwater licences listed in Table 31. Groundwater intercepted from Hunter River is estimated to have contributed 945 ML to the site during the reporting period. Seepage from the Wollombi Brook into South Lemington is estimated at 3.65 ML/year; a licence application to convert a current licence holding is still to be assessed by DPI Water. No fresh water was pumped from the Hunter River during the reporting period.

Table 31: Water take for the reporting period

Water Licence #	Water Sharing Plan, source and management zone	Entitlement Units (ML/a)	Passive take/inflows (ML/a)	Active pumping (ML/a)	Total (ML/a)
WAL962 HVO North	Hunter Regulated River WSP, Hunter Regulated River Water Source, Zone 1B	3,165	84	0	84
WAL970 HVO South	Hunter Regulated River WSP, Hunter Regulated River Water Source, Zone 2A	500	430.7	0	430.7
WAL1006 HVO South	Hunter Regulated River WSP, Hunter Regulated River Water Source, Zone 2A	500	430.7	0	430.7
WAL1070 HVO South	Hunter Regulated River WSP, Hunter Regulated River Water Source, Zone 2A	500	0	0	0
20BL167860 HVO North Carrington Pit	Part 5 Water Act 1912	220	7.3	0	7.3
20BL169962 HVO West Pit	Part 5 Water Act 1912	180	175	0	175
20BL170010 HVO South Pit	Part 5 Water Act 1912	350	51.1	0	51.1

Figure 30: HVO Water Licence - Seepage inflow area

7.1.2.3 Water Outputs

Significant water users at HVO in 2015 were for dust suppression on haul roads, mining areas and coal stockpiles (2,638ML), evaporation from Dams (2,100ML) and water entrained in Process Waste (1,9303ML).

HVO participates in the Hunter River Salinity Trading Scheme (HRSTS) allowing it to discharge from licensed discharge points during declared discharge events, associated with increased flow in the Hunter River. HVO maintains three licensed discharge monitoring locations:

- Dam 11N, located at HVO North, which discharges to Farrell's Creek
- Lake James, located at HVO South, which discharges to the Hunter River; and
- Parnell's Dam, located at HVO West, which discharges to Parnell's Creek.

During 2015 Hunter Valley Operations discharged 497ML of water under the Hunter River Salinity Trading Scheme and Environment Protection Licence 640.

7.2 Surface Water

7.2.1 Water Management

Surface water monitoring activities continued in 2015 in accordance with the HVO Water Management Plan and HVO Surface Water Monitoring Programme. HVO maintains a network of surface water monitoring sites located on mine site dams, discharge points and surrounding natural watercourses (Figure 31). Water quality monitoring is undertaken to verify the effectiveness of the water management system onsite, and to identify the emergence of potentially adverse effects on surrounding watercourses. Mine site dams are monitored routinely to verify the quality of mine water, used in coal processing, dust suppression, and other day to day activities around the mine.

Surface water monitoring data is reviewed on a quarterly basis. The review involves a comparison of measured pH, Electrical Conductivity (EC) and Total Suspended Solids (TSS) results against internal trigger values which have been derived from the historical data set. The response to measured excursions outside the trigger limits is detailed in the HVO Water Management Plan.

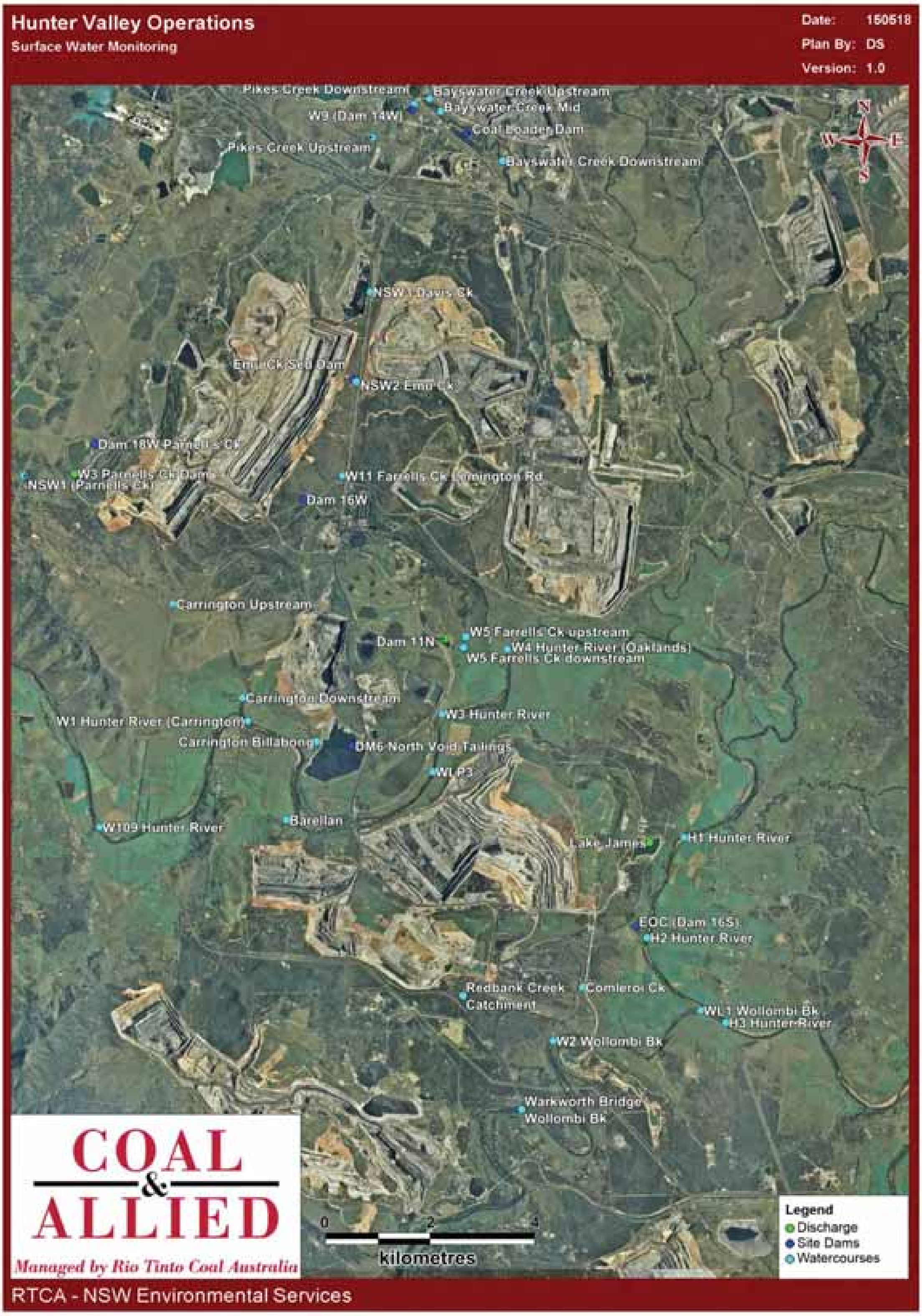


Figure 31: Surface Monitoring Locations

7.2.2 Surface Water Monitoring

Routine surface water monitoring was undertaken from 38 sites at the frequencies described the Surface Water Monitoring Programme. Data recovery for 2015 was 100 per cent from 29 monitoring sites; however 9 sites had less than 100 per cent data recovery and are further explained in Table 32. All sampling of surface waters was carried out in accordance with AS/NZS 5667.6 (1998). All analysis of surface water was carried out in accordance with approved methods by a NATA accredited laboratory.

Water quality is evaluated through the parameters of pH, EC and TSS. Pertinent surface water sites were also sampled for comprehensive analysis annually. Long term water quality trends for the Hunter River, Wollombi Brook, other surrounding tributaries and site dams are presented in this section. Where review of monitoring data has identified results outside of the internal statistical triggers, these are discussed in this section. ANZECC criteria are shown in the figures for comparative purposes.

Table 32: HVO Water Monitoring Data Recovery for 2015 (by exception)

Location	Data Recovery (%)	Comments
Bayswater Creek Downstream	20%	Site recorded as dry during March, September, November and December monitoring events.
Carrington Billabong	0%	Site recorded as dry during all 2015 monitoring events.
NSW 1 Parnells Creek	60%	Site recorded as dry during March monitoring event; no safe access during December monitoring event.
NSW 2 Emu Creek	80%	Site recorded as dry during September monitoring event.
NSW 3 Davis Ck	0%	Site recorded as dry during all 2015 monitoring events.
Pikes Creek Downstream	60%	Site recorded as dry during March and December monitoring events.
Pikes Creek Upstream	80%	Site recorded as dry during March monitoring event.
W5 Farrells Ck upstream	0%	Site recorded as dry during all 2015 monitoring events.
W5 Farrells Ck downstream	0%	Site recorded as dry during all 2015 monitoring events.

7.2.2.1 Hunter River

The Hunter River was sampled on 28 occasions from seven monitoring locations during 2015. Long term trends for pH, EC and TSS are shown in Figure 32 to Figure 34.

Results for water quality were consistent with historical trends and acceptable ranges, indicating no adverse impacts on the Hunter River during 2015.

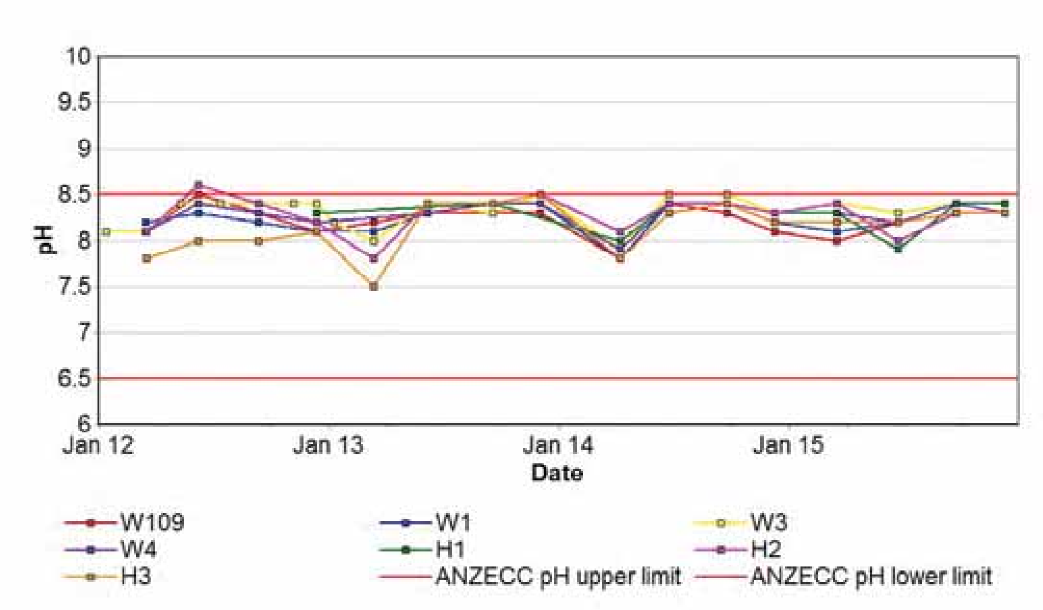


Figure 32: Hunter River pH Trends 2012-2015

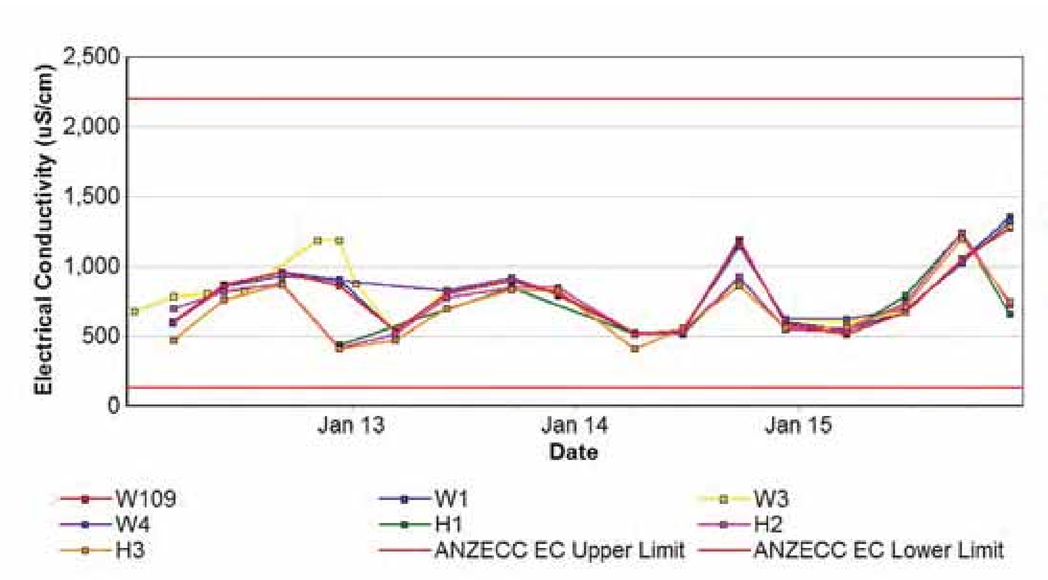


Figure 33: Hunter River EC Trends 2012– 2015

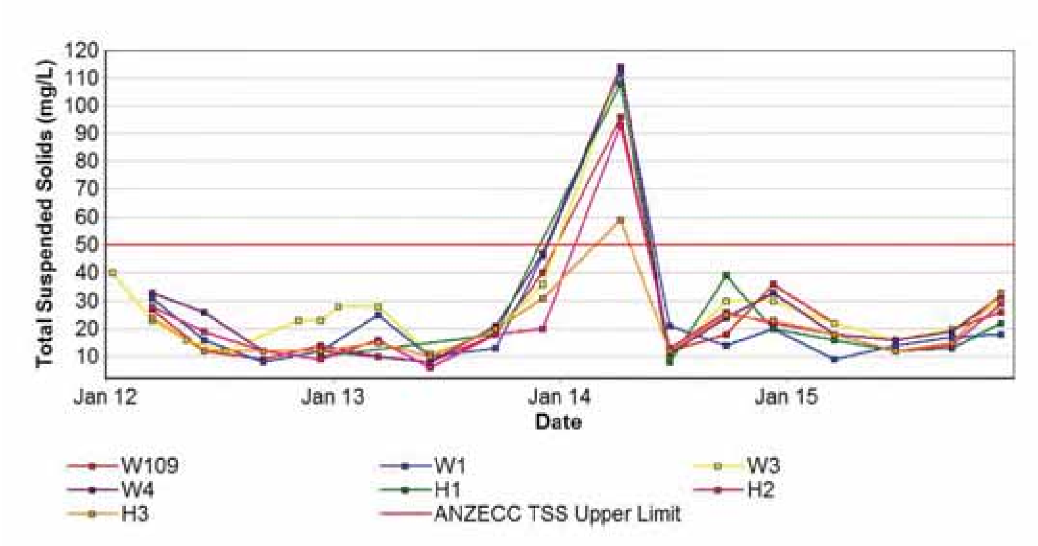


Figure 34: Hunter River TSS Trends 2012 – 2015

7.2.2.2 Wollombi Brook

Wollombi Brook was sampled on 12 occasions from three monitoring locations during 2015. Long term trends for pH, EC and TSS from Wollombi Brook are shown in Figure 35 to Figure 37. Results were consistent with historical trends and acceptable ranges, indicating no adverse impacts on Wollombi Brook during 2015.

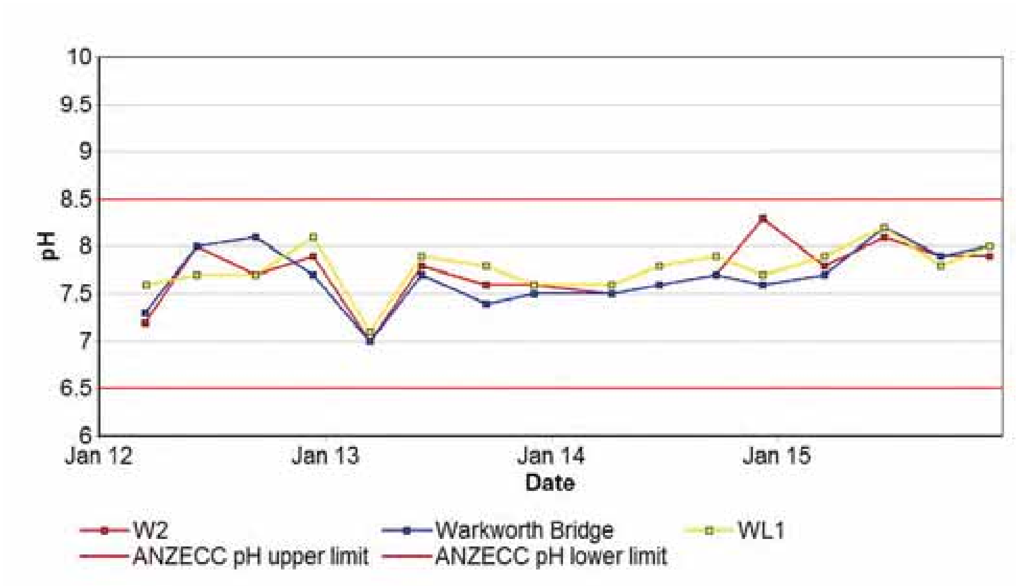


Figure 35: Wollombi Brook pH Trends 2012 – 2015

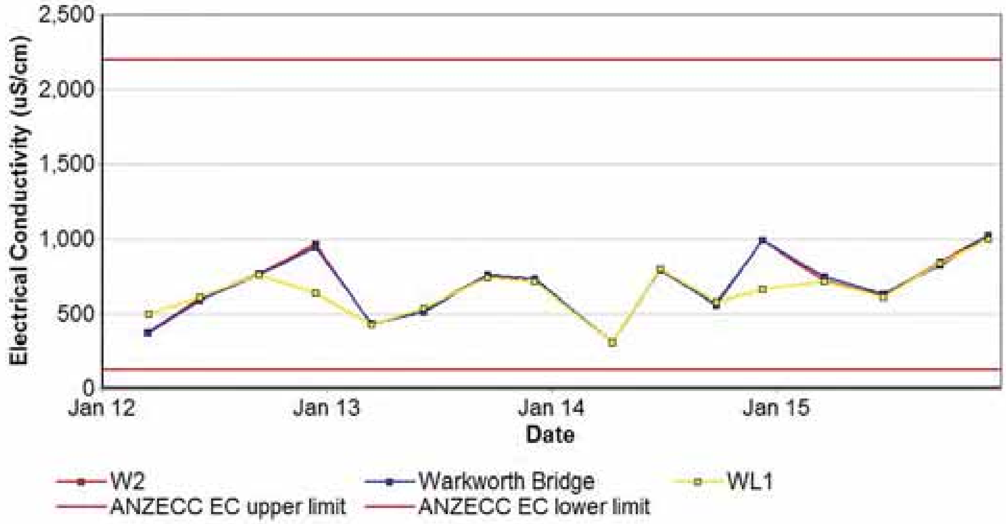


Figure 36: Wollombi Brook EC Trends 2012 – 2015

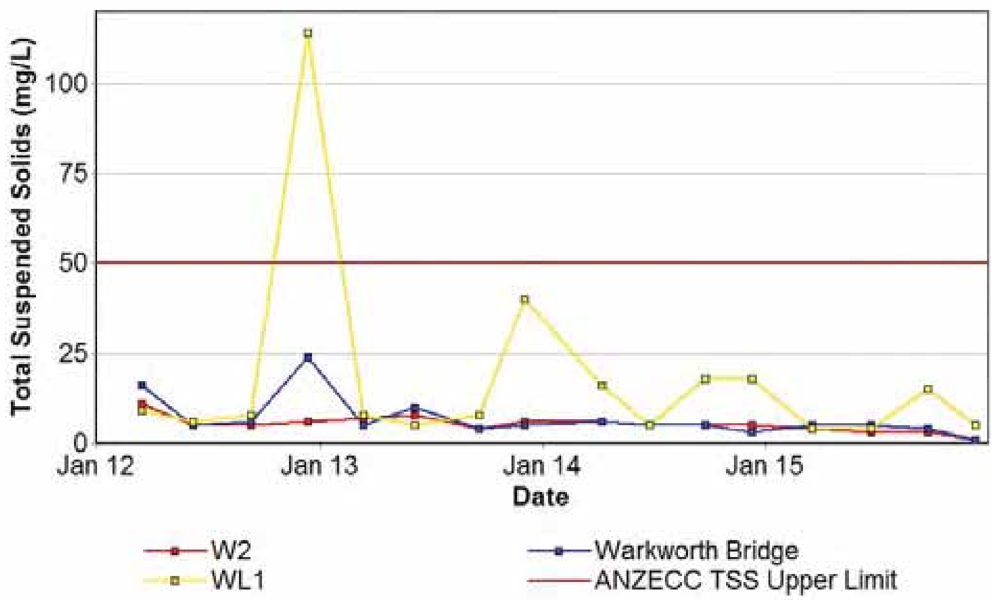


Figure 37: Wollombi Brook TSS Trends 2012 – 2015

7.2.2.3 Other Surrounding Tributaries

35 samples were collected across 13 watercourses during 2015. Routine monitoring of natural tributaries surrounding HVO continued during 2015, from monitoring locations on the following water courses:

- Comleroi Creek
- Emu Creek
- Farrells Creek
- Pikes Creek
- Davis Creek
- Bayswater Creek
- Parnells Creek

A number of these sites are ephemeral in nature, and are often dry on the scheduled day of sampling. To improve sample recovery the sampling regime was revised from quarterly to event-based sampling following rainfall; this change commenced in late 2015. Four sites were reported as dry during 2015; Carrington Billabong, NSW3 Davis Creek, W5 Farrells Creek downstream and W5 Farrells Creek upstream and consequently not sampled.

Long term trends for pH, EC and TSS are shown Figure 38 to Figure 40. Results for water quality remained generally within historical trends and acceptable ranges, indicating no adverse impacts on the other tributaries during 2015. The ephemeral nature of these monitoring locations is the primary reason for the considerable variation physical water quality.

Trigger tracking results are detailed in Table 33.

Table 33: Other Tributaries Internal Trigger Tracking Results

Location	Date	Trigger limit	Action taken in response
Bayswater Creek Midstream	18/03/2015	EC - 1st Stage 95th Percentile	Watching Brief *
	23/06/2015	EC - 1st Stage 95th percentile	Watching Brief *
	23/09/2015	EC - 1st Stage 95th percentile	3rd consecutive measure above trigger limit. A review of the data/trend indicates that increasing electrical conductivity is likely caused by lack of rainfall. Furthermore as the trend is exhibited by both the upstream and midstream locations it is unlikely that HVO has contributed to this result. Site now monitored on a rain-event basis.
Pikes Creek Upstream	22/12/2015	TSS – 50mg/L (ANZECC criteria)	Elevated TSS associated with high runoff due to rainfall event (80mm of rain recorded 21/12 to 22/12). No mine-related sources of sediment in catchment.
W11	22/12/2015	TSS – 50mg/L (ANZECC criteria)	Elevated TSS associated with high runoff due to rainfall event (80mm of rain recorded 21/12 to 22/12). Up-gradient erosion and sediment controls reviewed and compliant.
NSW2 Emu Creek	22/12/2015	TSS – 50mg/L (ANZECC criteria)	Elevated TSS associated with high runoff due to rainfall event (80mm of rain recorded 21/12 to 22/12). Up-gradient erosion and sediment controls reviewed and compliant.

* = 1st/2nd trigger. Watching Brief established pending outcomes of subsequent monitoring events. No specific actions required

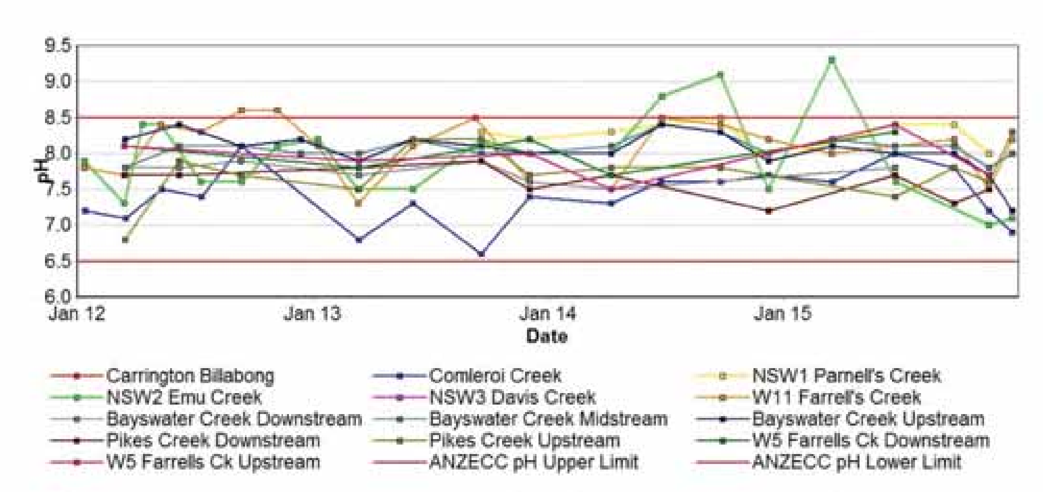


Figure 38: Other Tributaries pH Trends 2012 – 2015

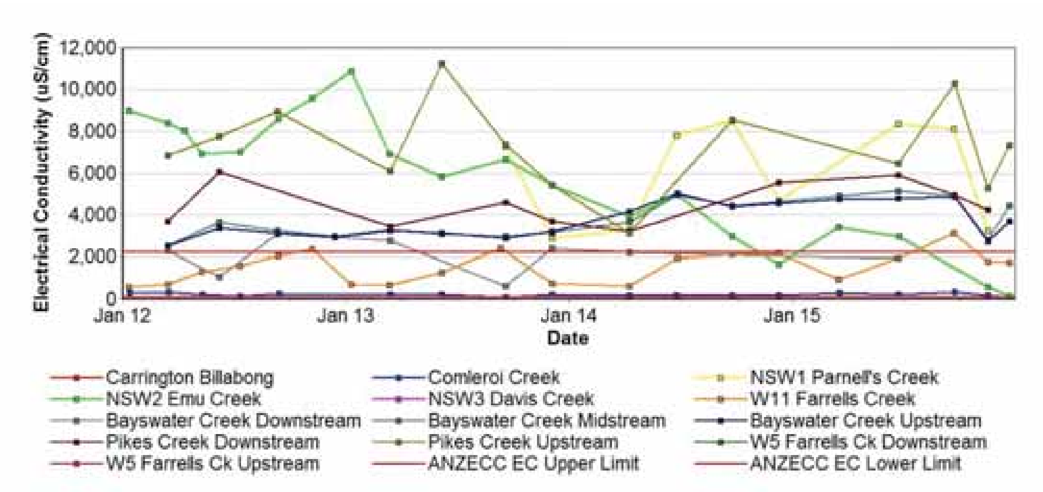


Figure 39: Other Tributaries EC Trends 2012 - 2015

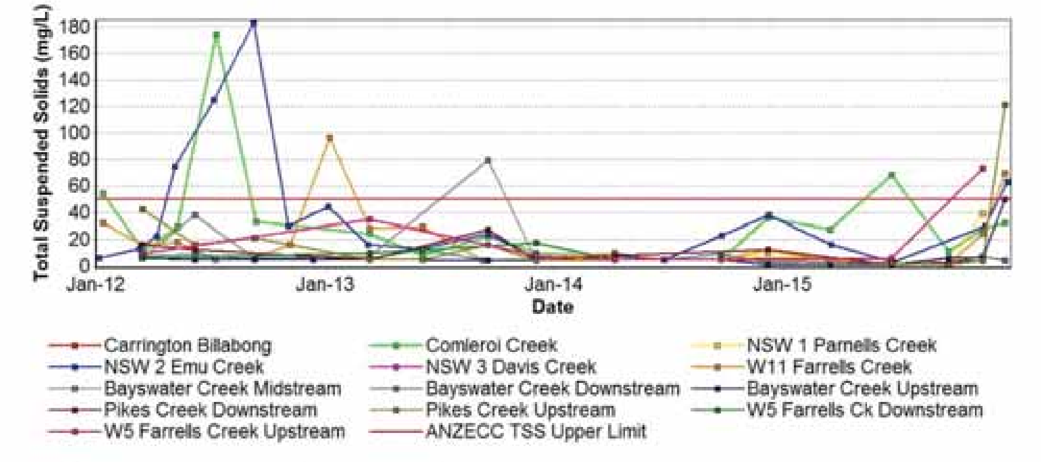


Figure 40: Other Tributaries TSS Trends 2012 – 2015

7.2.2.4 HVO Site Dams

46 samples were collected across 13 dams during 2015. Long term trends for pH, EC and TSS are shown in Figure 41 to Figure 43. Results for water quality were consistent with historical trends; Emu Creek Sed dam shows an increasing TSS trend associated with the advancement of mining around the dam. Erosion and sediment controls are in place to a standard consistent with that prescribed in the HVO Water Management Plan.

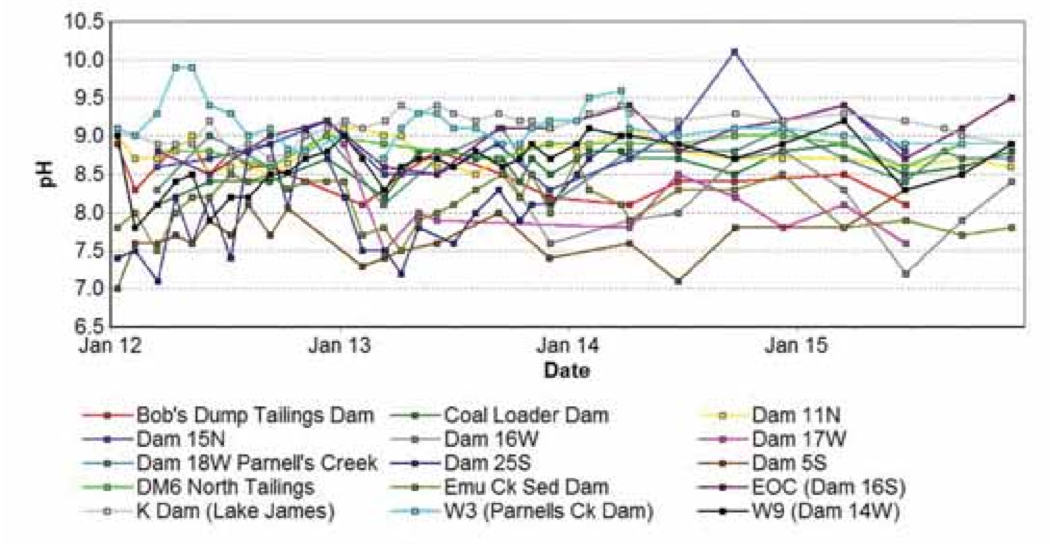


Figure 41: HVO Site Dams pH Trends 2012 – 2015

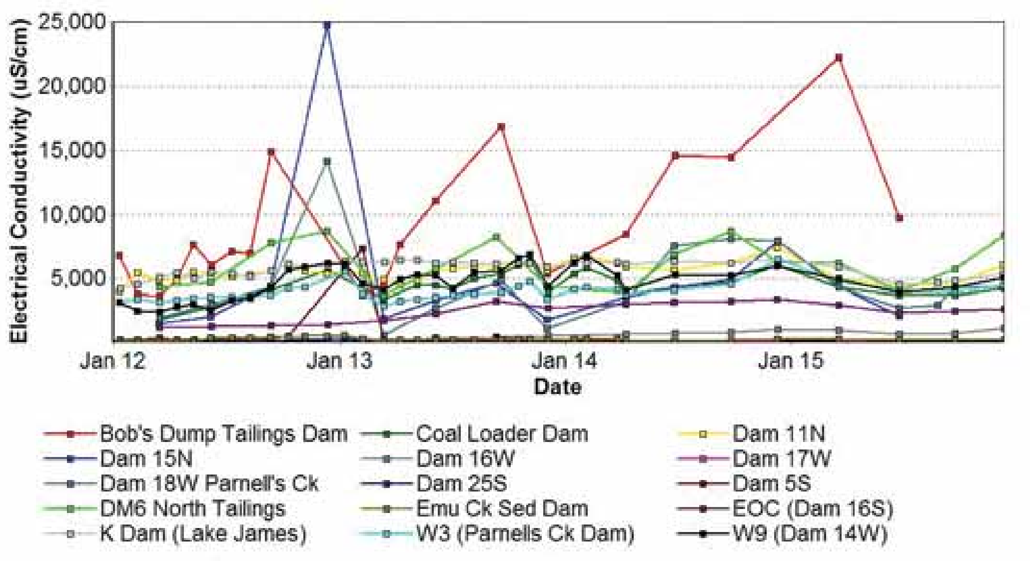


Figure 42: HVO Site Dams EC Trends 2012– 2015

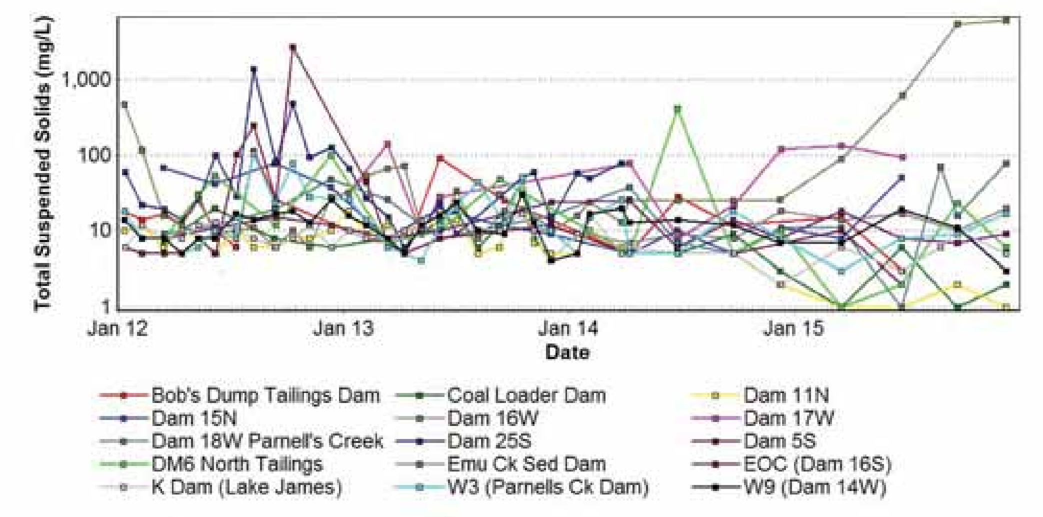


Figure 43: HVO Site Dams TSS Trends 2012 – 2015

7.3 Comparison of 2015 Water Quality Data with EIS Predictions

7.3.1 South Pit EIS Predictions

The South Pit EIS estimated an 'instantaneous' water quality for Electrical Conductivity of 5,700 µS/cm as an upper limit. Instantaneous water quality is a simple estimate obtained by dividing the total salt available by the maximum amount of possible void water. Electrical Conductivity measurements at Lake James averaged 5,230µS/cm, below the predicted 'instantaneous' measure. This is likely due to the high rainfall received, resulting in freshening of water, observed in all site dams in the first half of 2016.

The South Pit EIS estimated average runoff water quality from undisturbed catchments to be 400 mg/L for TSS and 615µS/cm for EC. Comleroi Creek, South of Cheshunt Pit had an average TSS of 33mg/L and EC of 239µS/cm during the review period, demonstrating that runoff water from undisturbed catchments in the HVO South area to be of better quality than that which was predicted in the EIS.

7.3.2 Carrington Pit EIS Predictions

The long term mine water quality for Carrington is discussed in the Carrington Mine Environmental Impact Statement (ERM 1999). The EIS estimated an "instantaneous" water quality for Electrical Conductivity of 7,050µS/cm.

Dewatering from Carrington is a mixture of surface runoff from overburden emplacements, coal mining areas and seepage from the coal seams and alluvium. Water is directed to Dam 9N and into Dam 11N. The average EC and TSS in Dam 11N during 2015 was 5,062µS/cm and 1mg/L respectively, and is considered broadly representative of mine water quality for Carrington.

The Carrington EIS states that runoff from undisturbed catchments within the Carrington Pit will be directed around the mine via contour banks or surface drains to discharge where possible into natural creeks. The salinity of the runoff water was predicted to be approximately 615 µS/cm. Runoff from rehabilitated lands was initially predicted to have higher TSS, with levels approaching pre-mining conditions after several years. Carrington

Billabong (where such water quality would be measured for this comparison) was reported as dry during all scheduled monitoring events in 2015 with no samples collected.

7.3.3 West Pit EIS Predictions

The West Pit EIS included the data below as representative of water quality (Table 34). The pH at Emu Creek (NSW2) averaged 7.8 during the review period, demonstrating good correlation with the EIS predictions. EC values at Emu Creek were variable, ranging between 161µS/cm and 3,420µS/cm. Sampling undertaken during the last quarter in the revised rain-event regime were well below the range predicted in the EIS. Davis Creek and Farrell's Creek were reported as dry throughout 2015 thus no comparison can be made against the predicted water quality. Parnell's Dam (W3) measured an average EC of 4,383µS/cm in 2015, within the predicted range.

Table 34: Representative Water Quality for West Pit:

Watercourse	pH (pH Units)	EC (µS/cm)
Davis Creek	7.7 to 8.4	767 to +8,000
Emu Creek	7.5 to 8.8	365 to +1,000
Farrells Creek	7.0 to 9.2	195 to +12,000
Mine Water (Parnell's Dam)	-	2,400 to 6,300

7.4 Performance relating to HRSTS Discharges

HVO participates in the Hunter River Salinity Trading Scheme (HRSTS), allowing it to discharge to the Hunter River via three licensed discharge points, including Dam 11N, Dam 15S (Lake James) and Dam 9W (Parnells Dam). Discharges can only take place subject to the schemes regulations.

As required by the EPL, HVO submitted a discharge report for the 2014/15 financial year. A total of 497 ML of excess water was discharged off site during 2015 via the Hunter River Salinity Trading Scheme (HRSTS). During the period 23 to 24 April 2015 incomplete datasets (for flow and Electrical Conductivity) were measured whilst discharging from Lake James. The event was due to a PLC issue resulting in an intermittent loss of data capture and subsequent communications to DPI Water.

7.5 Complaints

No complaints were received in regards to water during 2015.

7.6 Groundwater

7.6.1 Groundwater Management

Groundwater monitoring activities were undertaken in 2015 in accordance with the HVO Water Management Plan and Groundwater Monitoring Programme. The monitoring results are used to establish and monitor trends in physical and geochemical parameters of surrounding groundwater potentially influenced by mining.

The groundwater monitoring programme at HVO measures the quality of groundwater against background data, EIS predictions and historical trends. Ground water quality is evaluated through the parameters of pH, EC, and Standing Water Level (SWL) (measured as elevation in metres with respect to the Australian Height Datum, mAHD). On a periodic basis (nominally once per annum) a comprehensive suite of analytes are measured, including major anions, cations and metals. Prior to sampling for comprehensive analysis, bore purging is undertaken to ensure a representative sample is collected.

Groundwater monitoring data is reviewed on a quarterly basis. The review involves a comparison of measured pH and EC results against internal trigger values which have been derived from the historical data set. Trigger limits are calculated as the 95th percentile maximum value (EC and pH) and the 5th percentile minimum value (pH only) from data collected since 2011. Trigger levels have been set on the basis of geographical proximity and target stratigraphy. Bores that record as dry and bores of unknown seam have not been included in calculation of the trigger limits. The response to measured excursions outside the trigger limits is detailed in the HVO Water Management Plan. Where investigations and subsequent actions have been undertaken following review of monitoring data, these are detailed in this section. Monitoring locations are shown in Figure 44.

The alluvial lands area of North Pit was mined and subsequently backfilled between the late-1990's and mid-2000's, following initial approval in 1995. The original groundwater modelling predicted the backfilled void would recharge via rainfall runoff and equilibrate to a water quality that would ultimately allow mixing with the Hunter River. To ensure management commitments relating to the water quality objectives for Hunter River mixing could be achieved at some time in the future investigations determined dewatering of the void should be undertaken to reduce the salt load.

In 2015, the drilling of test holes to confirm the target site for a deep dewatering bore was undertaken. Four holes were drilled, none of which yielded sufficient water to support the construction of a dewatering bore. A consultant has been engaged to develop a hydraulic testing programme and review the conceptual hydrogeological model for the alluvial lands area. This will be undertaken in 2016.

7.6.2 Groundwater Performance

Sampling of ground waters was carried out from 106 monitoring bores across Hunter Valley Operations in accordance with AS/NZS 5667.6 (1998). Where laboratory analysis was undertaken, this was performed by a NATA accredited laboratory. Sites with a data capture rate of less than 100 per cent are outlined in Table 35.

Table 35: HVO Groundwater Monitoring Data Recovery for 2015

Location	Data Recovery (%)	Comments
Carrington Interburden Seam		
CGW47	0%	Site recorded as dry during all monitoring events.
Carrington West Wing Alluvium Seam		
CGW46a	0%	Site recorded as dry during all monitoring events.
Cheshunt Mt Arthur Seam		
BZ4A(2)	0%	Site recorded as dry during all monitoring events.
BZ3-3	0%	Site recorded as dry during all monitoring events.
Lemington South Alluvium Seam		
D317(ALL)	0%	Site recorded as dry during all monitoring events.
Cheshunt / North Pit Alluvium		
CHPZ8A	75%	Insufficient water during February monitoring event.

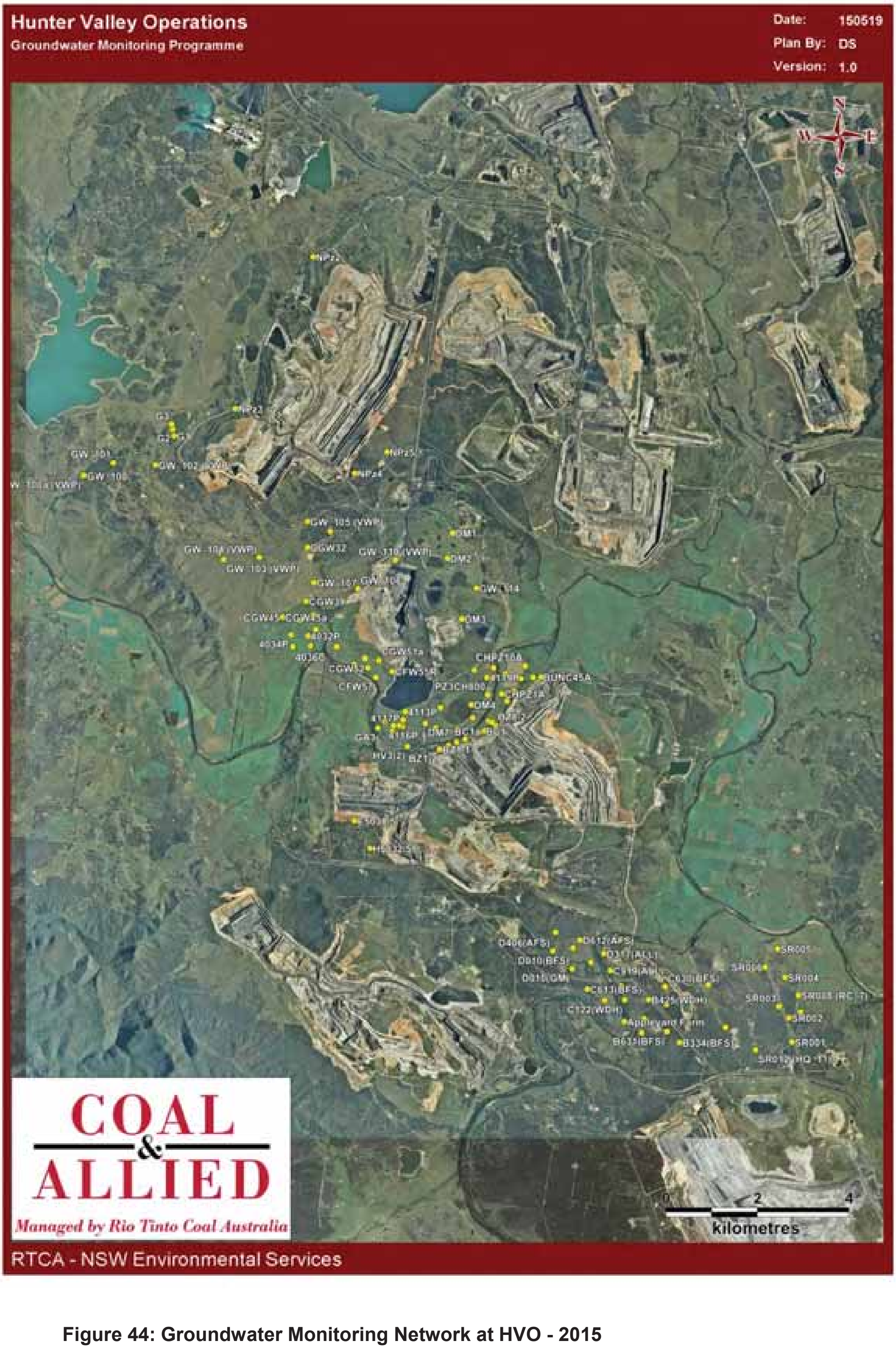


Figure 44: Groundwater Monitoring Network at HVO - 2015

7.6.2.1 Groundwater Monitoring Summary

The following section presents groundwater monitoring data in relation to the geographic locations and target stratigraphy for groundwater monitoring bores. Results are given for the following locations:

- Carrington Broonie
- Carrington Alluvium
- Carrington Interburden
- Carrington West Wing Alluvium
- Carrington West Wing Flood Plain
- Cheshunt / North Pit Alluvium
- Cheshunt Interburden
- Cheshunt Mt Arthur
- Cheshunt Piercefield
- Lemington South Alluvium
- Lemington South Arrowfield
- Lemington South Bowfield
- Lemington South Interburden
- Lemington South Woodlands Hill
- North Pit Spoil
- West Pit Alluvium
- West Pit Sandstone / Siltstone

Each location is discussed below, and a summary of monitoring data presented. Where monitoring results required further investigation following the recording of three consecutive measurements outside the internal statistical limits, these results are summarised in tables for each location.

7.6.2.1.1 Carrington Broonie

Carrington Groundwater was sampled on 8 occasions during 2015 from two monitoring locations. The EC, pH and SWL trends for 2012 to 2015 for Carrington Broonie Seam groundwater bores are shown in Figure 45, Figure 46 and Figure 47 respectively.

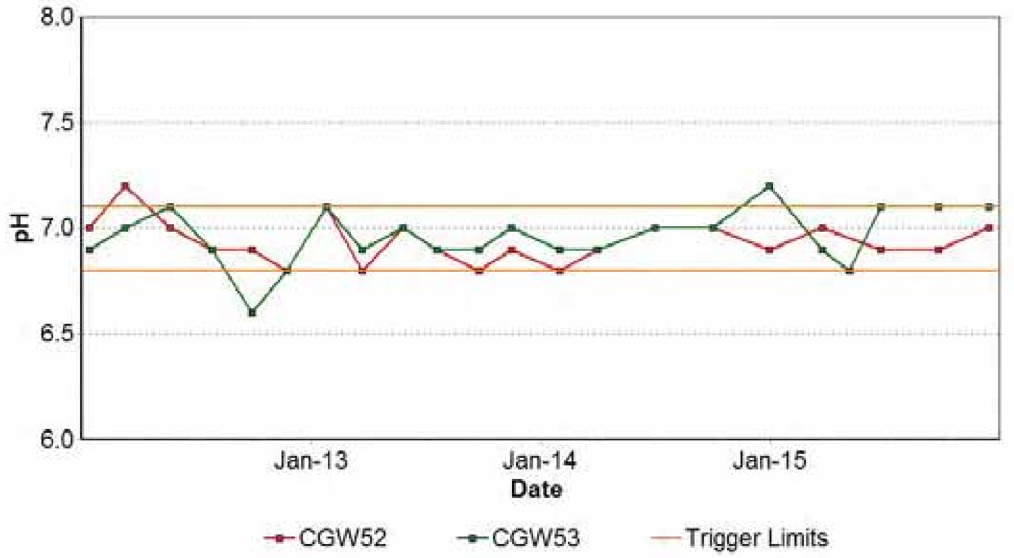


Figure 45: Carrington Broonie Groundwater pH Trends 2012-2015

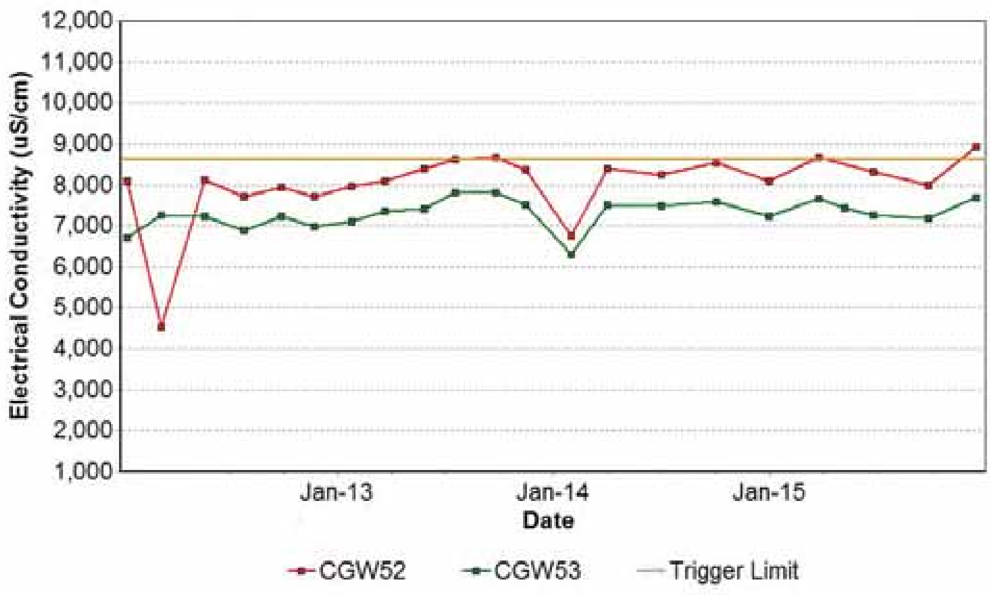


Figure 46: Carrington Broonie Groundwater EC Trends 2012-2015

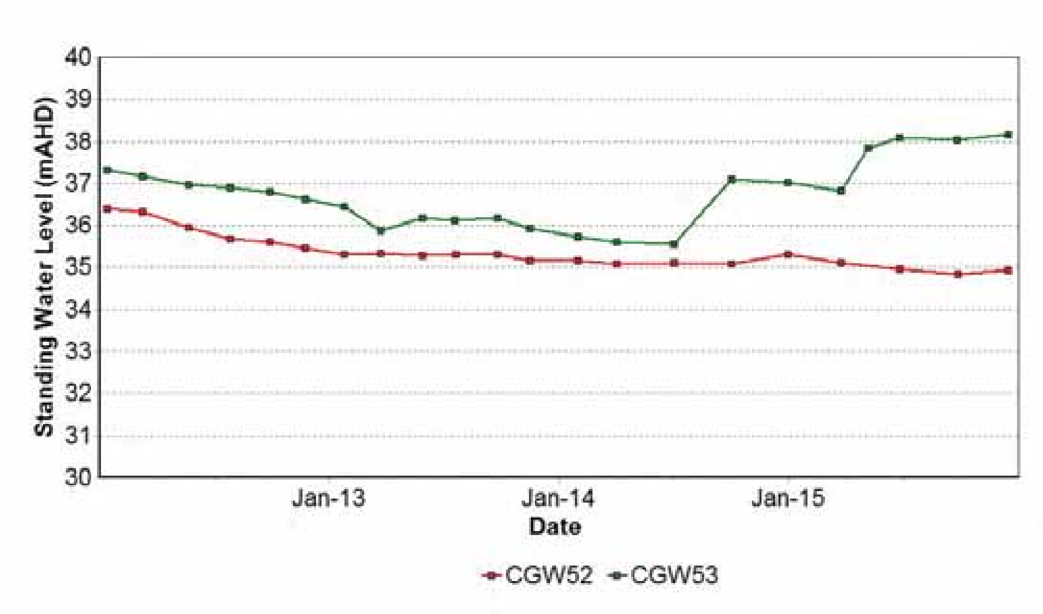


Figure 47: Carrington Broonie Groundwater SWL Trends 2012-2015

7.6.2.1.2 Carrington Alluvium

Groundwater monitoring in the Carrington Alluvium area was undertaken at five sites during 2015, with 20 samples collected during the reporting period. The EC, pH and SWL trends for 2012 to 2015 for Carrington Alluvium groundwater bores are shown in Figure 48 to Figure 50. Trigger tracking results are listed in Table 36.

Table 36: HVO Carrington Alluvium Groundwater 2015 Monitoring Internal Trigger Tracking

Location	Date	Trigger limit	Action taken in response
CFW55R	24/03/2015	pH - 5th percentile & EC - 95th percentile	Watching Brief *
	25/06/2015		Watching Brief *
	17/09/2015		Investigation determined that hydro geochemical speciation has not changed in 2015 and that water quality is consistent with nearby bore CFW57. This, coupled with historical data showing similar elevated EC and depressed pH, suggests the variations are natural and unlikely to be due to anthropogenic impact. Watching brief, no further action required.
	14/12/2015		Watching brief maintained- see above.

* = 1st/2nd trigger. Watching Brief established pending outcomes of subsequent monitoring events. No specific actions required

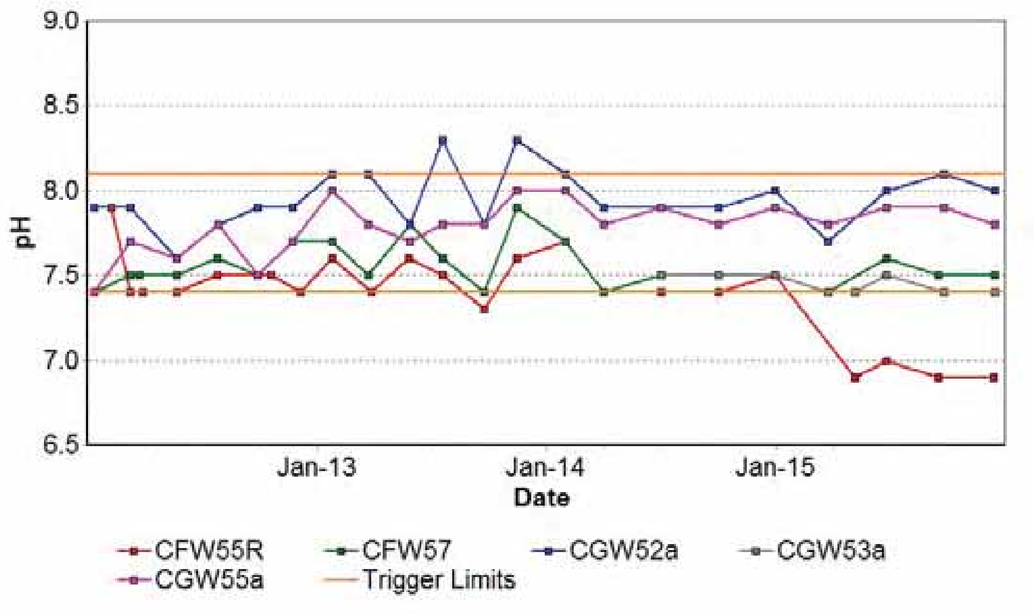


Figure 48: Carrington Alluvium Groundwater pH Trends 2012-2015

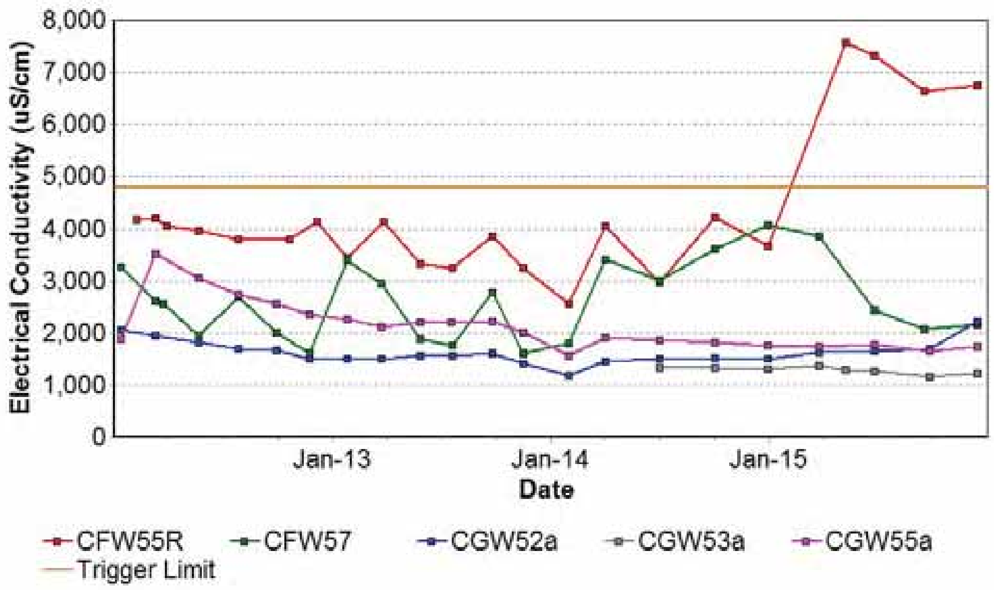


Figure 49: Carrington Alluvium Groundwater EC Trends 2012-2015

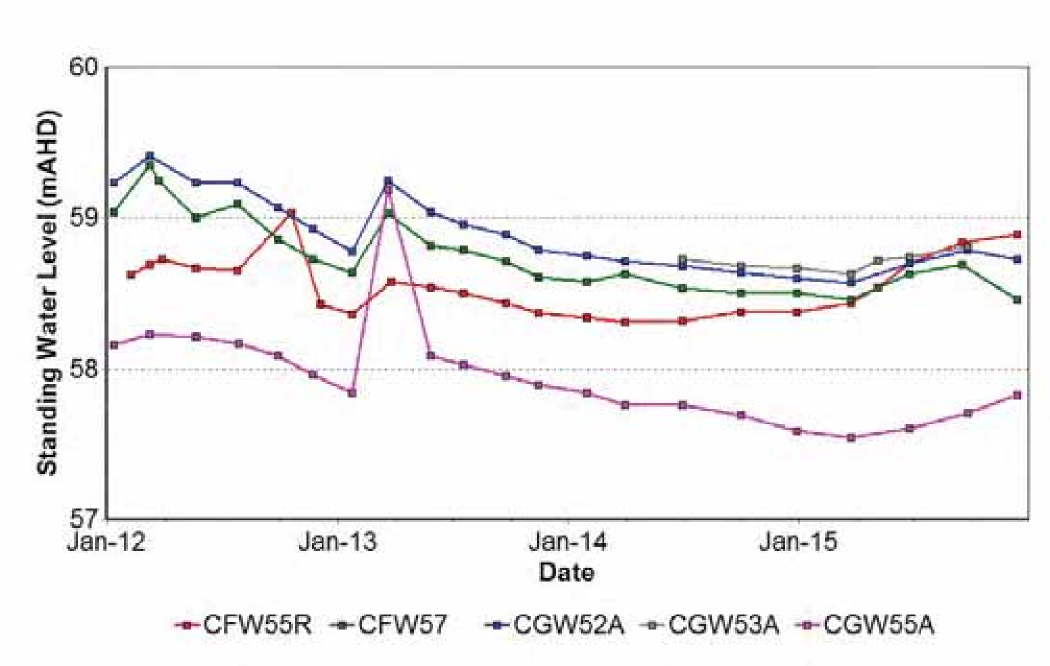


Figure 50: Carrington Alluvium Groundwater SWL trends 2012– 2015

7.6.2.1.3 Carrington Interburden

Groundwater monitoring in the Carrington Interburden was undertaken four sites during 2015, with 12 samples collected for field analysis during the reporting period. CGW47 was dry during all monitoring events for the reporting period. The EC, pH and SWL trends for 2012 to 2015 for groundwater bores in the Carrington Interburden are shown in Figure 51 to Figure 58 respectively.

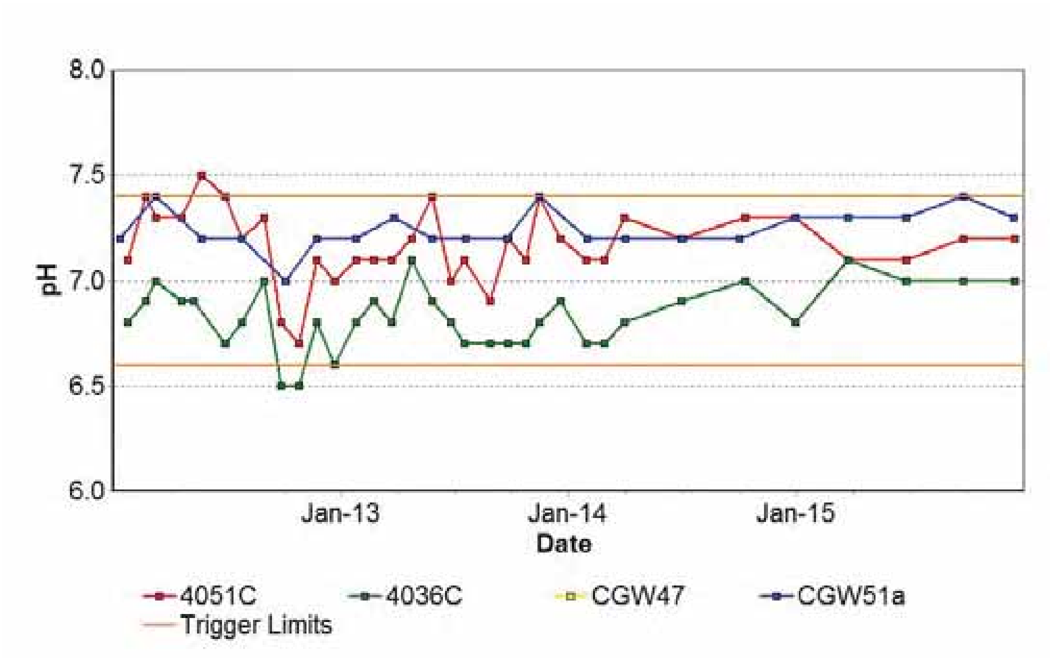


Figure 51: Carrington Interburden Groundwater pH Trends 2012-2015

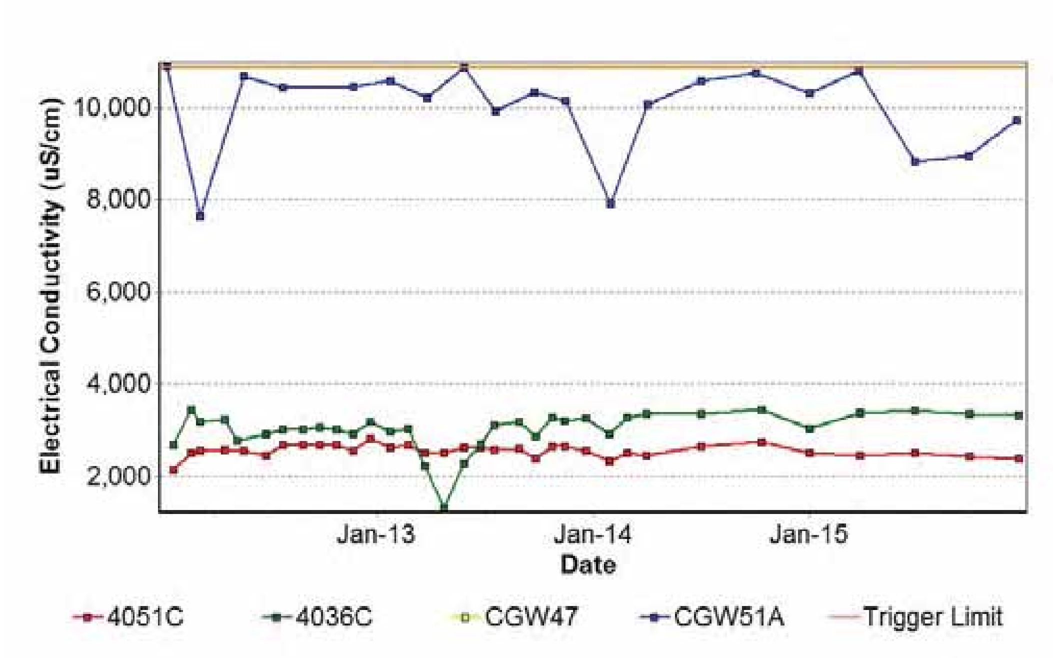


Figure 52: Carrington Interburden Groundwater EC Trends 2012 – 2015

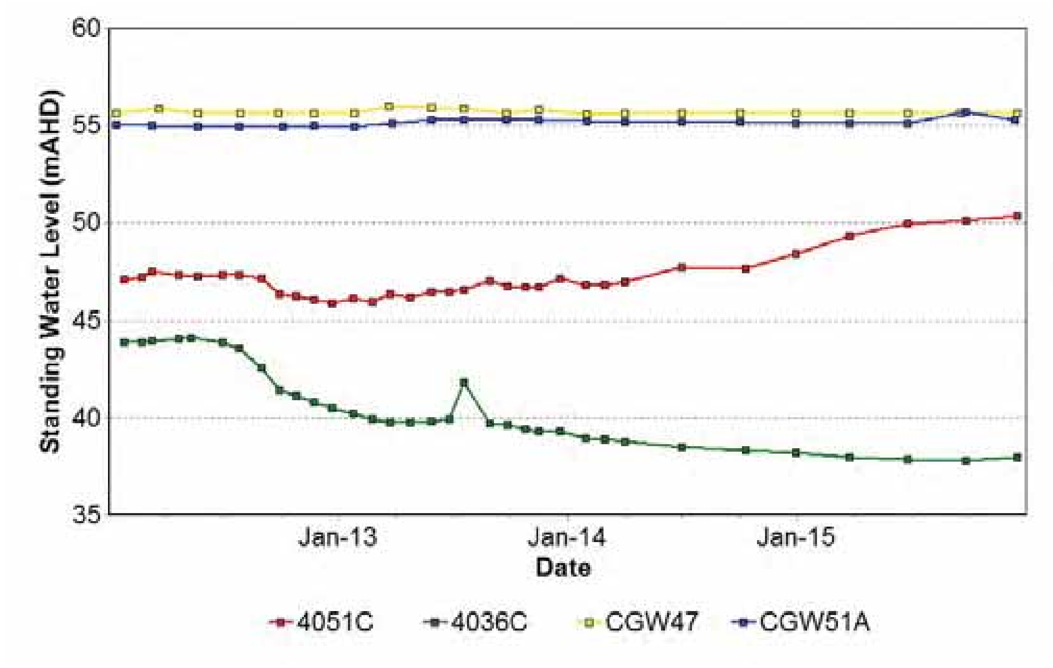


Figure 53: Carrington Interburden Groundwater SWL Trends 2012-2015

7.6.2.1.4 Carrington West Wing Alluvium

Groundwater monitoring in the Carrington West Wing Alluvium was undertaken at seven sites in 2015 with 24 samples collected for field analysis during the reporting period. CGW46a was dry during all monitoring events for the reporting period. Results are shown in Figure 54, Figure 55 and Figure 56. The water level in Bore CGW45 increased by 20 metres in late 2015 and is under investigation; the bore may be damaged or blocked.

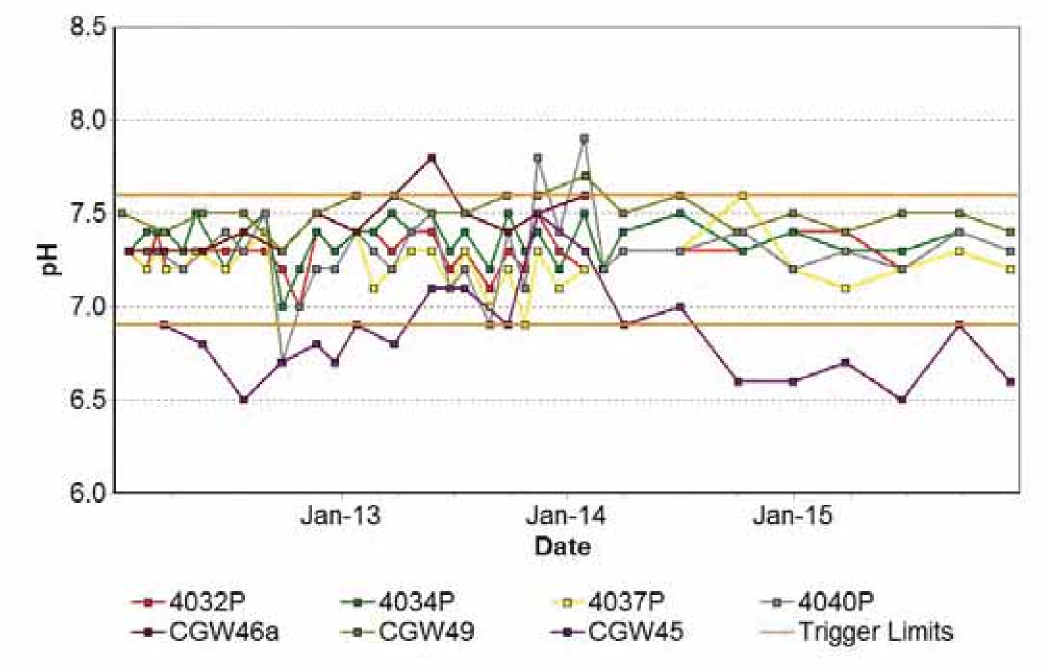


Figure 54: Carrington West Wing Alluvium Groundwater pH Trends 2012-2015

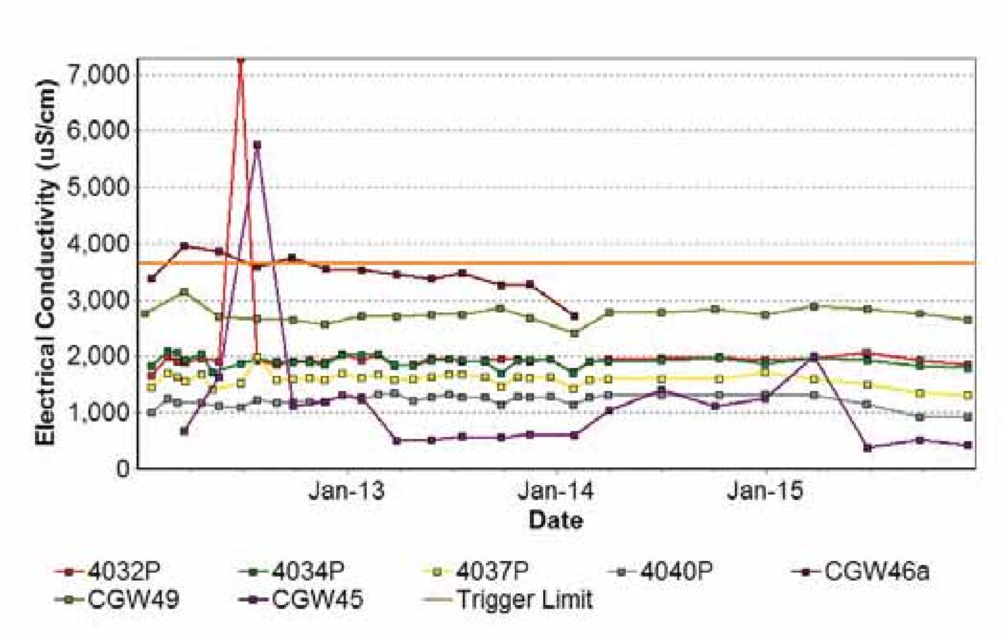


Figure 55: Carrington West Wing Alluvium Groundwater EC Trends 2012 – 2015

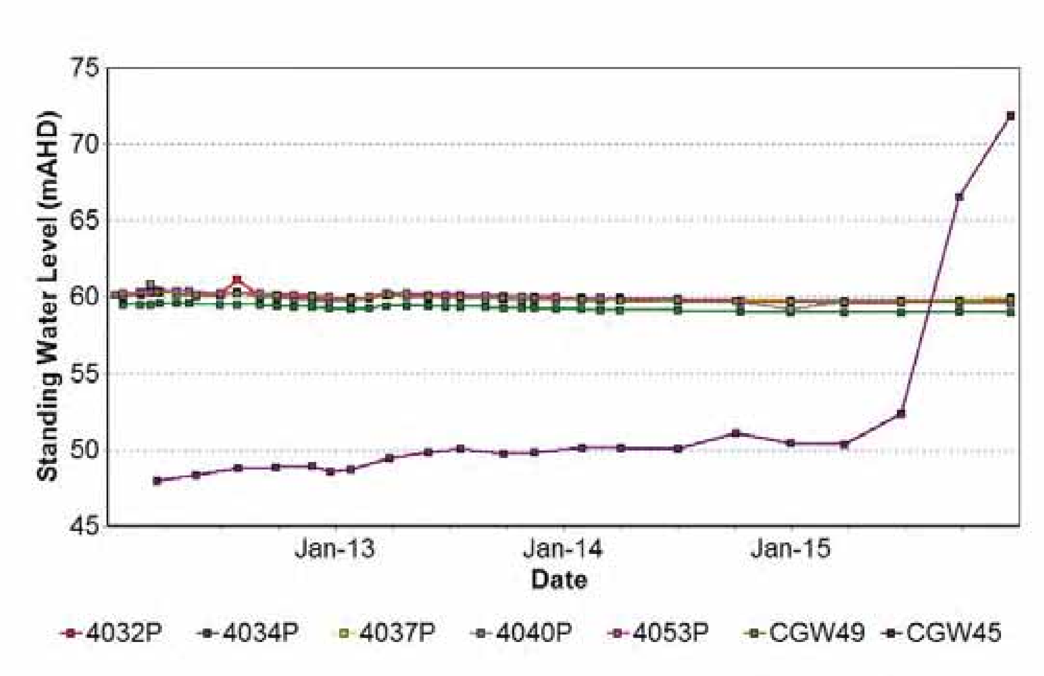


Figure 56: Carrington West Wing Alluvium Groundwater SWL Trends 2012-2015

7.6.2.1.5 Carrington West Wing Flood Plain

Groundwater monitoring in the Carrington West Wing Flood Plain was undertaken at four sites in 2015 with 16 samples collected for field analysis during the reporting period. Results are shown in Figure 57, Figure 58 and Figure 59, with trigger exceedances shown in Table 37.

Table 37: Carrington West Wing Flood Plain 2015 Internal Trigger Tracking

Location	Date	Trigger limit	Action taken in response
GW_106	25/3//2015	EC - 95th percentile	Watching Brief *
	25/6//2015		
	24/09/2015		GW106 is stable and consistent with historical range. Watching brief, no further action required.
	17/12/2015		GW106 is stable and consistent with historical range. Watching brief maintained, no further action required.

*= 1st/2nd trigger. Watching Brief established pending outcomes of subsequent monitoring events. No specific actions required

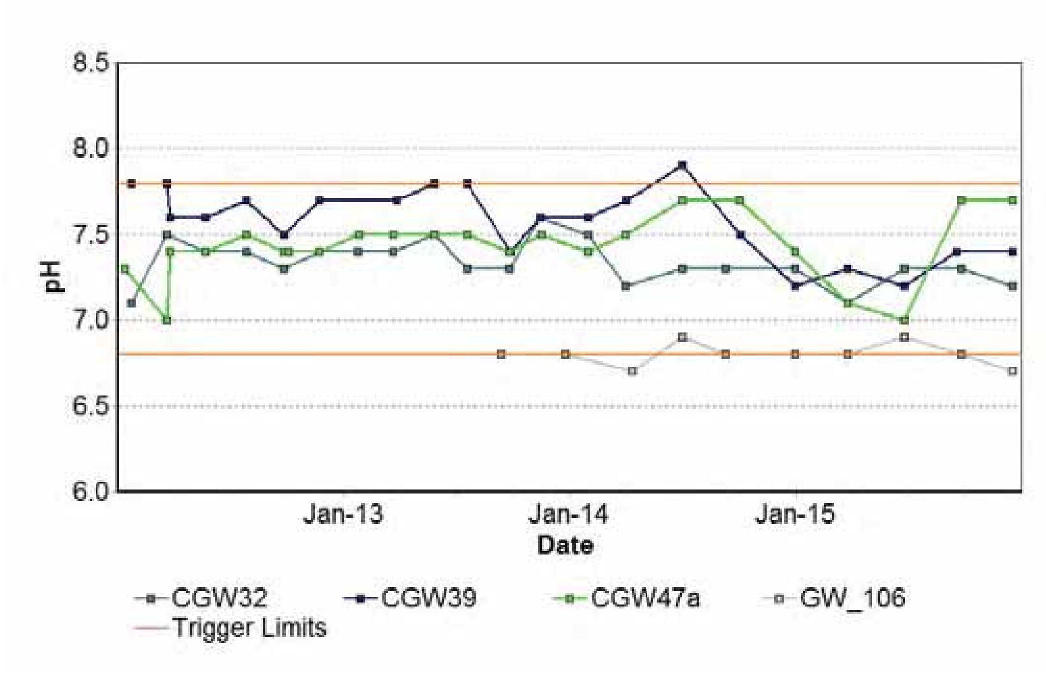


Figure 57: Carrington West Wing Flood Plain Groundwater pH Trends 2012 - 2015

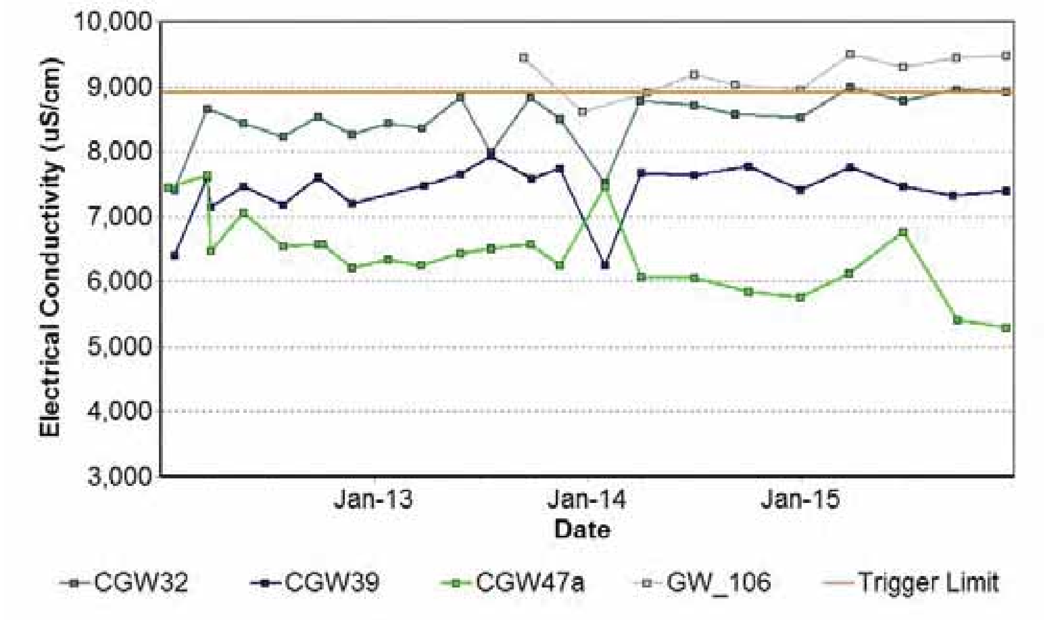


Figure 58: Carrington West Wing Flood Plain Groundwater EC Trends 2012 – 2015

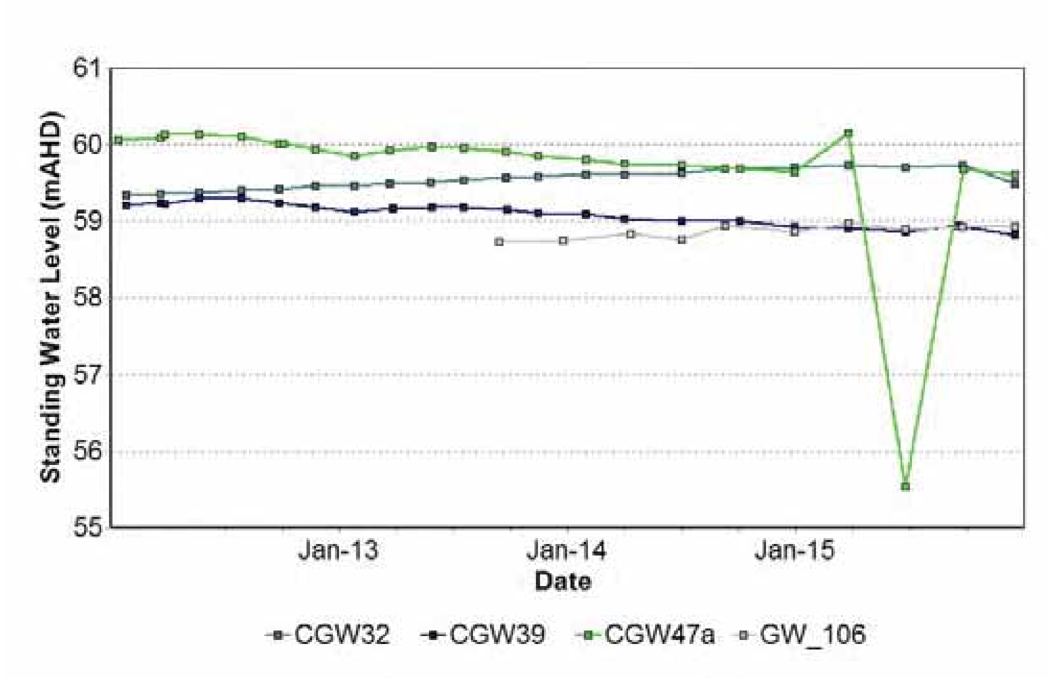


Figure 59: Carrington West Wing Flood Plain Groundwater SWL Trends 2012- 2015

7.6.2.1.6 Cheshunt / North Pit Alluvium

Groundwater monitoring in the Cheshunt / North Pit area was undertaken at 17 sites during 2015, with 67 samples collected during routine monitoring. Electrical Conductivity, pH and SWL trends for 2012 to 2015 for groundwater bores in the Cheshunt / North Pit are shown in Figure 60, Figure 61 and Figure 62.

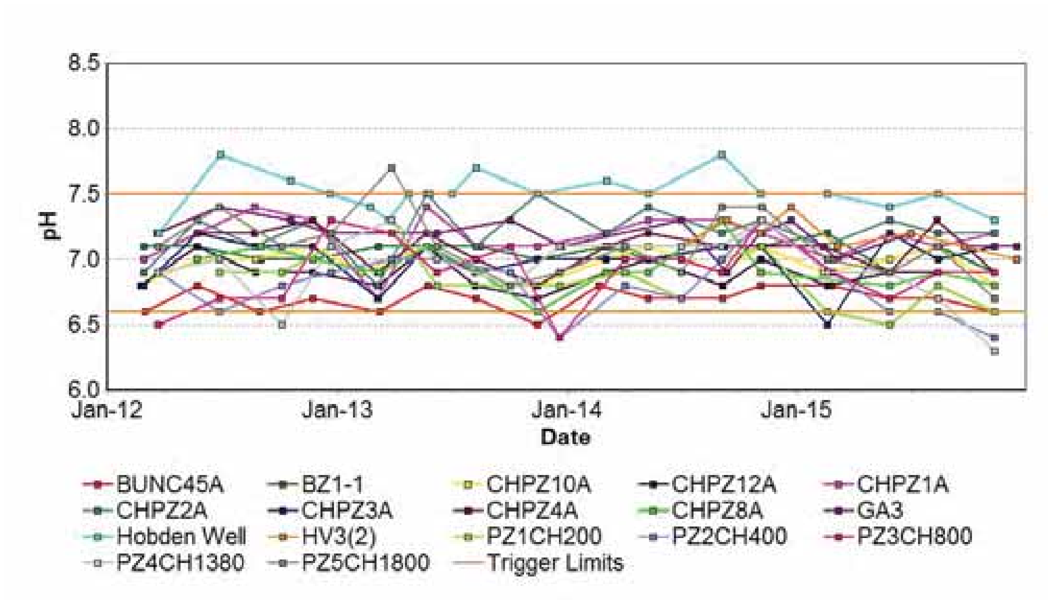


Figure 60: Cheshunt/North Pit Alluvium Groundwater pH trends 2012– 2015

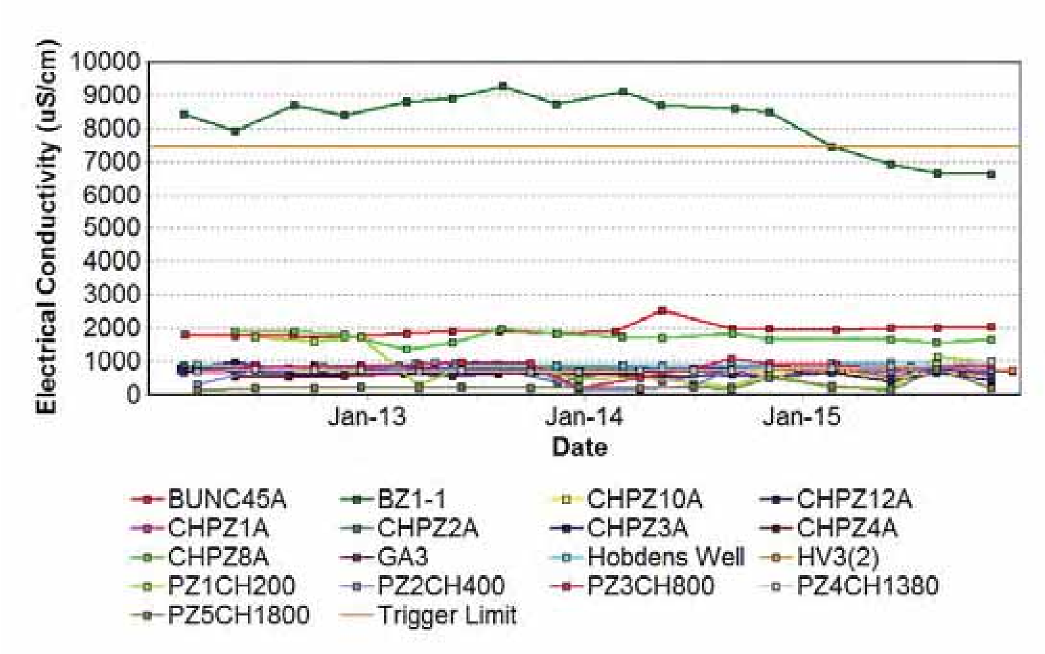


Figure 61: Cheshunt/North Pit Alluvium Groundwater EC Trends 2012 - 2015

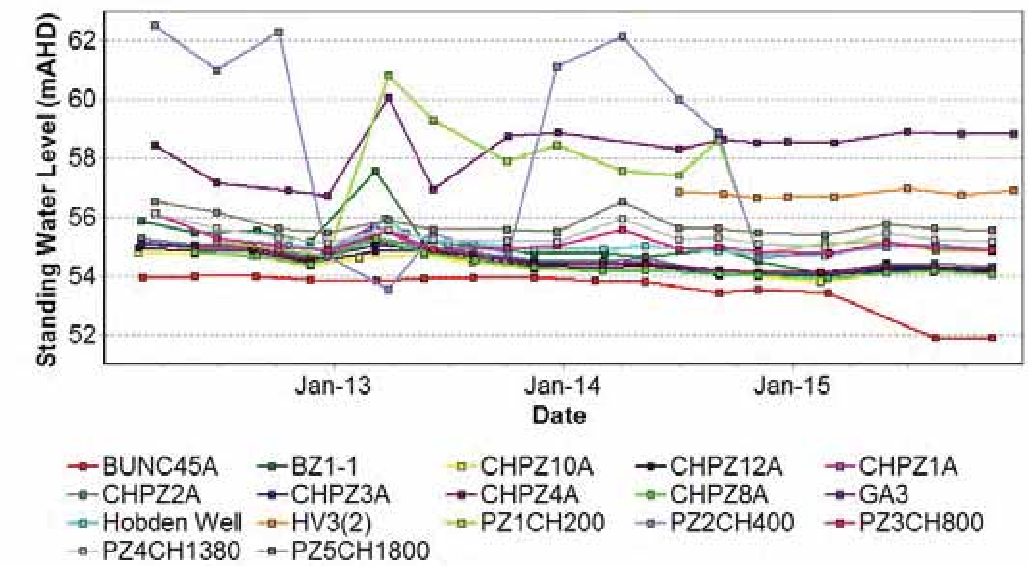


Figure 62: Cheshunt/North Pit Alluvium Groundwater SWL trends 2012- 2015

7.6.2.1.7 Cheshunt Interburden

Groundwater monitoring in the Cheshunt Interburden area was undertaken at three sites during 2015, with 12 samples collected during the reporting period. The EC, pH and SWL trends for 2012 to 2015 for Cheshunt Interburden bores is shown in Figure 63 to Figure 65.

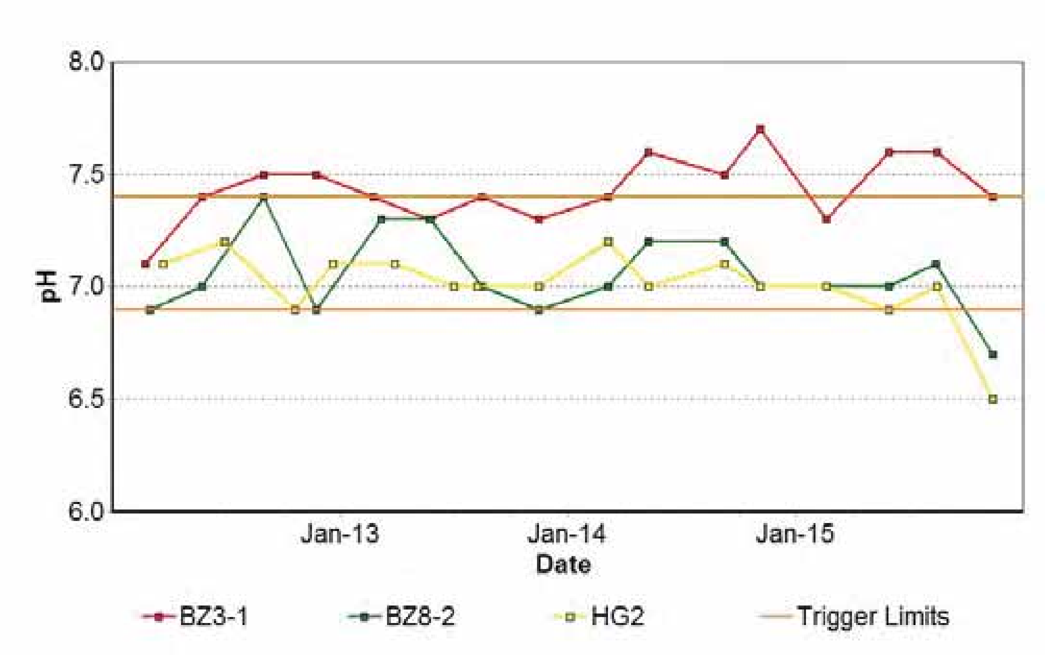


Figure 63: Cheshunt Interburden Groundwater pH Trends 2012 – 2015

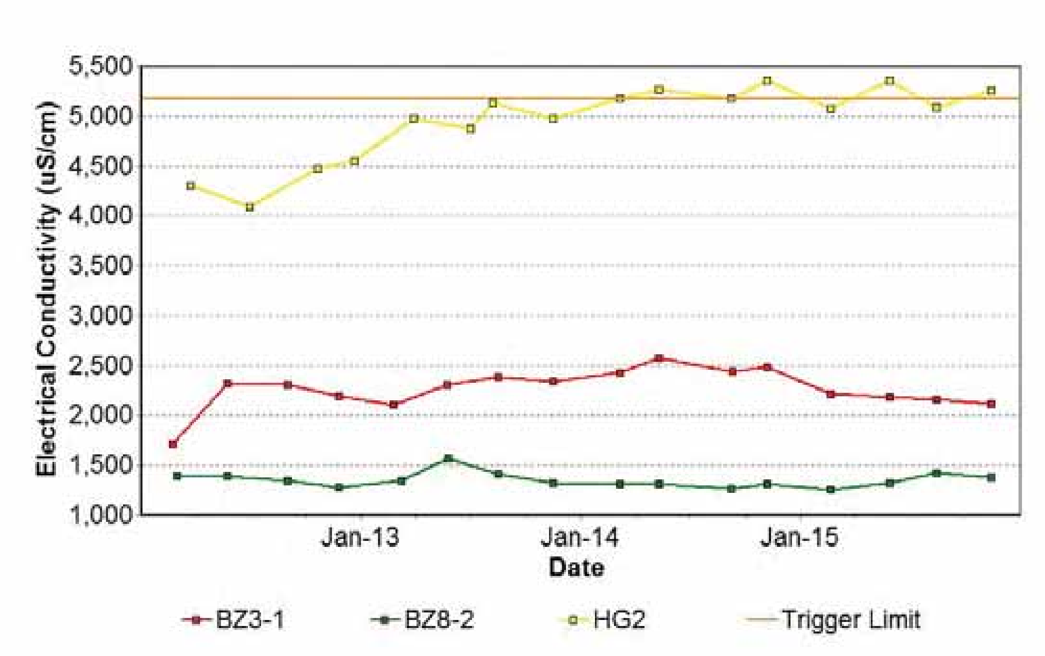


Figure 64: Cheshunt Interburden Groundwater EC Trends 2012 – 2015

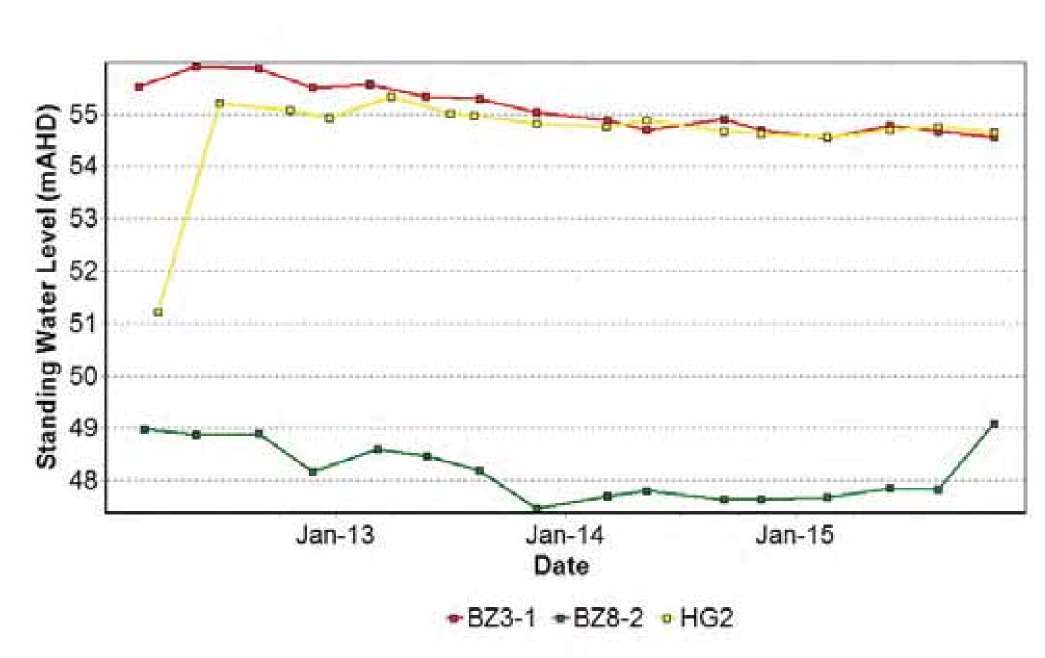


Figure 65: Cheshunt Interburden Groundwater SWL Trends 2012- 2015

7.6.2.1.8 Cheshunt Mt Arthur

Groundwater monitoring in the Cheshunt Mt Arthur area was undertaken at nine sites during 2015. A total of 28 samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for Cheshunt Mt Arthur groundwater bores are shown in Figure 66, to Figure 68. BZ3-3 and BZ4A(2) were recorded as dry throughout the monitoring period; both bores will be reviewed and considered for removal from the monitoring programme.

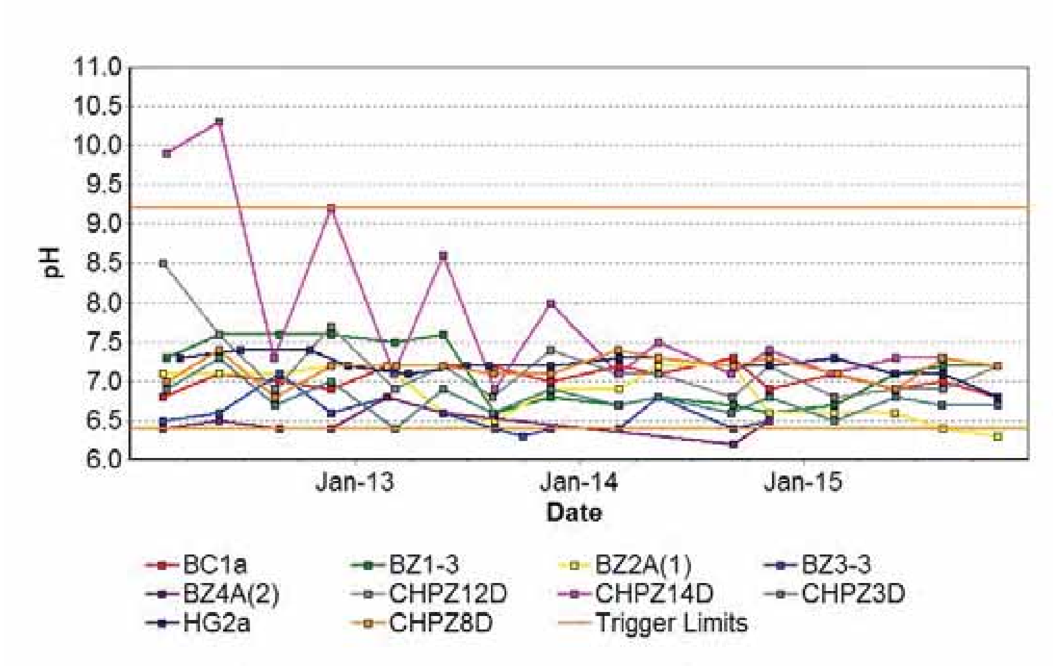


Figure 66:Cheshunt Mt Arthur Groundwater pH Trends 2012 – 2015

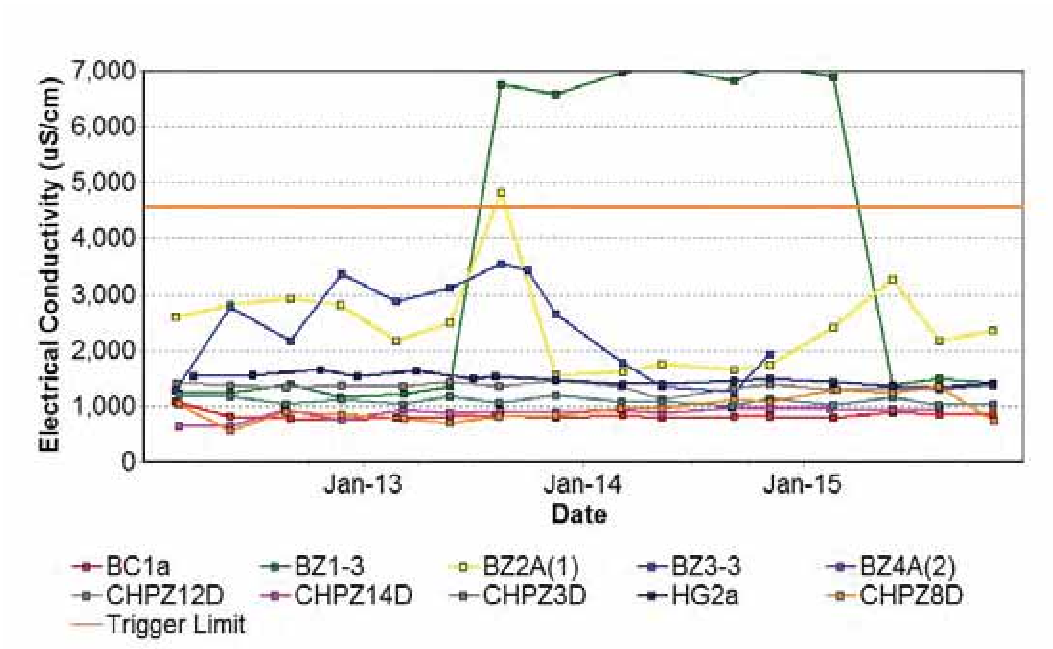


Figure 67: Cheshunt Mt Arthur Groundwater EC Trends 2012 – 2015

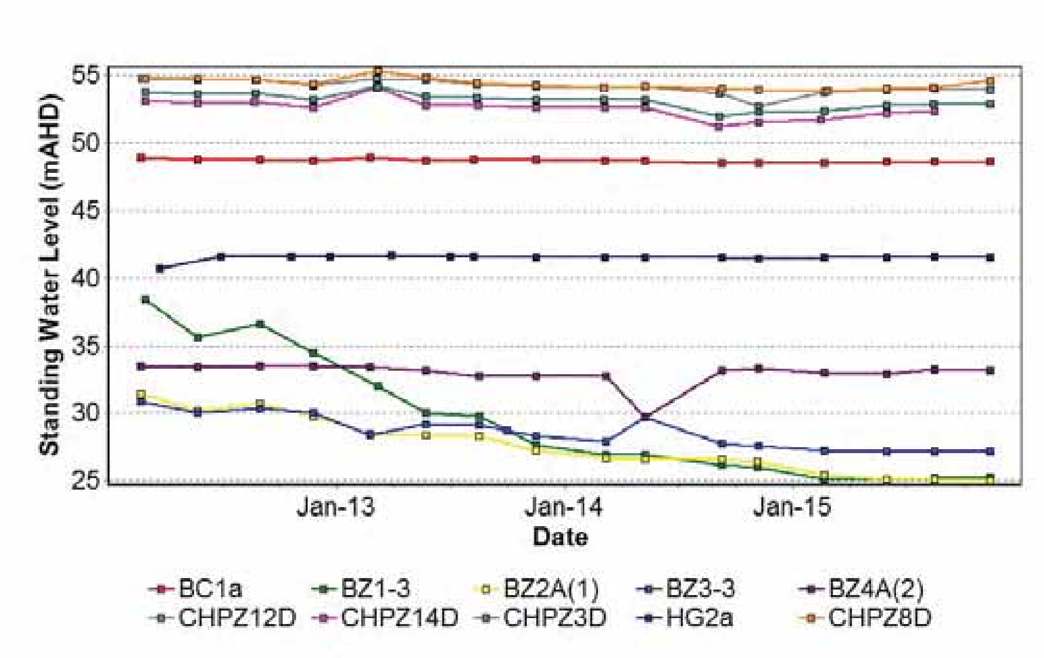


Figure 68: Cheshunt Mt Arthur Groundwater SWL Trends 2012 - 2015

7.6.2.1.9 Cheshunt Piercefield

Groundwater monitoring in the Cheshunt Piercefield area was undertaken from one site during 2015. A total of 4 samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for the Cheshunt Piercefield groundwater bore are shown in Figure 69, to Figure 71.

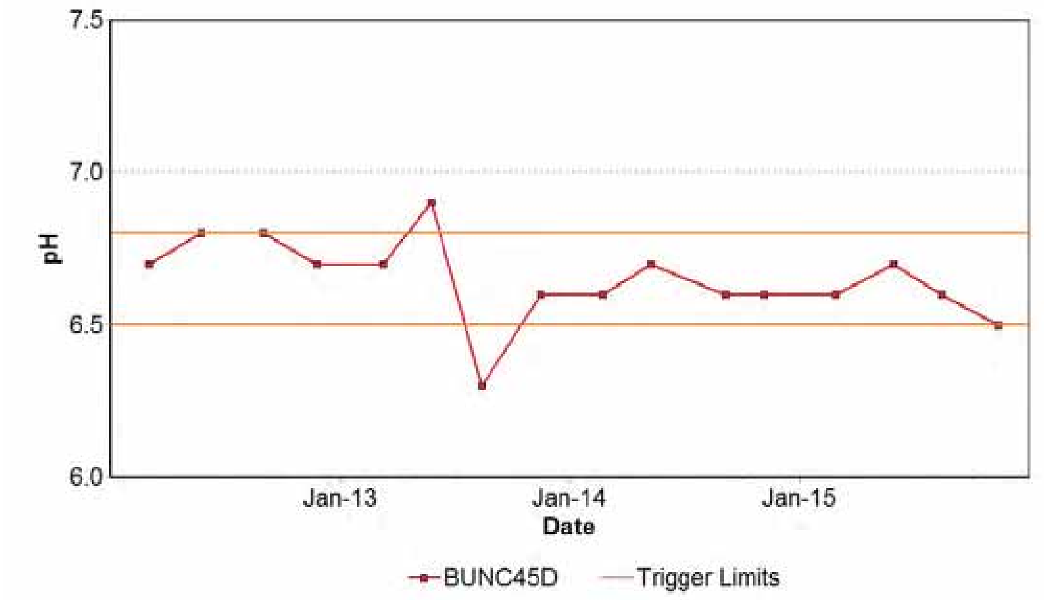


Figure 69: Cheshunt Piercefield Groundwater pH Trends 2012 - 2015

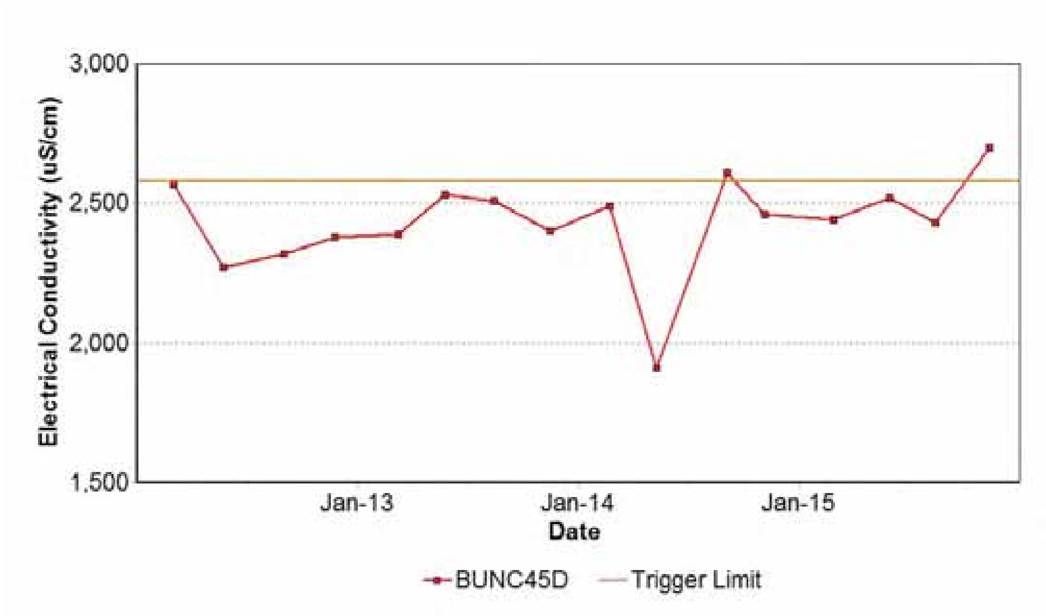


Figure 70: Cheshunt Piercefield Groundwater EC Trends 2012 – 2015

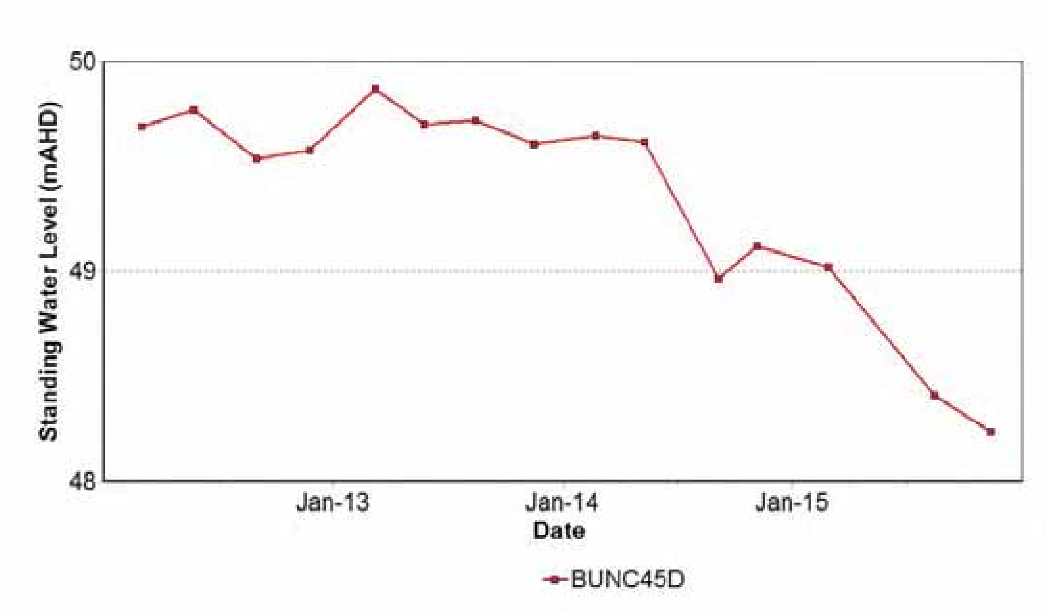


Figure 71: Cheshunt Piercefield Groundwater SWL Trends 2012 - 2015

7.6.2.1.10 Lemington South Alluvium

Groundwater monitoring in the Lemington South Alluvium area was undertaken at four sites during 2015. A total of 12 samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for Lemington South Alluvium groundwater bores are shown in Figure 72 to Figure 74. D317(ALL) was recorded as dry during the reporting period.

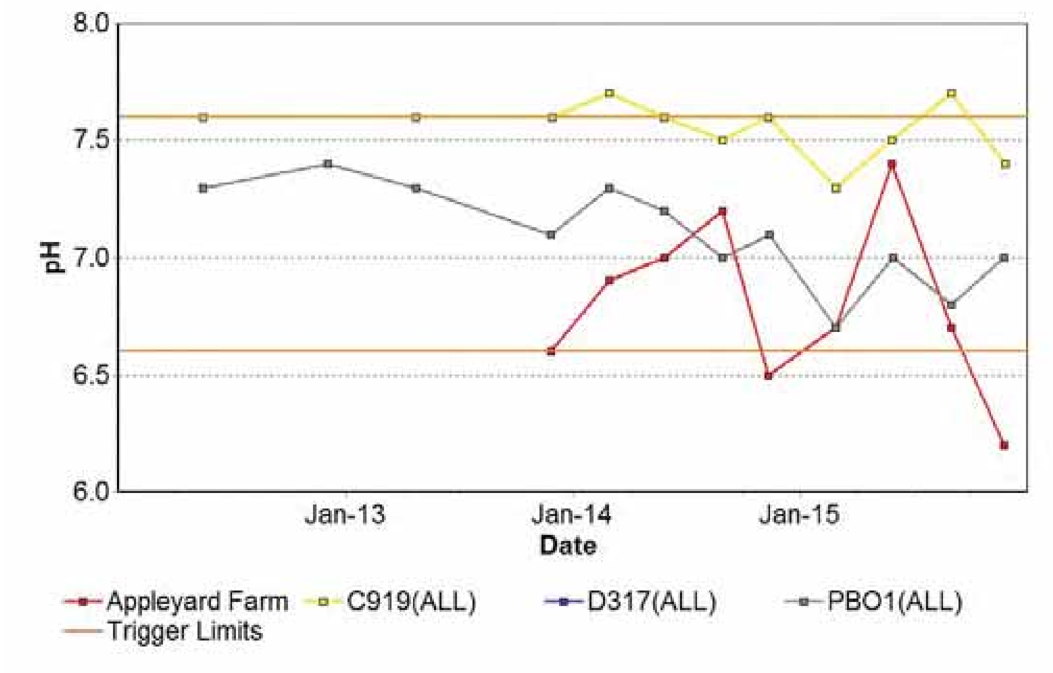


Figure 72: Lemington South Alluvium Groundwater pH Trends 2012 – 2015

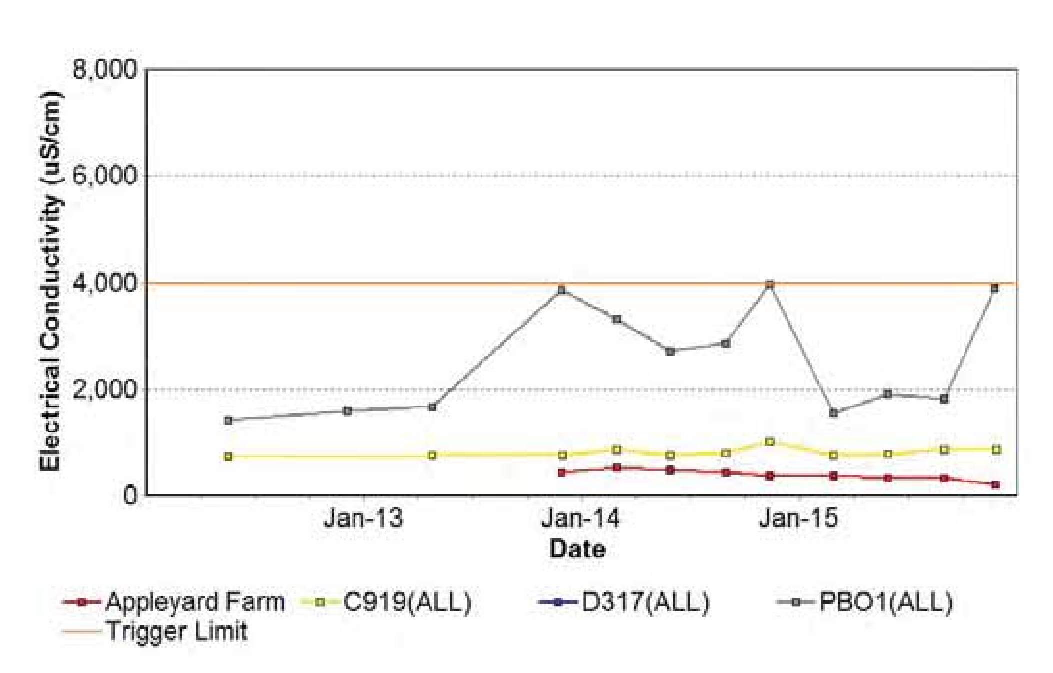


Figure 73: Lemington South Alluvium Groundwater EC Trends 2012 - 2015

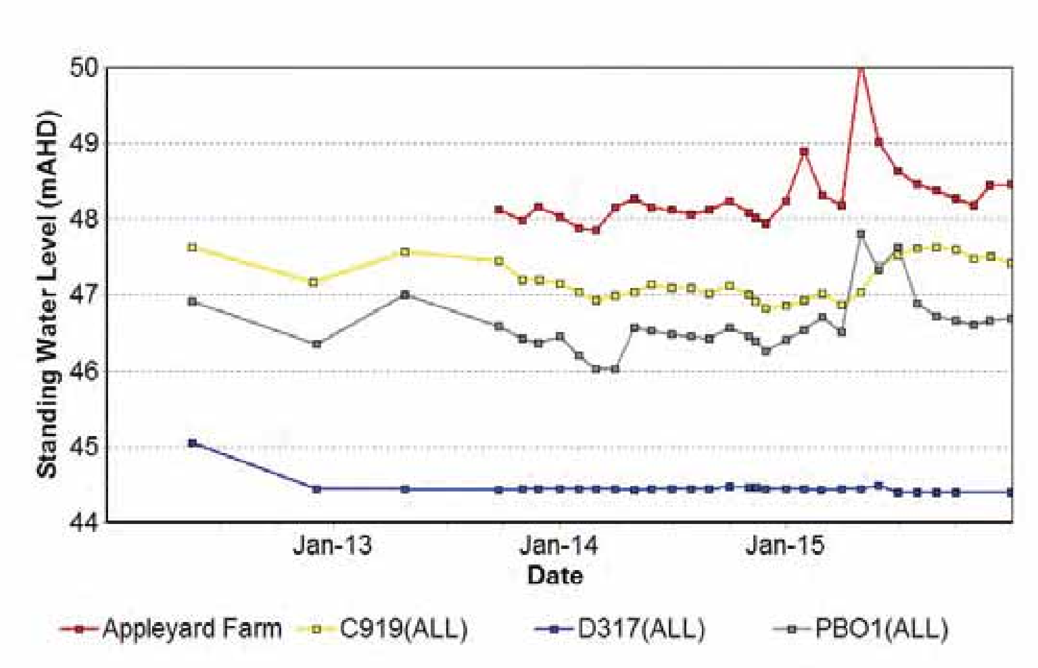


Figure 74: Lemington South Alluvium Groundwater SWL Trends 2012 - 2015

7.6.2.1.11 Lemington South Arrowfield

Groundwater monitoring in the Lemington South Arrowfield area was undertaken at four sites during 2015. A total of 8 samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for Lemington South Arrowfield groundwater bores are shown in Figure 75 to Figure 77.

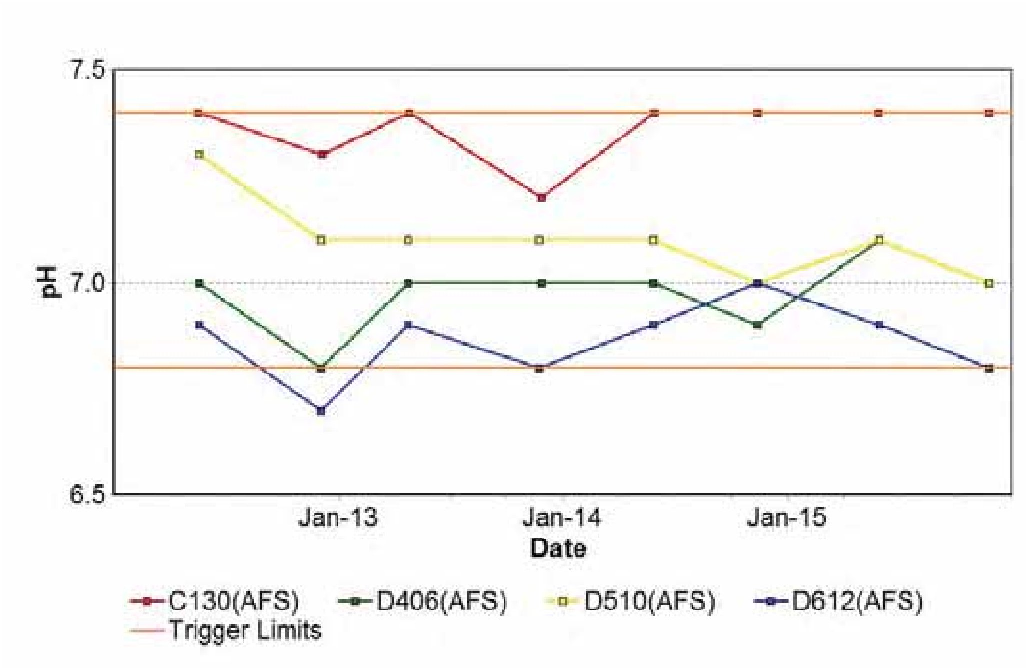


Figure 75: Lemington South Arrowfield Groundwater pH Trends 2012 - 2015

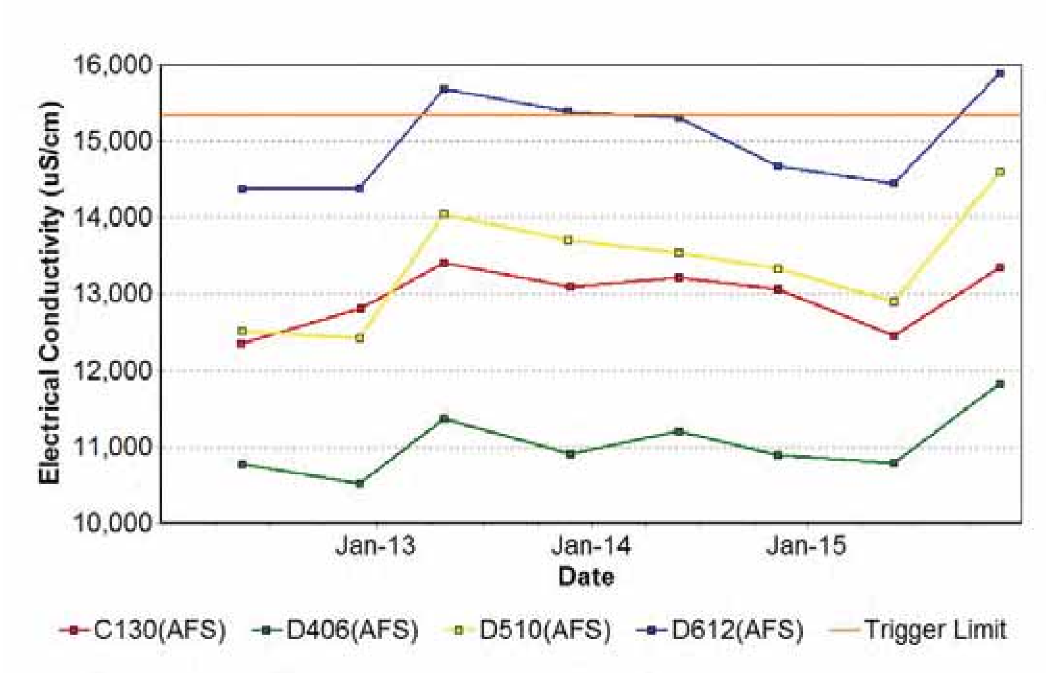


Figure 76: Lemington South Arrowfield Groundwater EC Trends 2012 -2015

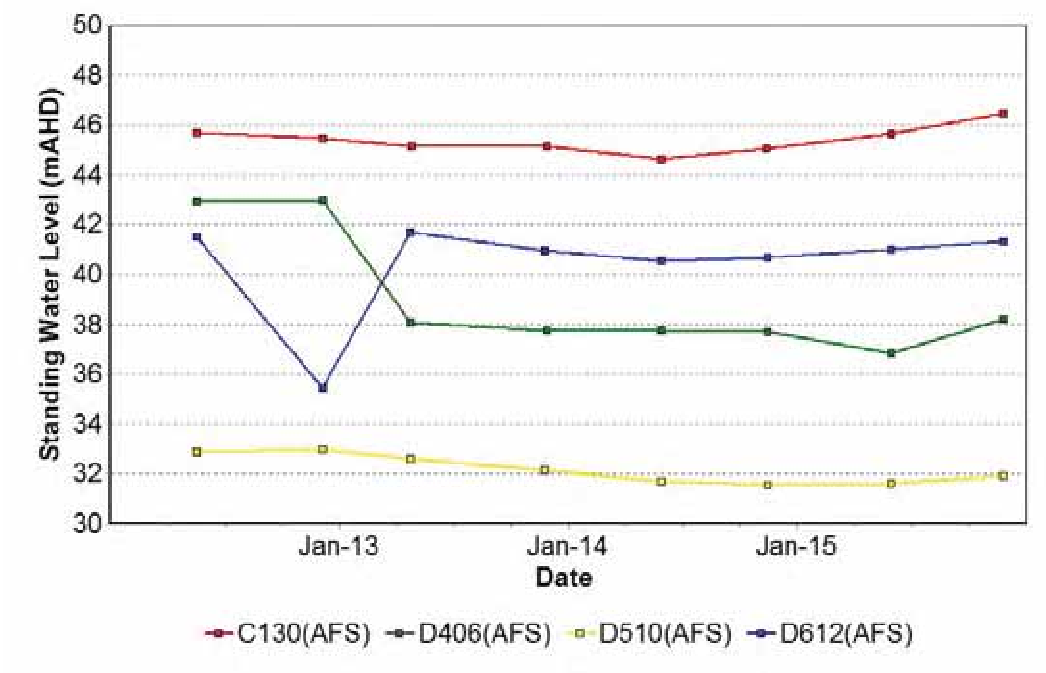


Figure 77: Lemington South Arrowfield Groundwater SWL Trends 2012 - 2015

7.6.2.1.12 Lemington South Bowfield

Groundwater monitoring in the Lemington South Bowfield area was undertaken at 15 sites during 2015. A total of 30 samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for Lemington South Bowfield groundwater bores are shown in Figure 78 to Figure 80.

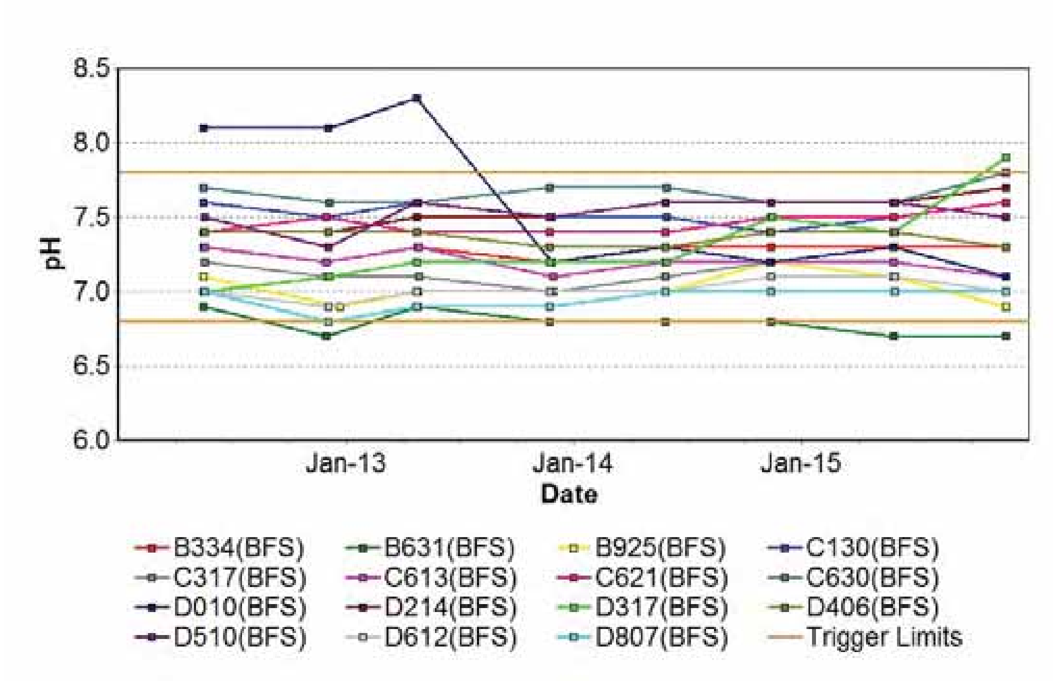


Figure 78: Lemington South Bowfield Groundwater pH Trends 2012 – 2015

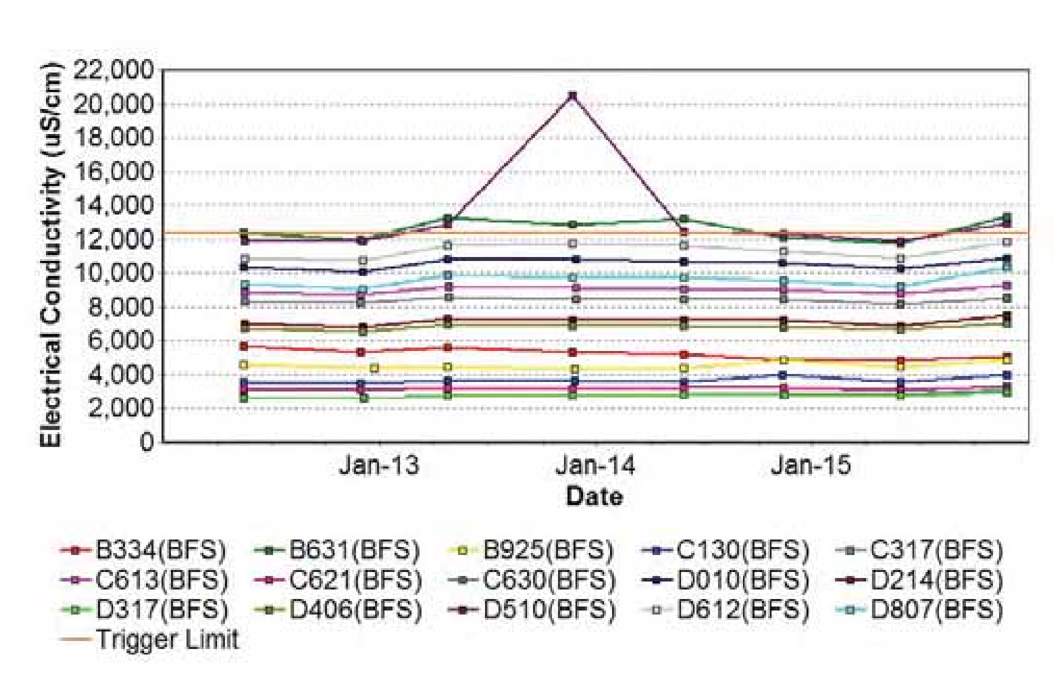


Figure 79: Lemington South Bowfield Groundwater EC Trends 2012 – 2015

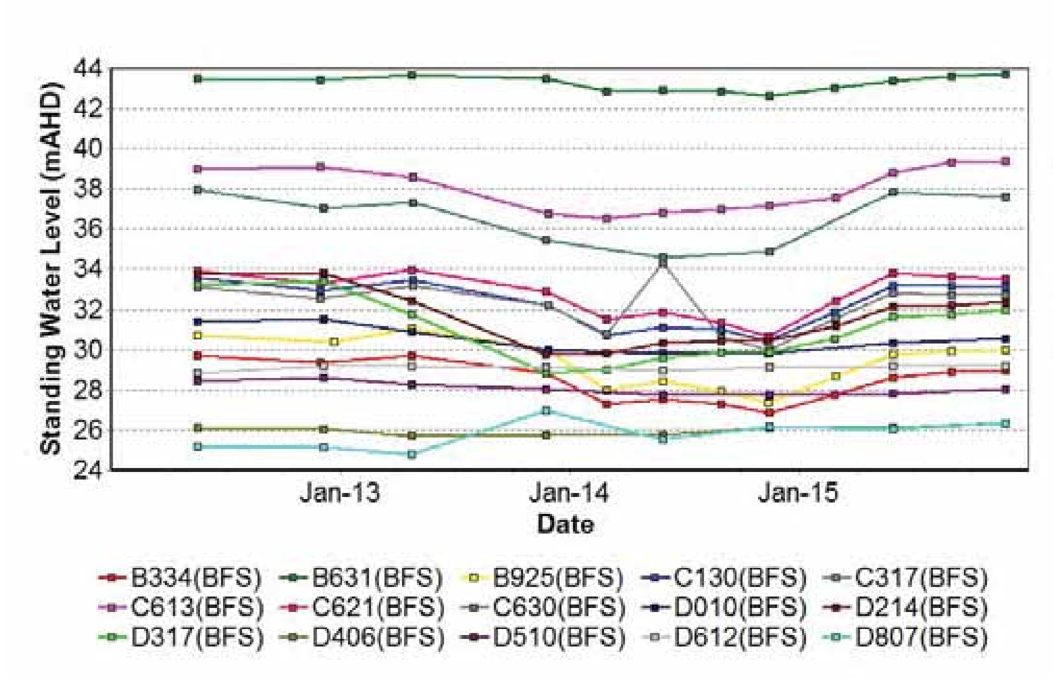


Figure 80: Lemington South Bowfield Groundwater SWL Trends 2012 - 2015

7.6.2.1.13 Lemington South Interburden

Groundwater monitoring in the Lemington South Interburden area was undertaken at one site during 2015. A total of four samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for the Lemington South Bowfield groundwater bore is shown in Figure 81 to Figure 83.

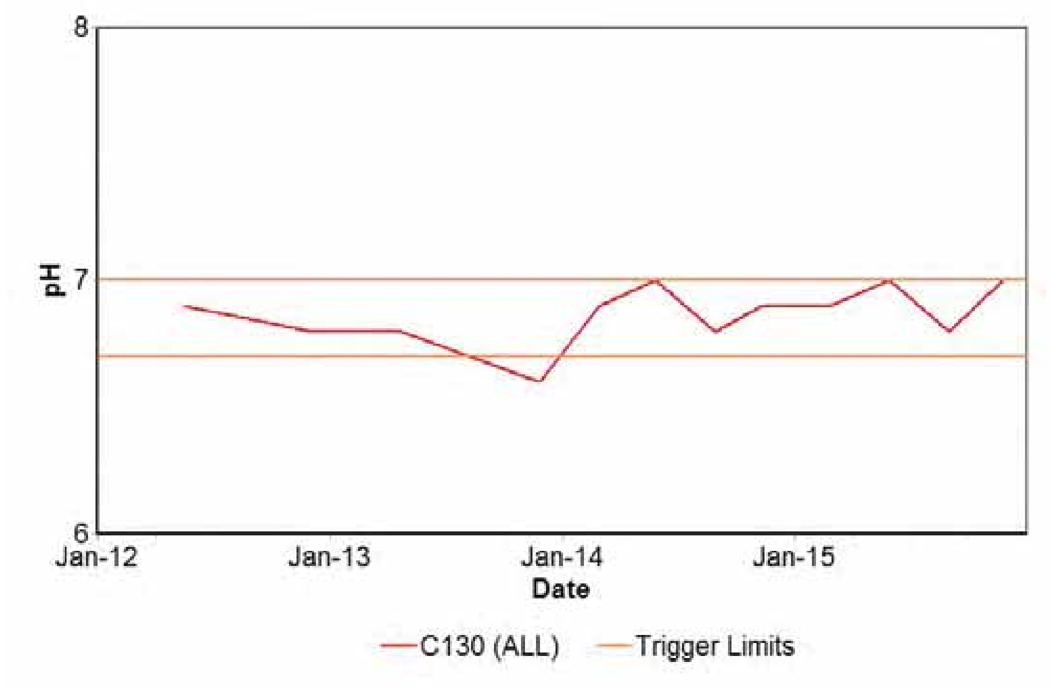


Figure 81: Lemington South Interburden pH Trends 2012 – 2015

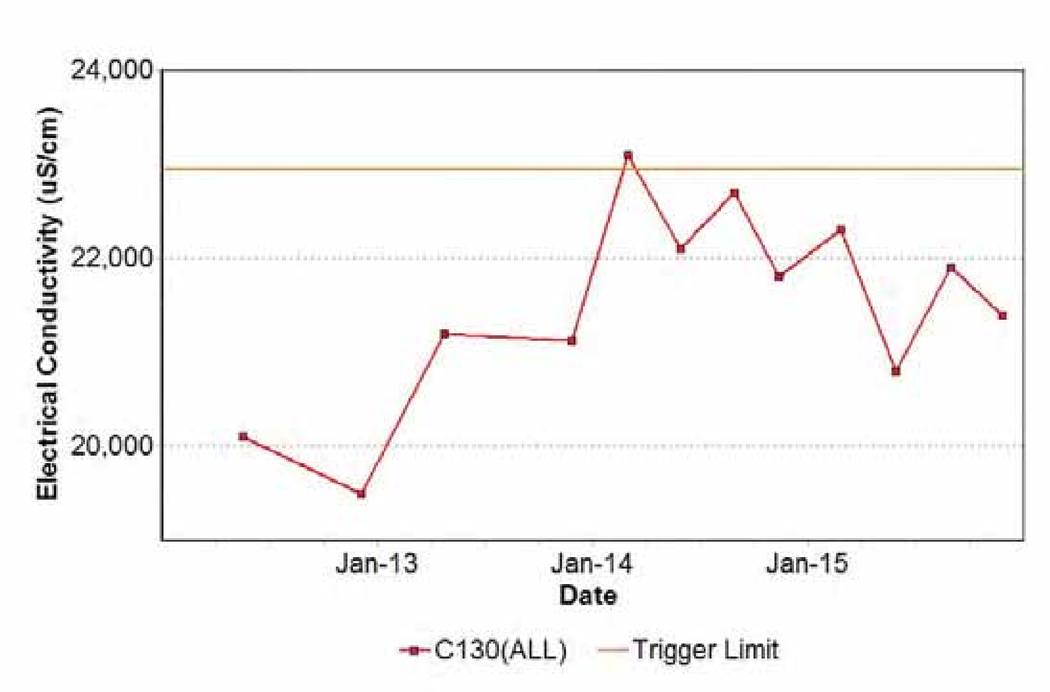


Figure 82: Lemington South Interburden EC Trends 2012 - 2015

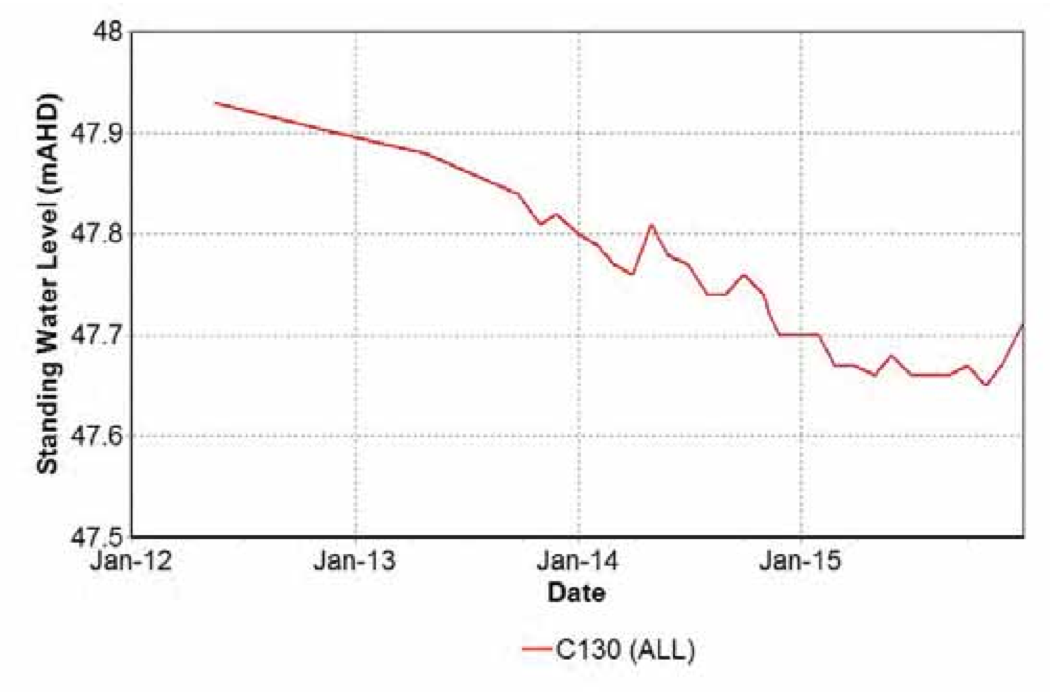


Figure 83: Lemington South Interburden SWL Trend 2012 - 2015

7.6.2.1.14 Lemington South Woodlands Hill

Groundwater monitoring in the Lemington South Woodlands Hill seam was undertaken at seven sites during 2015. A total of 14 samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for Lemington South Woodlands Hill groundwater bores are shown in Figure 84 to Figure 86.

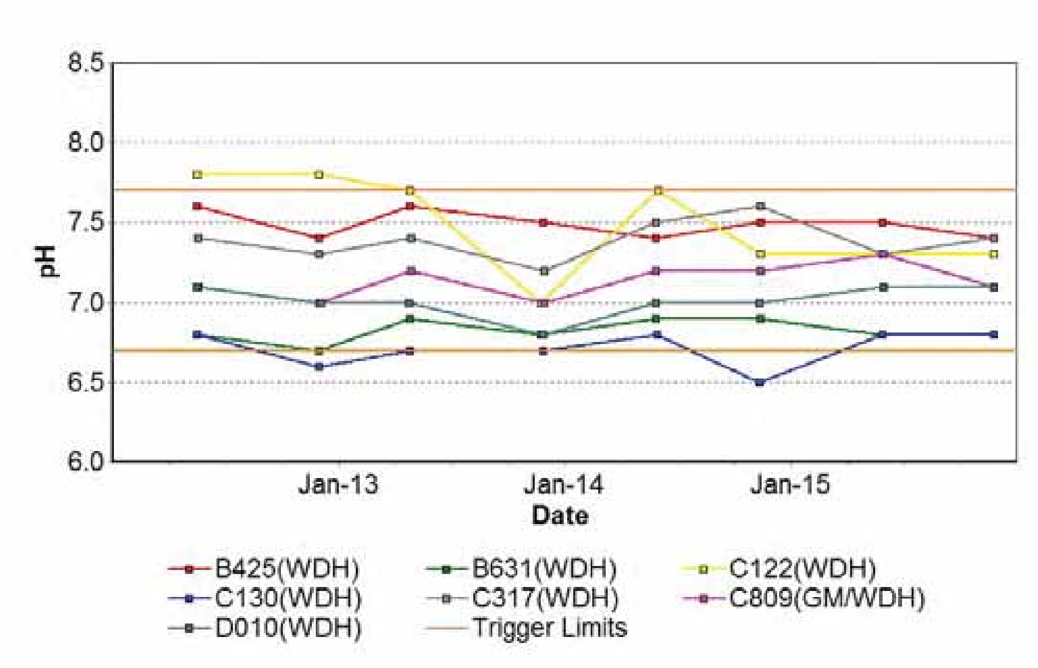


Figure 84: Lemington South Woodlands Hill Groundwater pH Trends 2012 – 2015

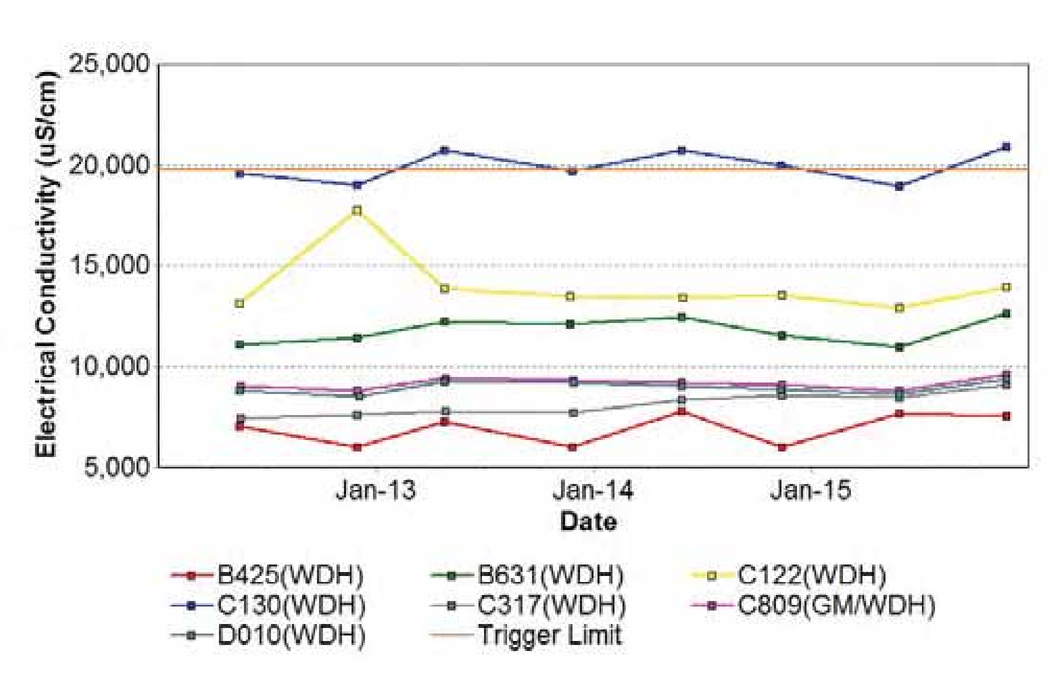


Figure 85: Lemington South Woodlands Hill Groundwater EC Trends 2012 – 2015

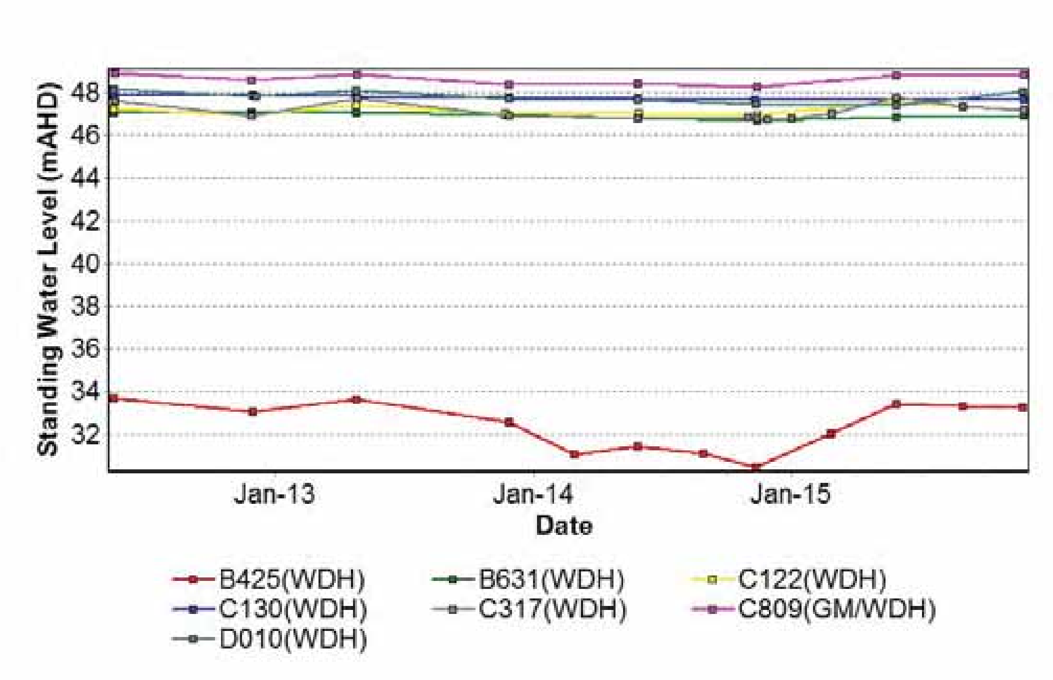


Figure 86: Lemington South Woodlands Hill Groundwater SWL Trends 2012 - 2015

7.6.2.1.15 North Pit Spoil

Groundwater monitoring in the North Pit Spoil area was undertaken at 15 sites during 2015. A total of 60 samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for North Pit Spoil groundwater bores are shown in Figure 87 to Figure 94.

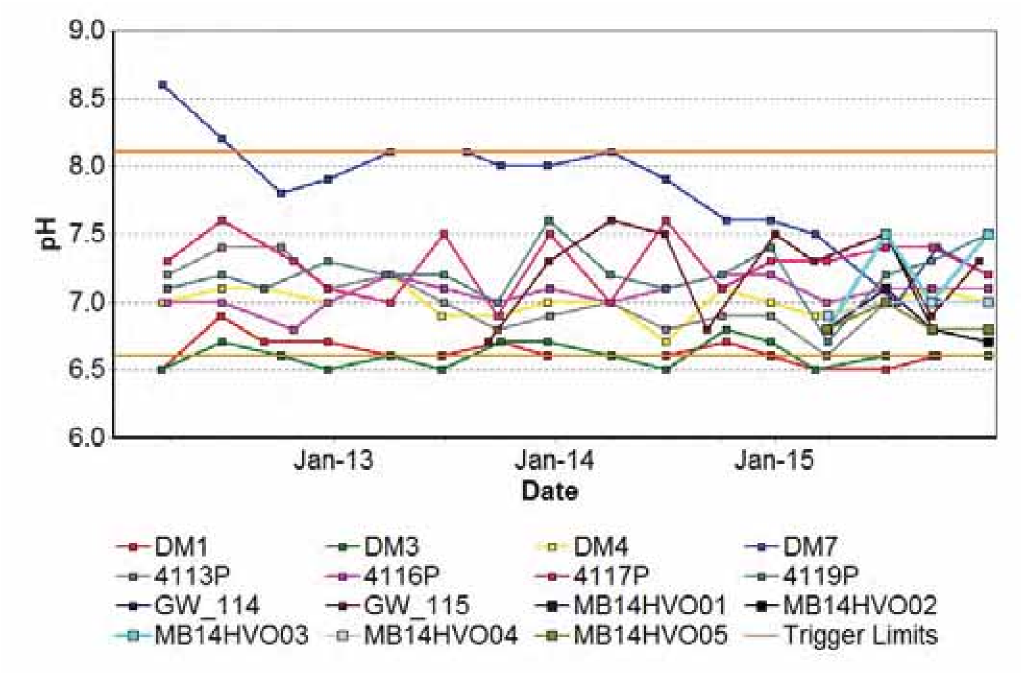


Figure 87: North Pit Spoil Groundwater pH Trends 2012 – 2015

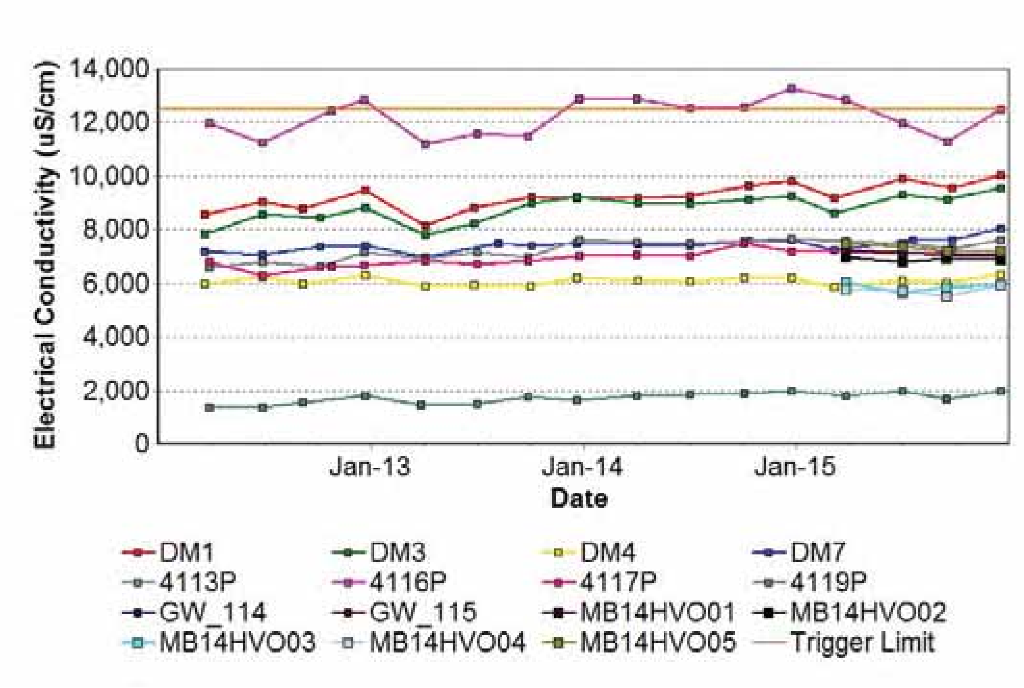


Figure 88: North Pit Spoil Groundwater EC Trends 2012 – 2015

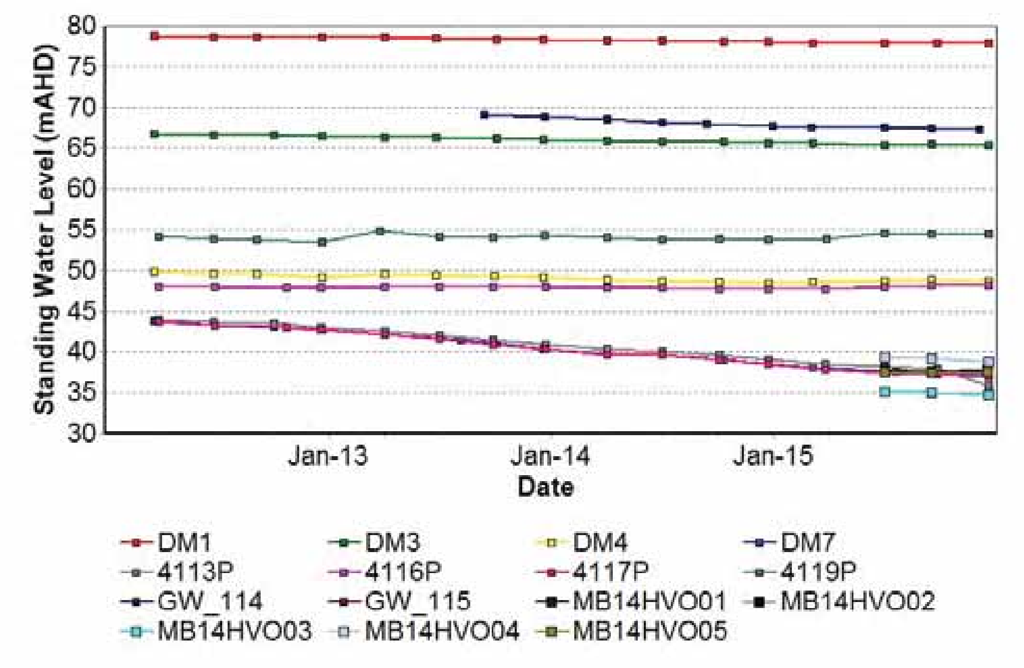


Figure 89: North Pit Spoil Groundwater SWL Trends 2012 – 2015

7.6.2.1.16 West Pit Alluvium

Groundwater monitoring in the West Pit Alluvium area was undertaken at three sites during 2015. A total of 12 samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for West Pit Alluvium groundwater bores are shown in Figure 90 to Figure 92.

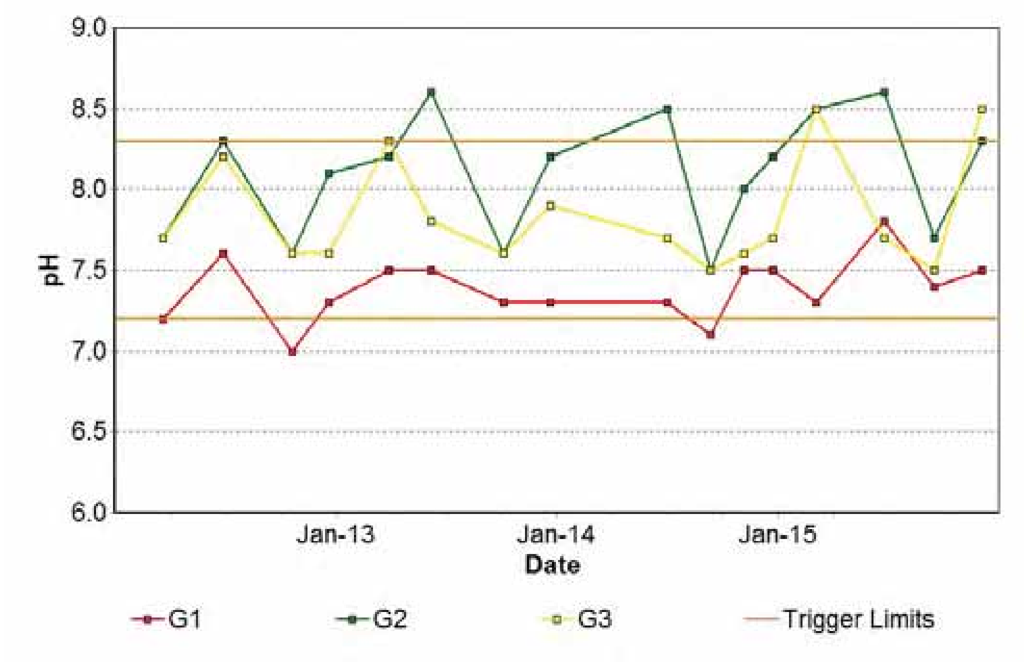


Figure 90: West Pit Alluvium Groundwater pH Trends 2012 – 2015

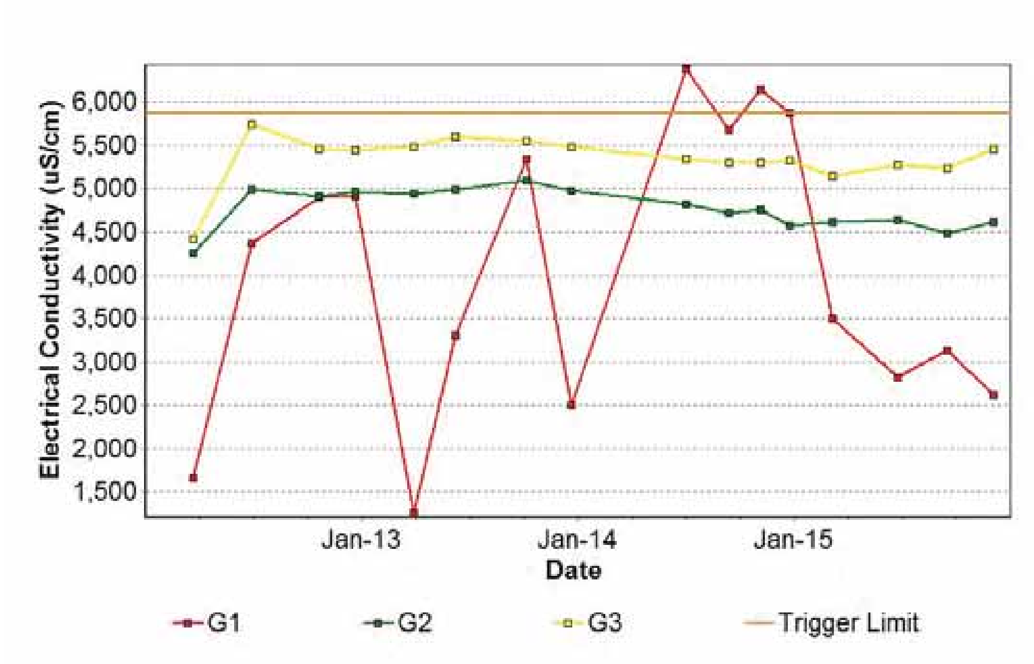


Figure 91: West Pit Alluvium Groundwater EC Trends 2012 – 2015

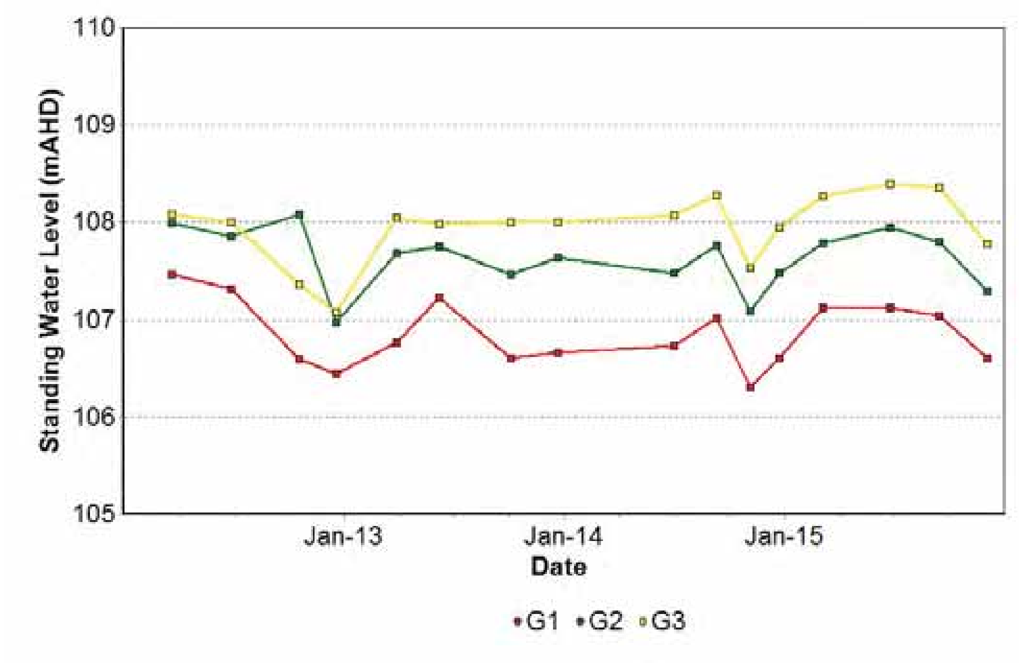


Figure 92: West Pit Alluvium Groundwater SWL Trends 2012 – 2015

7.6.2.1.17 West Pit Sandstone/ Siltstone

Groundwater monitoring in the West Pit Sandstone/ Siltstone area was undertaken at four sites during 2015. A total of 16 samples were collected during the reporting period. The pH, EC and SWL trends for 2012 to 2015 for West Pit Sandstone/ Siltstone groundwater bores are shown in Figure 93 to Figure 95.

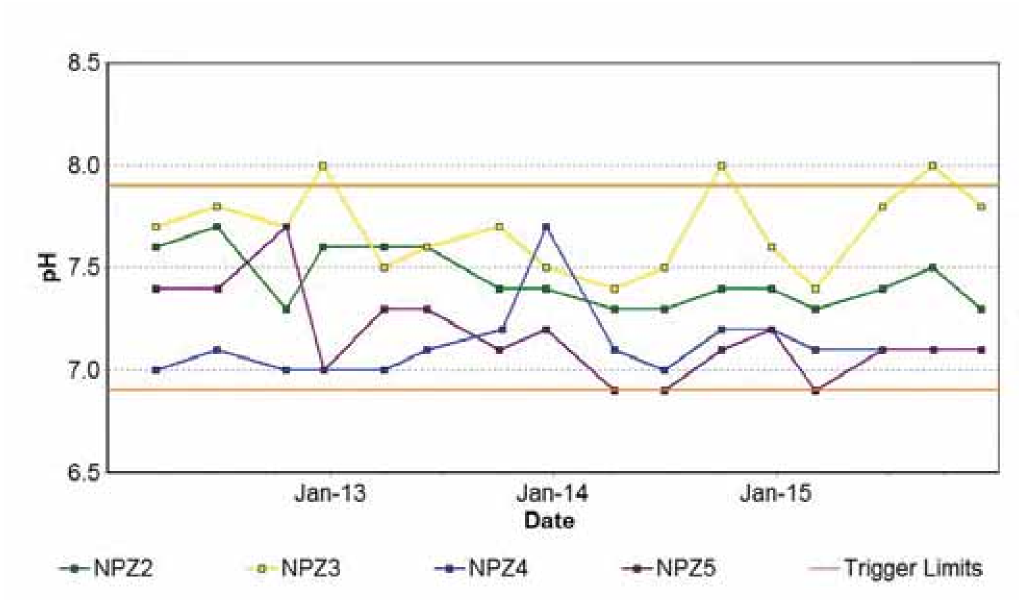


Figure 93: West Pit Sandstone/ Siltstone Groundwater pH Trends 2012 – 2015

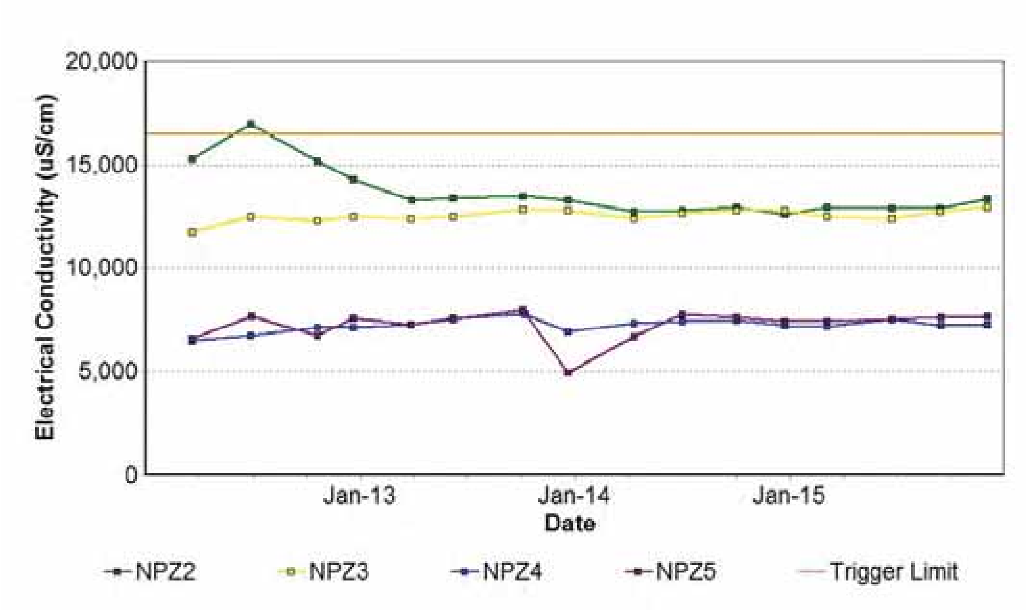


Figure 94: West Pit Sandstone/ Siltstone Groundwater EC Trends 2012 – 2015

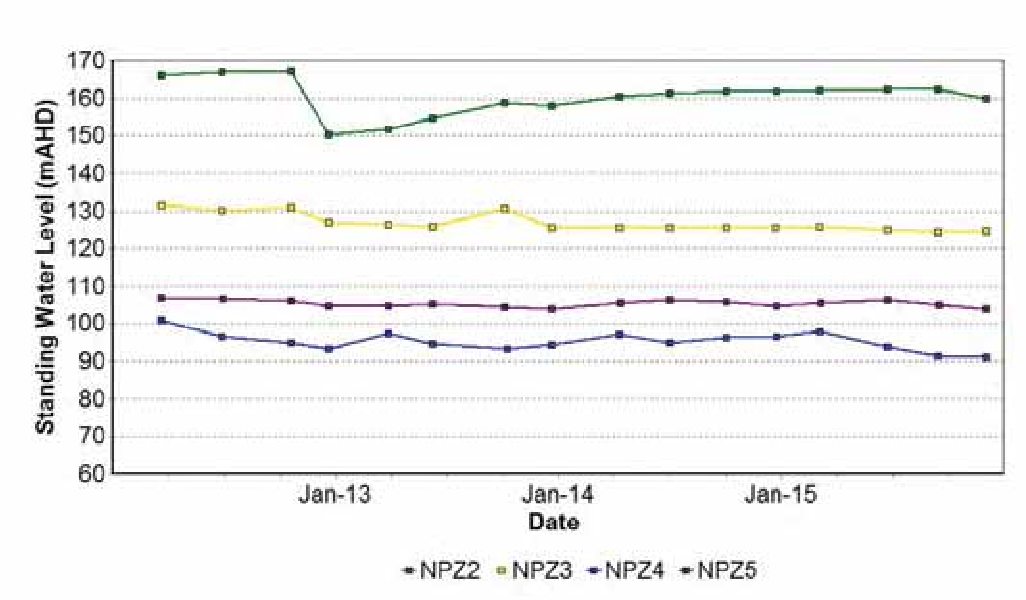


Figure 95: West Pit Sandstone/ Siltstone Groundwater SWL Trends 2012 – 2015

7.6.3 Groundwater Contours

Groundwater contour maps showing the alluvial and coal seam aquifers for HVO North and South are given in Appendix 2. The data is consistent with historical trends.

7.6.3.1 Ground Water Non-compliances during reporting period

There were no reportable incidents/non-compliances of consent or other approval conditions and no complaints relating to groundwater.

8 REHABILITATION AND LAND MANAGEMENT

8.1 Summary of Rehabilitation

Rehabilitation at HVO is undertaken in accordance with commitments made in the various Mining Operations Plans (MOPs) covering the site: Hunter Valley Operations North MOP (includes Newdell CHPP and Hunter Valley Load Point) and Hunter Valley Operations South MOP.

A summary of the key rehabilitation performance indicators is shown in Table 38.

Table 38: Key Rehabilitation Performance Indicators

Mine Area Type	Previous Reporting Period (Actual) Year 2015-1 (ha)	This Reporting Period (Actual) Year 2015 (ha)	Next Reporting Period (Forecast) Year 2015+1 (ha)
A. Total mine footprint[2]	6,155.9	6,462.0	6,669.8
B. Total Active Disturbance[3]	3,387.2	3,679.1	4,096.5
C. Land being prepared for rehabilitation[4]	29.1	49.3	43.3
D. Land under active rehabilitation[5]	2,739.6	2,733.6	2,530
E. Completed rehabilitation[6]	0	0	0

[2] **Total mine footprint** includes all areas within a mining lease that either have at some point in time or continue to pose a rehabilitation liability due to mining and associated activities. As such it is the sum of total active disturbance, decommissioning, landform establishment, growth medium development, ecosystem establishment, ecosystem development and relinquished lands (as defined in DRE MOP/RMP Guidelines). Please note that subsidence remediation areas are excluded.

[3] **Total active disturbance** includes all areas ultimately requiring rehabilitation such as: on-lease exploration areas, stripped areas ahead of mining, infrastructure areas, water management infrastructure, sewage treatment facilities, topsoil stockpiles areas, access tracks and haul road, active mining areas, waste emplacements (active/unshaped/in or out-of-pit), and tailings dams (active/unshaped/uncapped).

[4] **Land being prepared for rehabilitation** – includes the sum of mine disturbed land that is under the following rehabilitation phases – decommissioning, landform establishment and growth medium development (as defined in DRE MOP/RMP Guidelines).

[5] **Land under active rehabilitation** – includes areas under rehabilitation and being managed to achieve relinquishment – includes the following rehabilitation phases as described in the DRE MOP/RMP Guidelines – "ecosystem and land use sustainability" (revegetation assessed as showing signs of trending towards relinquishment OR infrastructure development).

[6] **Completed rehabilitation** – requires formal sign off by DRE that the area has successfully met the rehabilitation land use objectives and completion criteria.

8.1.1 Management

Performance criteria for each rehabilitation phase have been detailed in the Mining Operations Plan (MOP) for both HVO North and HVO South. These criteria have been developed so that the rehabilitation success can be quantitatively tracked as it progresses through the phases outlined below:

- Stage 1 – Decommissioning
- Stage 2 – Landform Establishment
- Stage 3 – Growing Media Development
- Stage 4 – Ecosystem and Land use Establishment
- Stage 5 – Ecosystem and Land use Sustainability
- Stage 6 – Rehabilitation Complete

The performance criteria are objective target levels or values that can be measured to quantitatively demonstrate the progress and ultimate success of a biophysical process. A monitoring methodology has been developed to measure the performance criteria outlined in the MOPs utilising a combination of tools that provide quantitative data to assess changes occurring over time.

Although the performance criteria have been set, the target levels or values will be based on monitoring results from reference sites and therefore not determined until the end of 2016. After 2016, the results of the rehabilitation monitoring programme will be able to be compared against the target levels to determine if rehabilitation has been successful or if additional intervention is needed.

Monitoring of grazing sites has commenced for both reference sites and rehabilitation sites across HVO and MTW. AECOM prepared a report detailing the monitoring results and this was included in the 2014 Annual Environmental Review. Eight reference sites have been selected across Coal & Allied owned land adjacent to HVO and MTW. These sites were selected to cover the various soil types found in the area and to cover different Land Capability Classes (five sites on Land Capability Class IV to VI; and three sites on Land Capability Class I-III). Monitoring has also been conducted on four sites each at HVO and MTW on rehabilitated land returned to grazing.

The monitoring program for rehabilitated land returned to native vegetation was commenced by ecologists from Niche Environment and Heritage during 2015. A report has been prepared, detailing the results of this monitoring program, and is presented in Appendix 5. Monitoring was conducted across 12 reference sites within the two target vegetation communities Central Hunter Grey Box-Ironbark Woodland EEC, and Ironbark-Spotted Gum-Grey Box Forest EEC. A total of 19 rehabilitation sites were monitored across HVO with sites selected to include rehabilitation of varying ages and different rehabilitation methods.

8.2 Grazing Trial

Monitoring of the grazing trial by DPI personnel continued during 2015. This trial was initiated by the Upper Hunter Mining Dialogue in 2014 and is designed to test the suitability of rehabilitated mined land for cattle grazing. The grazing trial consists of two trial sites, one on rehabilitated land at HVO, and a control site on neighbouring un-mined land. The trial sites are 40 hectares each, with 10 Angus steers currently being grazed on each site.

The results of the cattle weighing are shown in Figure 96 and Figure 97 below. It can be seen that the cattle grazing on the rehabilitation paddocks have consistently outperformed the cattle on the unmined paddocks. After 17 months on the grazing trial the rehabilitation cattle, on average, weigh 160kg per head more than the cattle on the unmined paddocks.

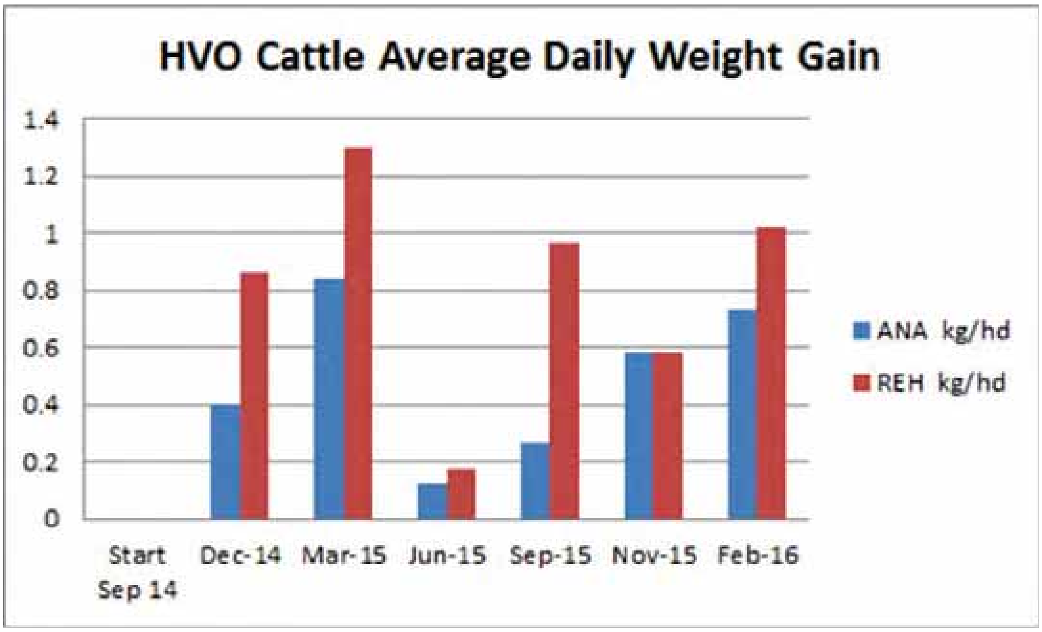


Figure 96: Grazing Trial Results – Cattle Average Daily Weight Gain

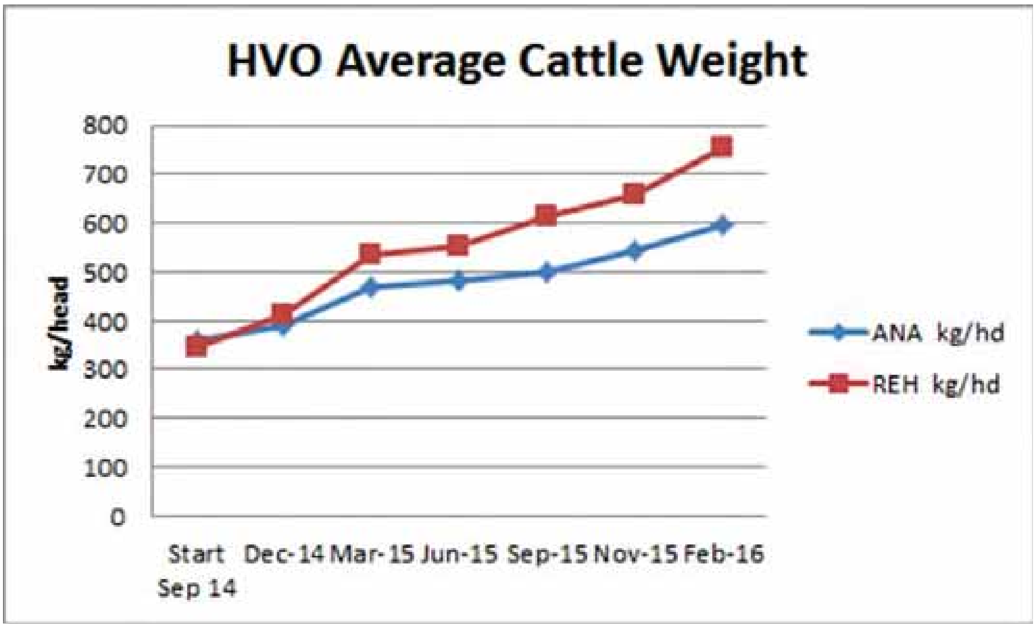


Figure 97: Grazing Trial Results - Average Weight Gain

8.3 Rehabilitation Performance

A total of 129.6 ha rehabilitation was undertaken during 2015. Details of the rehabilitation areas and the works undertaken are provided in Appendix 4. A map outlining the location of completed rehabilitation is included in Figure 98.

Table 39 and Table 40 detail the amount of rehabilitation and disturbance completed during the reporting period compared with commitments in the respective MOP's. Appendix 3 provides the Annual Rehabilitation Report Form, including rehabilitation progress for each domain through the rehabilitation phases.

Table 39: Summary of completed rehabilitation in 2015

MOP	2015 Rehabilitation (ha)		Cumulative Rehabilitation During Current MOP Period (ha)	
	Actual	MOP Commitment	Actual	MOP Commitment
HVO North	64.6	75.2	239.2	328.7*
HVO South	65.0	54.8	65.0	54.8*
HVO Total	129.6	130.0	304.2	383.5

Notes:
Comparison with HVO North MOP (2012 to 2018) and HVO South MOP (2015 to 2018, approved 17 Dec 2015);

*Cumulative MOP figures are for periods: HVO North 2012-2015 and HVO South 2015

Table 40: Summary of completed disturbance in 2015

MOP	2015 Disturbance (ha)		Cumulative Disturbance During Current MOP Period (ha)	
	Actual	MOP Commitment	Actual	MOP Commitment*
HVO North	71.7	118.6	290.6	392.1
HVO South	101.1	103.3	101.1	103.3
HVO Total	172.8	221.9	391.7	495.4

Notes:
Comparison with HVO North MOP (2012 to 2018) and HVO South MOP (2015 to 2018);
*Cumulative MOP figures are for periods: HVO North 2012-2015 and HVO South 2015

Rehabilitation figures presented relate to areas at or past the phase of Ecosystem and Landuse Establishment. The area of rehabilitation that was sown during the reporting period was only 0.4 hectares below the MOP commitment.

The area of land disturbed at HVO during 2015 was 172.8 ha, which was lower than the projected MOP disturbance of 221.9 ha. Disturbance of rehabilitation land accounted for 63.2 ha of the total area disturbed, with 42 ha of this rehabilitation disturbance occurring in West Pit to allow dumps to be lifted to the level of the MOP final landform. The remainder was primarily associated with relocation of the HVO Link Road and Cheshunt crib hut facilities.

A comparison for rehabilitation progression against predictions in Figure 9 of the HVO West Pit Extension and Minor Modifications Environmental Impact Statement (EIS) Volume 4 (October 2003) indicate that rehabilitation progression is generally consistent with EIS predictions. At the end of 2015, rehabilitation area totalling 1,746ha has been completed for HVO North compared to the EIS projection at 2011 of 1,733ha. West Pit rehabilitation is ahead of projections while Carrington/North Pit is behind. Contributing factors for this lag are: Southeast and Central TSF's haven't been rehabilitated due to geotechnical instability preventing capping; Carrington Out of Pit Dump planned to provide capping material for North Void, SE and Central TSF's and hence not rehabilitated; and approval gained from Carrington Pit Extended Statement of Environmental Effects (October 2005) for additional disturbance of previously rehabilitated areas that are included in the EIS 2003 rehab polygons for 2011.

As at the end of 2015, rehabilitation progress for HVO South is ahead of the predictions in the HVO South Coal Project Environmental Assessment Report (January 2008). Figure 19.3 of the Environmental Assessment Report shows 597.2ha of rehabilitation completed as at the end of 2007 with a prediction of a further 275.5ha to be completed in the period 2008 to 2016. The actual rehabilitation area at the end of 2015 is 996ha which is ahead of the EA report predictions for the end of 2016 of 872ha.

Maps in Appendix 4 show the progression of rehabilitation in the various pits at HVO, including comparisons to the EA predictions.

8.4 Rehabilitation Programme Variations

The variations to the rehabilitation programme are summarised in Table 41.

Table 41: Variations to the Rehabilitation Programme

Has rehabilitation work proceeded generally in accordance with the conditions of an accepted Mining Operations Plan	HVO North - Substantially (see below) HVO South – Yes
If not please cite any approval granted for variations, or briefly describe the seasonal conditions or other reasons for any changes and the nature of any changes which have been made.	
Actual rehabilitation completed in HVO North during period 2012 to 2015 = 239.2ha. MOP target for rehabilitation in HVO North during period 2012 to 2015 = 328.7ha. Spoil dump areas at Carrington that were planned to be rehabilitated in the HVO North MOP by the end of 2015 have not been completed due to uncertainty surrounding the possible interacting uses of Carrington as an in-pit tailings storage facility and evaporative sink. Dump progress in West Pit Centre Dump area has also been slower than the MOP forecast.	

Management of Rehabilitated Areas is undertaken when required or when issues are identified through monitoring, auditing or inspections. During 2015, a maintenance fertiliser application was applied to 89 ha of established pasture rehabilitation in North Pit. Rehabilitation maintenance, in the form of re-grading of the slope above the Riverview Void and contour bank repairs was continued in 2015 to repair approximately 5.7 ha of eroded rehabilitation.

A licence agreement is in place for grazing 719 ha of HVO North rehabilitation area. Temporary grazing licences aimed at reducing fuel loads are in place for a further 212 ha of rehabilitated land across HVO North.

During 2015, a weed wiper was trialled in rehabilitation areas to enable taller growing weeds to be selectively targeted with herbicide. The weed wiper was found to be effective at removing quick-growing exotic grass species (ie Rhodes Grass, Green Panic etc.) from areas that had been sown with native seed mixes.

Figure 98: HVO Rehabilitation areas - 2015

8.5 Top Soil Management

Topsoil is managed according to Coal & Allied Ground Disturbance Permit and land management procedures. Table 42 outlines the topsoil used and stockpiled during 2015. There were 129 ha of rehabilitation top soiled during 2015, using stockpiled and pre-stripped soil resources.

Table 42: Soil Management

Soil Used This Period (m^3)	Soil Prestripped This Period (m^3)	Soil Stockpiled to Date (m^3)	Soil Stockpiled Last Report (m^3)
129,000	172,900	1,798,013	1,841,913

8.6 Tailings Management

Australian Tailings Consultants have designed a Stage 1 Capping program for the Southeast TSF following geotechnical investigations that were conducted during 2014. Capping of this facility will commence during 2016, with rehabilitation scheduled to be completed during 2017. A Fine Rejects Management Strategy for HVO has been developed in accordance with the planning approval for HVO North (Clause 28A of DA 450-10-2003 Mod 4). A revised strategy was submitted on 3rd February 2016 to address feedback provided by DP&E and DRE. The strategy outlines tailings management for the time horizon spanned by current approvals.

Minimising the amount of standing water on tailings storage facilities, by managing the decant water, is important during and post tailings deposition to assist with closure of these facilities. Effective removal of decant water enables better consolidation of the tailings material, which in turn facilitates earlier capping and rehabilitation of the storage facility. Table 43 below outlines the current state of decant water pumping infrastructure across the active and inactive TSF's at HVO.

Table 43: HVO Tailings Storage Facilities

Facility	Status	Decant System
North Void	Active	Decant pumps in place, regular pumping.
Dam 6W	Active	Decant pump in place, regular pumping.
Bob's Dump	Inactive	No pumps installed due to decant pond being inaccessible. Works to be undertaken during 2016 to allow access for pumping.
Southeast TSF	Inactive	Diesel pump in place, pumping as required.
Central TSF	Inactive	No pumps required due to rapid drying after rainfall (small catchment reporting to TSF).

8.7 Carrington Billabong

Cattle grazing has been excluded from the Carrington Billabong since 2007 to reduce the impact on native vegetation. During spring 2015 a native tube stock planting programme was undertaken in the Carrington Billabong including grasses, shrubs and small trees making up a total of 1000 plants. These were broken down into 500 grasses, 250 shrubs and 250 small trees. The tube stock were planted into weed mat islands that were fenced off for protection against rabbit and kangaroo browsing. In addition to these tube stock 300 River Red Gum tube stock were planted into the area during early December. Plants were watered in at the time of planting and have received ongoing watering over the summer period.

Figure 99: Native tube stock planting at Carrington Billabong 2015

Fencing works were undertaken in 2014 to exclude cattle from a number of priority sites along the Hunter River and Wollombi Brook. Weed management commenced in these areas and continued in 2015 to reduce the weed population. Weed management activities were implemented in accordance with the Weed Management Plan at the Billabong which included the use of selective herbicide to eradicate annual weeds, as well as targeting Galenia (*Galenia pubescens*), Tiger Pear (*Opuntia aurantiaca*), Prickly Pear (*Opuntia stricta*), Castor Oil (*Ricinus communis*), Farmer's Friend (Bidens pilosa) and various Thistles (*Onopordum acanthium*), (*Carthamus lanatus*), (*Silybum mariamum*). Throughout 2016 ongoing weed control will be targeted at facilitating survival of seedlings from planting activities and from natural recruitment of *E. camaldulensis*.

8.8 Weed Control

8.8.1 Weed Treatment

Weed management and control work occurred between January and December 2015. Monitoring of the weed control program to assess the success of weed control works has been undertaken on a quarterly basis by REM, with the results used to provide a services plan for the upcoming quarter.

Weed management targeted a variety of areas across the site, including mining rehabilitation areas (Carrington Billabong and River Red Gum populations) and maintenance and improvement of environmental monitoring sites such as tracks and groundwater bores to improve accessibility and safety by monitoring contractors. A total of 71 days of weed treatment work was undertaken on site at Hunter Valley Operations during 2015 with a total of approximately 103 hectares of land treated, including maintenance of access tracks and approximately 134 environmental monitoring points. The target species and treatment areas are shown in Figure 97 to Figure 99.

The species focussed on during treatment included:

- *African Boxthorn (Lycium ferocissimum)*
- *Castor Oil Plant (Ricinus communis)*
- *Galenia (Galenia pubescens)*
- *Golden Dodder (Cuscuta campestris)*
- *Mother of Millions (Bryophyllum delagoense)*
- *Opuntia (Pear) species (Tiger, Prickly and Creeping Pear)*
- *St John's Wort (Hypericum perforatum)*
- *Thistles: Saffron Thistle (Carthamus lanatus), Scotch Thistle (Onopordum acanthium) and Variegated Thistle (Silybum marianum)*

8.8.2 Annual Weed Survey

The management and control of weeds at Hunter Valley Operations is governed by the Annual Weed Survey (AWS) produced by Rural & Environmental Management Pty Ltd (REM). The AWS lists Weeds of National Significance (WONS), noxious and environmental weed species as identified at Hunter Valley Operations, and provides a framework to allow for structured weed management and control across operational and non-operational areas of Hunter Valley Operations.

The annual site weed survey was undertaken during November 2015. The following summarises the results of the survey:

Five WONS were identified during the survey, they included:

- African Boxthorn (*Lycium ferocissimum)*
- Lantana (Lantana camara)
- Pear Species,
- Creeping Pear (Opuntia humifusa)
- Prickly Pear Opuntia stricta)
- Tiger Pear (Optunia aurantiaca)

Five other noxious weeds were identified at HVO during the survey, including:

- Mother of Millions (Bryophyllum delagonese)
- St Johns Wort (Hypericum perforatum)
- Golden Dodder (Cuscuta campestris)
- Pampas Grass (Cortaderia selloana)
- Green Cestrum (Cestrum parquil)

Nine environmental weed species were identified at HVO during the survey, they included:

- African Olive (Olea europea subspecies cuspidae)
- Balloon Vine (Cardiospermum grandiflorum)
- Caster Oil Plant (Ricinus communis)
- Galenia (Galenia pubescens)
- Moth Vine (Araujia sericifera)
- Tree Tobacco (Nicotiana glauca)
- Various Thistles
  - Scotch Thistle (Onopordum acanthium),
  - Scotch Thistle (Onopordum acanthium),
  - Saffron Thistle(Carthamus lanatus)
  - Variegated Thistle (Silybum marianum) (to a lesser degree)

Seven weeds that are not officially declared or listed were also recorded at HVO including:

- Century plant (Agave americana)
- Fennel (Foeniculum vulgare), sparsely scattered over entire site
- Golden wreath wattle or Saligna (Acacia saligna) – sparsely scattered over entire site
- Narrow Leaved cotton bush (Gomphocarpus fructicosus)- sparsely scattered over entire site
- Mallow (Small-flowered Mallow) (Malva parviflora)
- Mustard Weed(Sisymbrium sp)
- Spiny Rush (Juncas acutus)
- Species identified during the 2015 survey will form the basis of ongoing weed management works during 2016.

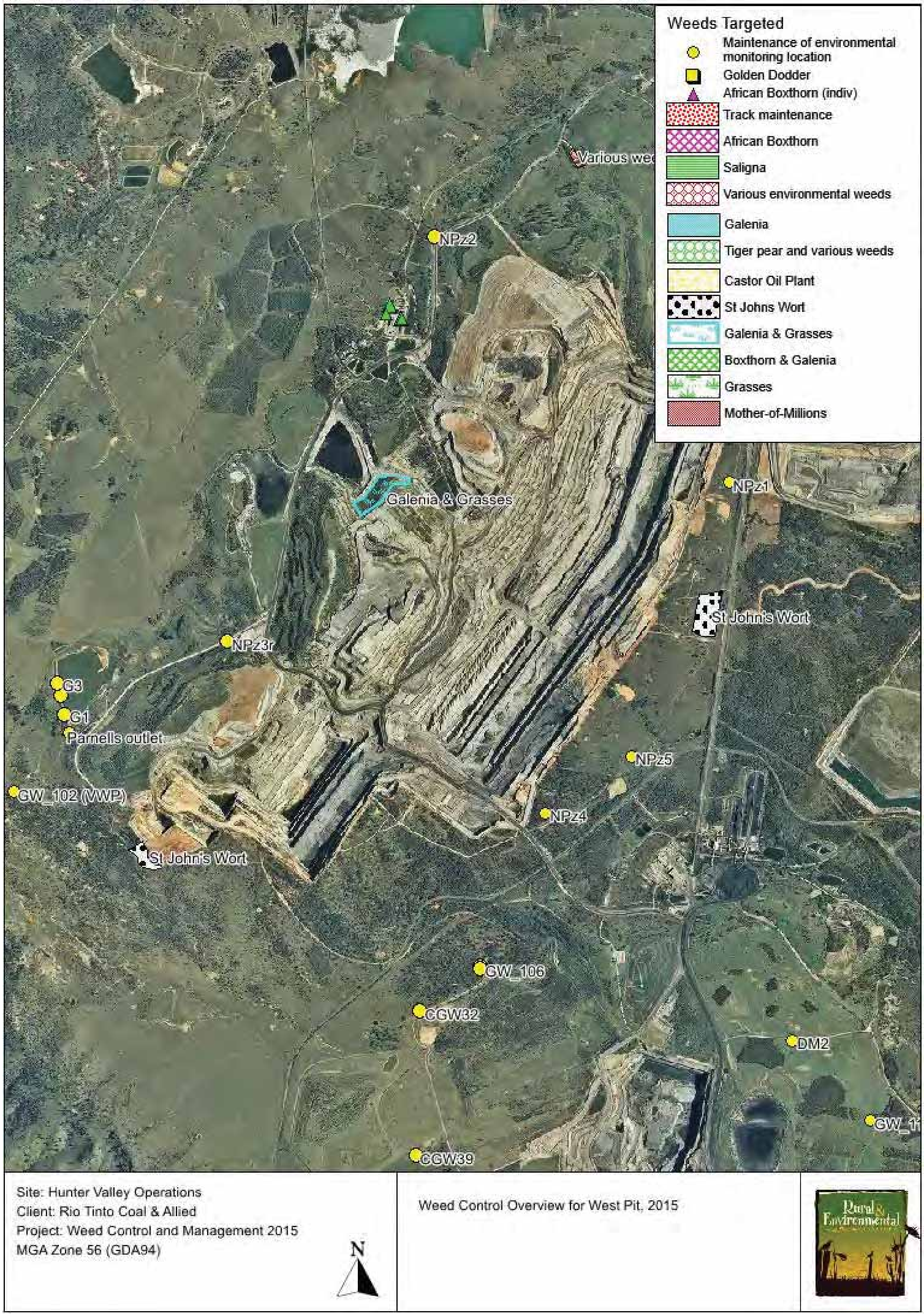


Figure 100: Weed Control Overview for West Pit - 2015

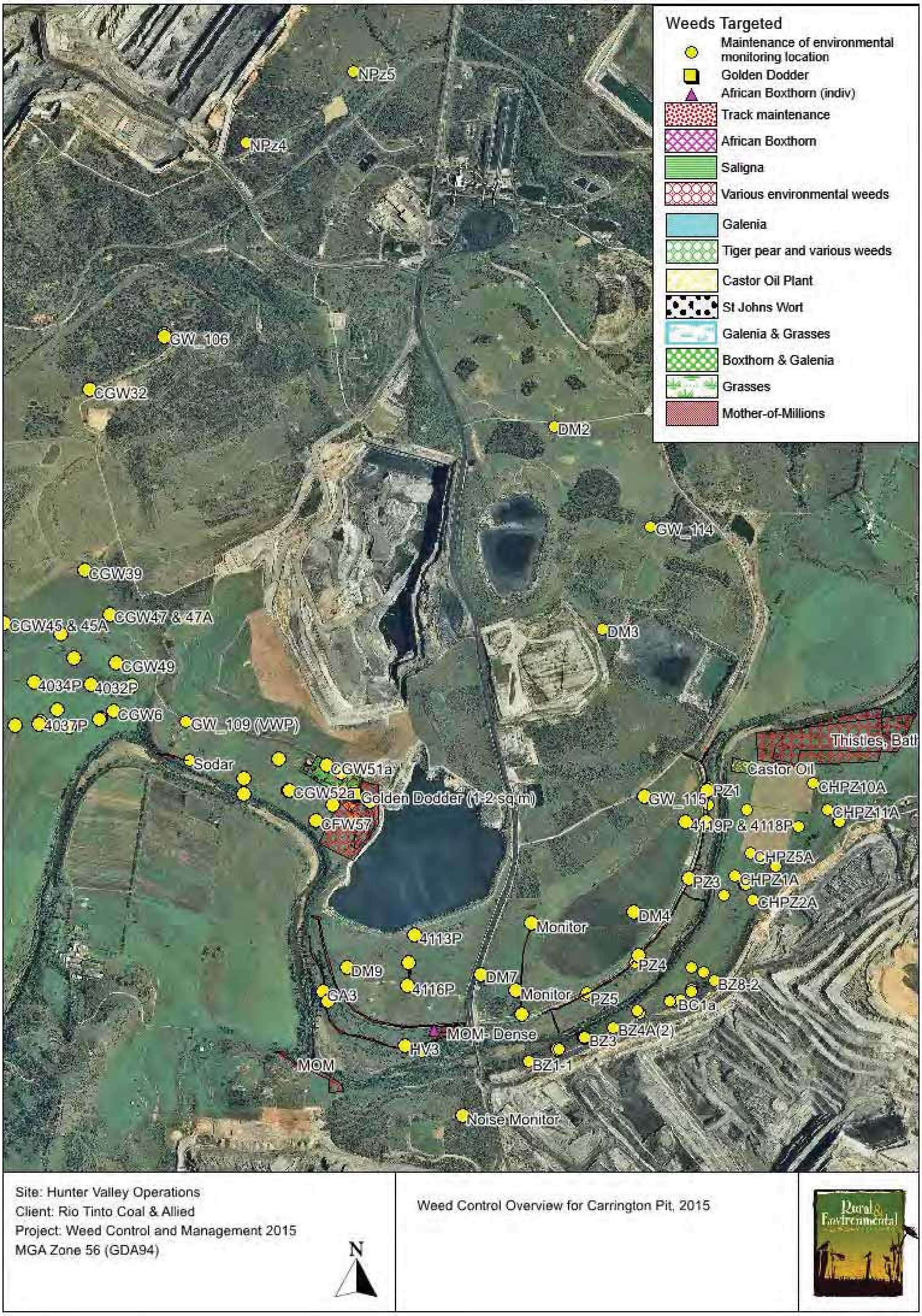


Figure 101: Weed Control Overview for Carrington Pit - 2015

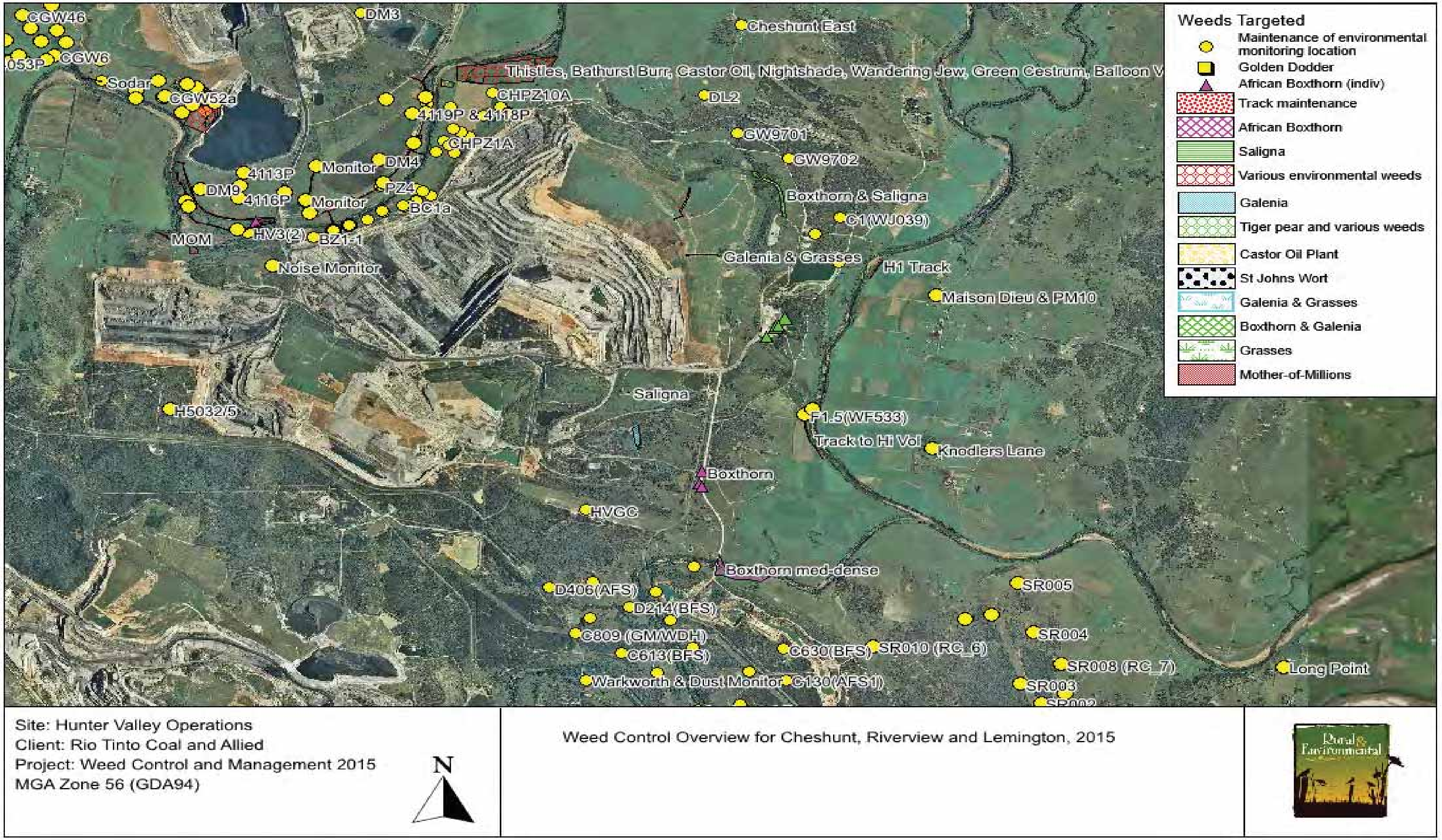


Figure 102: Weed Control Overview for Cheshunt and Riverview Pit - 2015

8.9 Vertebrate Pest Management

As part of HVO's Vertebrate Pest Action Plan, a control programme is carried out quarterly and on a seasonal basis. Two 1080 baiting programmes were undertaken during Winter and Spring 2015, to target wild dogs and foxes. Baits were checked weekly over a four week period and replaced each week where taken. In Winter, 55 baits were taken by dogs (and one by a feral pig) across 40 bait sites. In Spring, 71 baits were taken by dogs and eight taken by foxes over 60 bait sites.

Additional pest management programmes included:

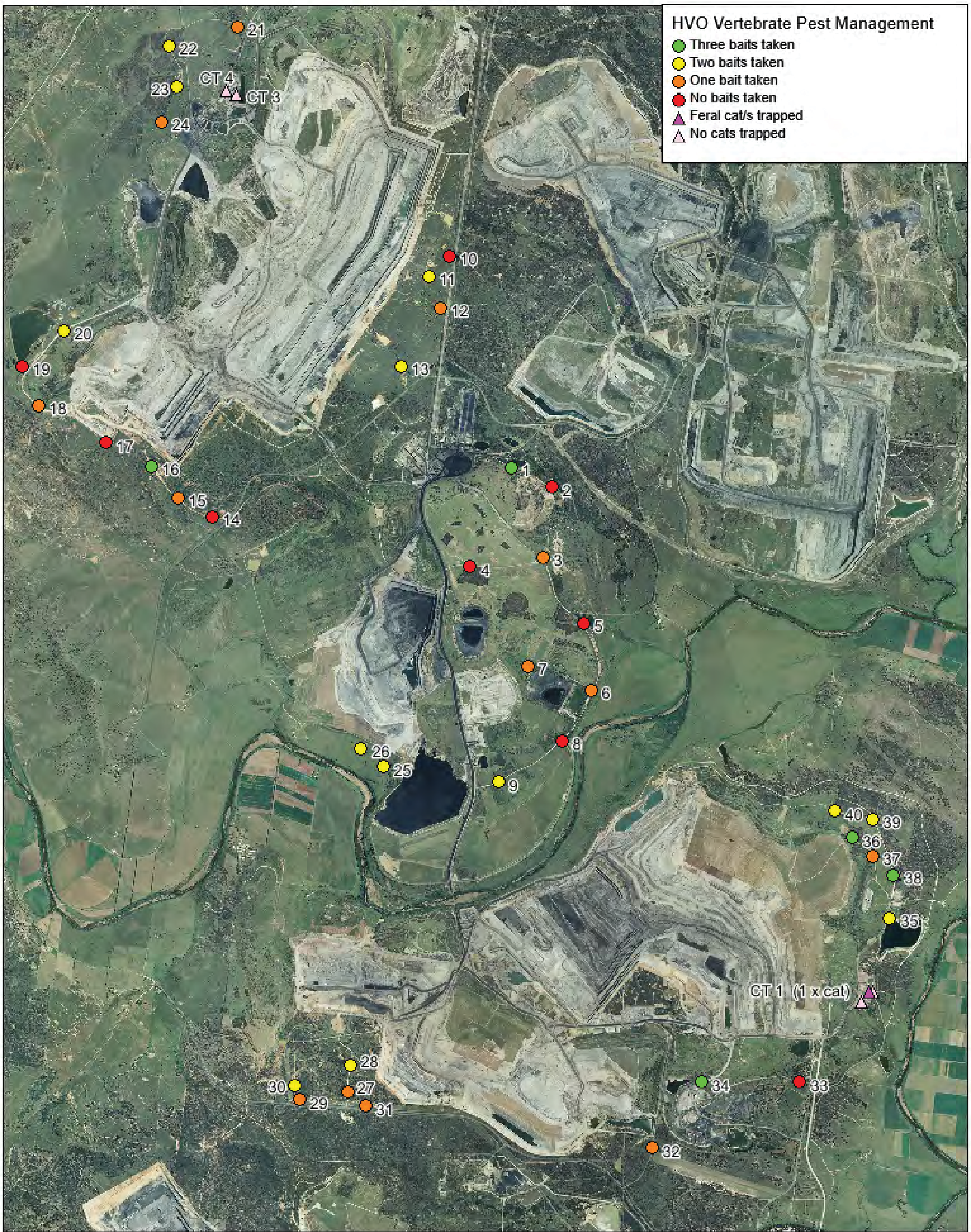
- Feral cat trapping; two cats were caught and humanely euthanised.
- Rabbit poisoning at the Carrington Billabong; 2400g out of 3200g of poisoned carrots were consumed over a six day period.
- Feral pig trapping in areas where pigs were evident at HVO during winter; three traps were set with eleven feral pigs trapped and euthanised.
- A further 180 pigs were trapped by control programmes undertaken by HVO and licensees on HVO owned non-mining land.

Table 44 summarises the results from the vertebrate management programmes carried out at HVO during 2015 with baiting locations and results for the Winter and Spring program illustrated in Figure 102 and Figure 103 respectively.

Table 44: Summary of Vertebrate Pest Management 2015

Season	Total Lethal Baits Laid	Baits taken by Wild Dog	Baits taken by Fox	Pigs Trapped	Wild Dogs Trapped	Feral Cats Trapped
Winter	120	55	0	191	1	1
Spring	180	71	8	-	-	1
Total	300	126	8	191	1	2

HVO will continue to carry out quarterly vertebrate pest control programmes during 2016 to limit feral pest impacts on landholdings and surrounding neighbours.



Site: Hunter Valley Operations
Client: Rio Tinto Coal & Allied
Project: Vertebrate Pest Management 2015
MGA Zone 56 (GDA94)

Program Results: Winter (16 June - 1 July 2015)
No. Bait Stations: 40
Poison Used: 1080 Baits

Figure 103: HVO Vertebrate Pest Management Bait Locations - Winter 2015

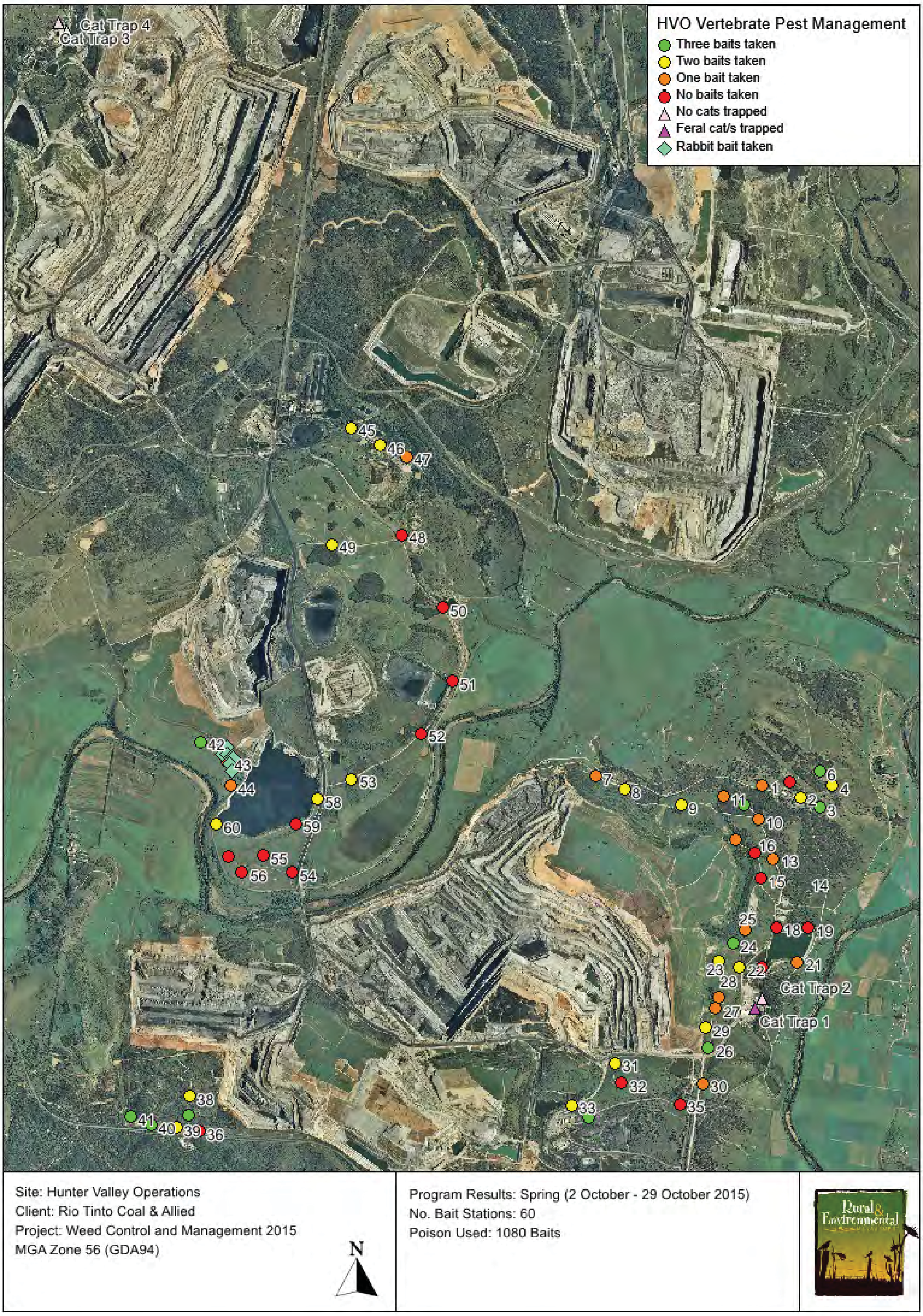


Figure 104: HVO Vertebrate Pest Management Bait Locations - Spring 2015

9 COMMUNITY

9.1 Complaints

During 2015 a total of 36 complaints were received by HVO. This represents an increase of 2 community complaints from the previous year. A full register of environmental complaints is detailed in Appendix 1. Complaints were received in relation to noise, dust and blasting. Figure 105 shows the breakdown of the environmental complaints for 2015, and also compares these complaints with those of previous years.

Coal & Allied provides a 24 hour Community Complaints Hotline (telephone: 1800 656 892) for community members to comment on concerns relating to its operations. All complaint details are recorded in accordance with Condition M4.2 of Environmental Protection Licence 640.

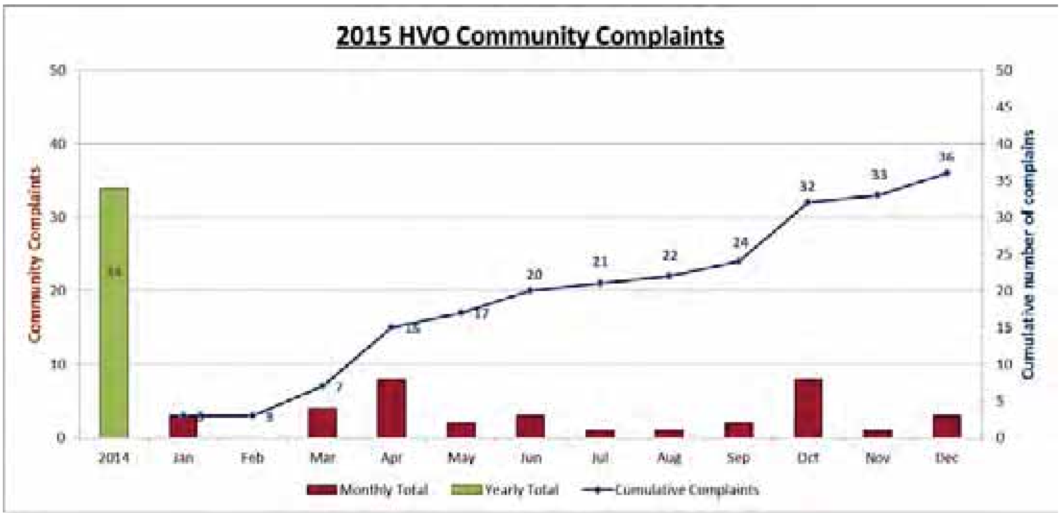


Figure 105: Community Complaints Breakdown

9.1.1 Noise Complaints

Fourteen noise complaints were received during 2015, compared to nine complaints received in 2014. Distribution of noise complaints received is as follows:

- Jerrys Plains Road residences – 11 complaints;
- Hunter Valley Gliding Club – 2 complaints; and
- Unknown location – 1 complaint.

9.1.2 Blasting Complaints

HVO received 19 complaints relating to blasting in 2015, the majority of which were regarding airblast overpressure or ground vibration from Jerrys Plains residents. The number of blast related complaints decreased from 2014 (24 complaints received). Of the 19 complaints, 15 were received from 2 households in Jerrys Plains. All blast measurements recorded in this area were below criteria and no significant increase in overpressure or vibration is evident compared to 2014 (Figure 9). One dust complaint was also received in relation to blasting during 2015.

9.1.3 Lighting Complaints

HVO received 2 lighting complaints during 2015. Both Lighting complaints related to lighting plants. The lighting plants were adjusted on the same shift to rectify the problem and lessen the lighting impact to the neighbouring properties.

9.2 Review of Community Engagement

9.2.1 Communication

Coal & Allied has previously distributed a Hunter Valley Community Newsletter, containing regular updates about HVO and its community activities, to businesses and residences in the Singleton and Muswellbrook Local Government Areas (LGAs). In 2015, an autumn edition of the newsletter was issued, before Coal & Allied transitioned to full-page newspaper advertorials. Newspaper advertorials were published in The Singleton Argus, Muswellbrook Chronicle and The Scone Advocate in the months of June and November. The three publications have a combined readership of approximately 16,000 people. Coal & Allied intends to continue to place these full-page advertorials as another way to communicate about its operations.

Quarterly letters are also sent to HVO's near neighbours to provide an overview of mining operations and other relevant activities, as well as inform residents about how impacts are being managed. In addition, Coal & Allied issues correspondence to specific near neighbours about work programmes occurring nearby. In 2015, this included communication about exploration drilling programmes and works at EL5291, as well as aerial seeding activities. Leasing tenants and nearby landowners were also informed of Coal & Allied's feral animal management program, including pig-culling and dog-baiting undertakings.

In 2015, Coal & Allied hosted two informal community barbeque events in June and December for near neighbours at Jerry's Plains. Events such as this are aimed at providing community members with an opportunity to speak with Coal & Allied representatives about current HVO mining plans and programmes. The events were attended by approximately 50 residents from Jerry's Plains, Maison Dieu, Long Point and surrounding areas in 2015, as well as Coal & Allied Environmental, Community Relations and Mining staff members. Details of the events were included in regular near neighbour communication, with invitations also displayed at Jerry's Plains Primary School and Jerry's Plains service station.

A range of consultation and engagement activities were also completed, including:

- Consultation with near neighbours to provide project updates at key project milestones and activities, and to response to concerns/queries raised by individual near neighbours
- School engagement- working with teachers and students to assist and enhance learning outcomes and build relationships
- Local Shire Council briefings

- Proactive near neighbour visits for residents living in the HVO area to discuss current operations and future plans for near neighbour engagement, as well as consultation to provide project updates at key project milestones and activities
- Participation in the Upper Hunter Mining Dialogue- a programme coordinated by the NSW Minerals Council to engage the community across the Hunter Valley
- Participation in the NSW Minerals Council Industry Business Agreement Steering Group

Coal & Allied's relationships with local communities were strengthened through involvement in events, such as the Singleton Show and Coal & Allied's Singleton Professions Forum. The Professions Forum was a career expo style event planned and organised by student leaders from Singleton High School, St Catherine's Catholic College and the Australian Christian College. The event aimed to support career options and diversity within the Singleton area.

Across the Hunter Valley, Coal & Allied is continually focused on building the capacity of local Aboriginal businesses and community organisations to bid for and win small to medium contracts in the mining industry. This involved Procurement and Projects team site visits, and support for the development of teaming agreements with mainstream contractors.

9.2.2 Community Consultative Committee

The HVO CCC met on a quarterly basis to discuss our operations. Presentations delivered at meetings provide committee members with updates on mining operations, environmental monitoring data, land management and community relations. The HVO CCC comprises an independent chair, and community and local Council representatives. In 2015, members included:

- Dr Col Gellatly (Chair – commenced August 2013)
- Cr Hollee Diemar-Jenkins
- Charlie Shearer
- Dr Neville Hodkinson
- Di Gee
- Brian Atfield
- David Love

In accordance with Coal & Allied Development Consent, copies of the minutes are available on the Rio Tinto website. Following CCC meetings, a letter is mailed to near neighbours to update them about what was discussed and provide any additional information about HVO's operations.

9.3 Community Development

In 2015, Coal & Allied continued its focus on ensuring the long-term sustainability of the communities in which it operates, through the facilitation of community development programmes such as:

- Coal & Allied Community Development Fund (CDF)

- Coal & Allied Aboriginal Community Development Fund (ACDF)
- HVO Site Donations Committee
- Community partnerships

9.3.3 Community Development Funding Programmes

In 2015, the ACDF and CDF programmes contributed a total of almost $1.4million to support capacity building and contribute to the long-term sustainability of surrounding communities. For more information about Coal & Allied community funding programmes visit http://www.riotinto.com/energy/community-funds-10413.aspx.

Community Development Fund (CDF)

This year marked 17 years of operation of the CDF, which has invested $14.5 million to support more than 120 community projects across the areas of health, education, environment and economic development in the Hunter Valley since its inception in 1999.

In 2015, the CDF invested more than $900,000 in 10 new programmes aimed at delivering long-term benefits for communities in the CDF catchment, which included the Singleton, Muswellbrook, and Upper Hunter LGAs. A further $1.5 million is available for allocation in 2016-2017.

Table 45: Coal & Allied Community Development Fund projects approved in 2015

Programme	Partner
Enterprise Facilitation	Sirolli Institute
Supporting Children's Developing Social Competence	Early Links Inclusion Support Service
Science and Enginnering Challenge, and SMART Program (2015-2017)	University of Newcastle
Upper Hunter Education Fund Scholarships (2015-2017)	Upper Hunter Education Fund
Upper Hunter Beef Bonanza	Upper Hunter Beef Bonanza
Singleton High School Agricultural Course	Singleton High School
University of Newcastle Scholarships	University of Newcastle
Singleton Community College Strategic Plan	Singleton Community College
HSC Study Camps	Upper Hunter Education Fund
Ready 4 School Program	Jerrys Plains Public School

Table 46: Active Coal &Allied Community Development Fund programmes running throughout 2015

Programme	Partner
Upper Hunter Shire Council Engagement	Upper Hunter Shire Council
Building Skills and Leadership Capacity in Rural NSW	Royal Agricultural Society(NSW) Foundation
Hunter Youth Leadership Program	The Australian Outward Bound Development Fund
People in Your Neighbourhood- Sustainability Street	Muswellbrook Shire Council
Tocal Schools Steer Challenge	Department of Primary Industries Tocal College
Local SME Supply Chain Participant Project	HunterNet
Scholarship Program	University of Newcastle
Economic Development and Funding Coordinator	Singleton Council
Business Development Officer	Singleton Business Chamber
Singleton Place Making (end July 2015)	Singleton Council
Science and Engineering Challenge and SMART Program	University of Newcastle
Enterprise Facilitation	Sirolli Institute
Upper Hunter Beef Bonanza	UHBB
Supporting Children’s Development Social Competence	Early Links
Upper Hunter education Fund Scholarships	UHEF

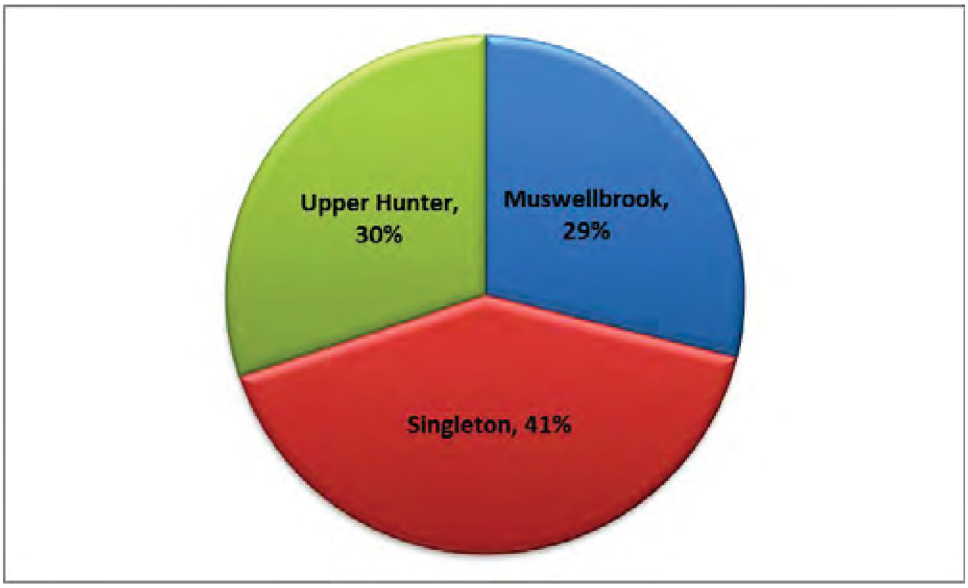


Figure 106: Distribution of Community Development Fund by LGA 2015

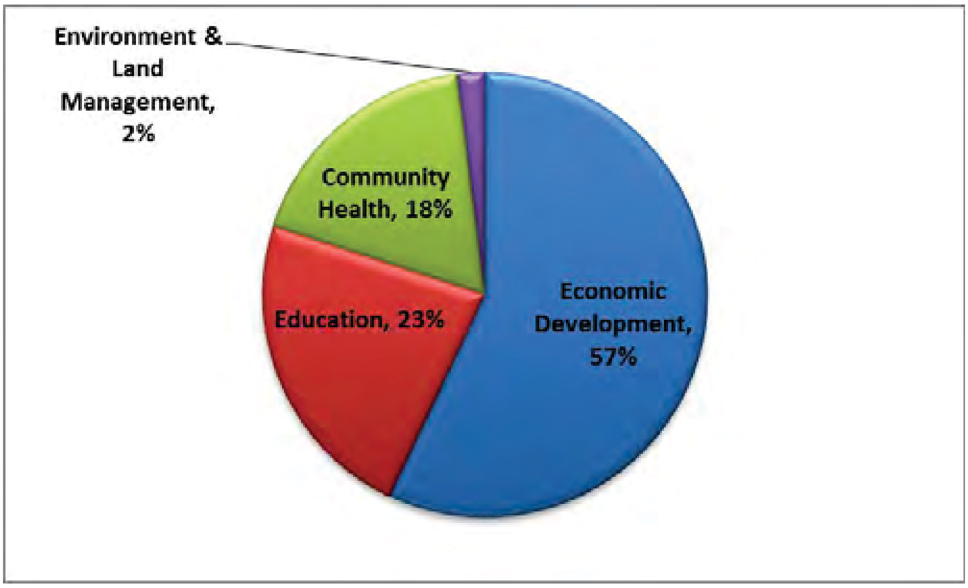


Figure 107: Distribution of Community Develop Fund by category 2015

Aboriginal Community Development Fund (ACDF)

In 2015, the ACDF invested almost $480,000 through 22 partnerships in education, community and business development and culture. This represented approximately 90% of available funds. These partnerships demonstrated strong potential to deliver meaningful benefit and/or long-term sustainable outcomes for Aboriginal communities in the Singleton, Muswellbrook and Upper Hunter Local Government Areas (LGA).

All flagship partnerships were aligned to ACDF strategic investment priorities, whilst smaller projects reflected a broad range of community needs and interests within established ACDF funding categories.

A longstanding and highly valued partnership is the Singleton Schools Dance Program. Through this program, Singleton High School and two town and rural primary schools employ a dance teacher each fortnight to educate and engage Aboriginal students in their culture. The participating schools have established dance groups which perform at school assemblies for NAIDOC and Reconciliation Week. A larger, inter-school dance group come together to perform at significant community events.

Now in its 6th year, the program has made a significant contribution to a visible and positive presence for Aboriginal peoples and culture within the schools and through the community performances, helped to build awareness and understanding between the school community, local Aboriginal and wider communities.

The ACDF is accessible to any Aboriginal person residing in, or who is from, the Upper Hunter Valley, or organisation undertaking a project to benefit specific Aboriginal target groups or wider Aboriginal communities in the Upper Hunter Valley.

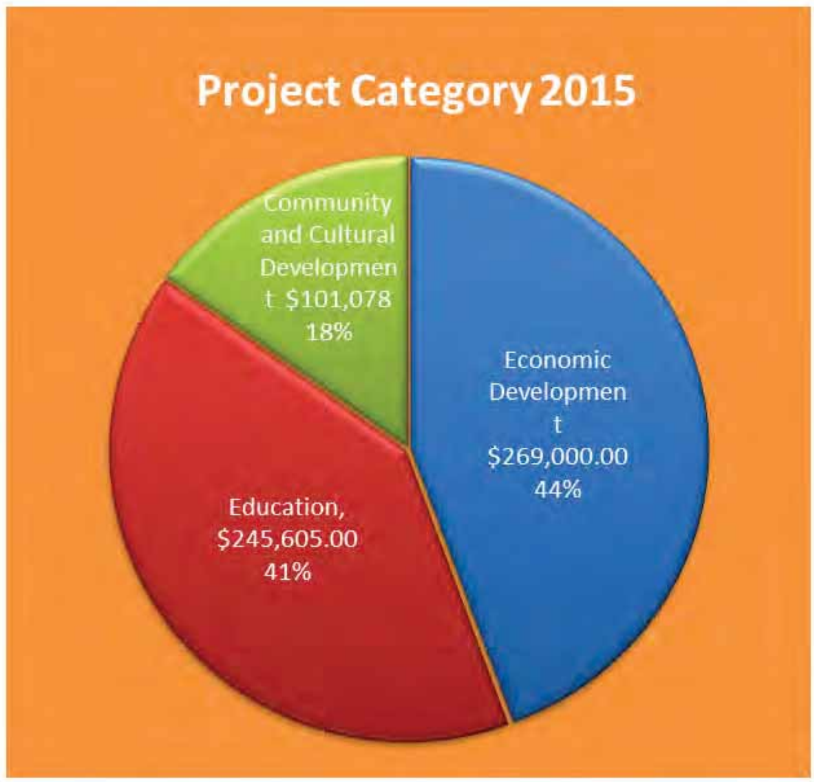


Figure 108: Distribution of Aboriginal Community Development Fund by category

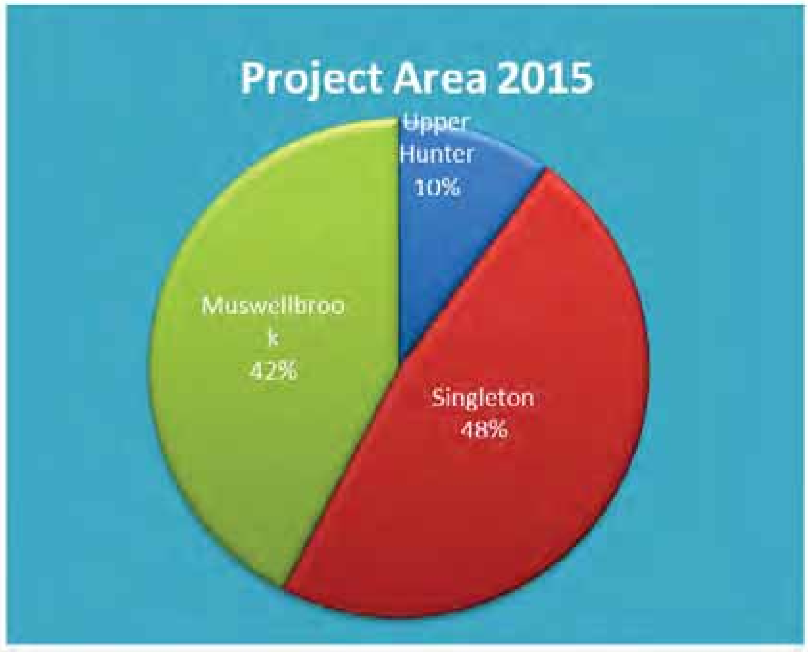


Figure 109: Distribution of Aboriginal Community Development Fund by LGA

Table 47: Coal & Allied Aboriginal Community Development Fund Projects approved in 2015

Programme	Partner
Max Potential	Future Achievement Australia Foundation
Microenterprise Development in the Upper Hunter (Renewed)	Many Rivers Microfinance
Wonnarua Mining Rehabilitation Operations	Wonnarua Mining Rehab Pty Ltd (Wonnarua Nation Aboriginal Corp)
Study Assistance	Fiona Murray
The Australian Outward Bound Scholarships	Australian Outward Bound
Ka Wul - New Definition (Renewed)	Singleton High School
Singleton Art Prize	Rotary Club of Singleton on Hunter Inc.
Aboriginal Business Development and Employment Forum	NSW Indigenous Chamber of Commerce
Partnerships for Success (Renewed)	Polly Farmer Foundation
Administration Traineeship	Wanaruah Local Aboriginal Land Council
Muswellbrook Youth Workshop	Bangarra Dance Theatre
NAIDOC Celebrations	St James Primary School
Les Elvin Funeral Expenses	NSW Indigenous Chamber of Commerce

Table 48: Active Coal & Allied Aboriginal Community Development Fund projects approved in prior funding cycles

Programme	Partner
Strategic planning and operational support	Wonnarua Nation Aboriginal Corp
Ka-wul New Beginnings	Singleton High School
NAIDOC Week	Singleton Schools Management Group
YINPI - Post School Pathways Program	Singleton High School
Warrae Wanni School Readiness (renewed 2014-2015)	Muswellbrook South School
Kawul - New Directions	Singleton High School
Parents and Learning (PAL)	Napranum Pre-School
Dookal Group Pty Ltd	Ungooroo Aboriginal Corporation
NAIDOC week activities	Wanaruah Local Aboriginal Land Council
Singleton Schools Aboriginal Dance Group (renewed)	Broke Public School
The Gundi Programme	St Heliers Correctional Centre
Industry scholarships	University of Newcastle
Wupa@Wanaruah Art and Cultural Event	Ungooroo Aboriginal Corporation

9.3.4 Site Donations

Coal & Allied considers applications for local donations and sponsorships that have a clear community benefit. In 2015, HVO provided almost $100,000 to 42 local projects and initiatives, including:

- Singleton Library
- Eastern Branch Australian Stock Horse Society
- Singleton Art Prize
- WildLife Aid
- Singleton Show
- Singleton Beef and Land Management Prime Stock Competition
- Singleton Council Mayoral Scholarships
- Cancer Council NSW Relay for Life
- Jerrys Plains School Cracker Night
- Australian Families of the Military Research and Support Foundation (AFOM)
- Invisible Wounds Community Workshop (mental health)

9.3.5 Community Partnerships

Coal & Allied has retained an active partnership programme in 2015 with key organisations that provide a service valued by the community and have an approach to their business that is aligned with Coal & Allied principles. Partners include:

- Hunter Valley Research Foundation
- Westpac Rescue Helicopter Service
- Olympic Park Muswellbrook

10 INDEPENDENT AUDIT

There were no independent audits undertaken during the reporting period. The next independent audit is scheduled for 2016.

11 INCIDENTS AND NON-COMPLIANCES DURING THE REPORTING PERIOD

11.1 Noise

Three measurements which exceeded an applicable noise criterion were reported to local residents and the Department of Planning & Environment during 2015. Two of these measurements constitute non-compliance with the HVO South Coal Project Approval noise criteria.

11.1.1 26th April 2015

Two non-compliant measurements were recorded at the Shearer's Lane monitoring location on the night of 26/04/2015. The measured results exceeded the HVO South Coal Project Approval L_{Aeq}, 15min criteria by 3dB (measured 44dB) and $L_{A1,1min}$ criteria by 5dB (measured 50dB) respectively.

Investigation into the noise source(s) determined that a continuum and rear dump truck engine and transmission noise (at frequencies less than 1000Hz) from HVO South Pit area was audible throughout the measurement and responsible for measured levels. Due to a breakdown in the notification protocol from the acoustic technician, HVO was not notified at the time of the measured exceedance, preventing any opportunity for immediate mitigation measures to be taken to address the elevated noise. Consequently, as the noise levels were not able to be verified as having returned below the relevant criteria within 75 minutes of detection, this event is considered non-compliant with the noise criteria.

An incident report was prepared and submitted to the Department of Planning & Environment in relation to the measurements.

11.1.2 11th June 2015

An exceedance of the HVO South Coal Project Approval LA1, 1min criterion was measured at the Shearer's Lane monitoring location on the night of 11/06/2015. The exceedance was attributed to a single instance of shovel impact noise. Following notification by the acoustic technician, a follow-up measurement completed shortly thereafter confirmed compliance with the noise criterion.

11.2 Blasting

During 2015, there was one exceedance of the 120dB (L) overpressure criteria. A Cheshunt Pit blast, P203WK602A fired at 14:24 on 17 July 2015, recorded a reading of 120.55 dB(L) at the Warkworth blast monitor. An investigation was undertaken and the exceedance was attributed to unidentified atmospheric reinforcement in the direction of the Warkworth monitoring location. No community complaints were received in relation to the blast. The exceedance was reported to the Department of Planning and Environment as well as the NSW EPA. Notifications were also made to Warkworth Village Residents.

There were no exceedances of the 5 mm/s or 10 mm/s ground vibration criteria at any residence on privately-owned land.

There were a total of 21 blasts that recorded an initial overpressure reading greater than 115 dB (L) during the reporting period. Upon investigation, 10 of these blasts were found to be due to wind reinforcement and as such are not considered to constitute non-compliance with HVO's conditions of approval. The resulting 11 readings over 115 dB (L) limit have been assessed for comparison against the 5% of the total number of blasts over a period of 12 months allowable exceedance limit, these results are shown in Table 49 below.

Table 49: Percentage of blasts over 115dB(L)

Monitoring Location	Allowable Exceedance over 115dB (L) of time over 12 months (%)	Percentage of blasts over 115dB (L) (%)
Moses Crossing	5	0
Jerrys Plains	5	0.3
Warkworth	5	0.3
Maison Dieu	5	1.6
Knodlers Lane	5	1.3

11.3 Water

11.3.1 17 April 2015

During routine environmental inspections at approximately 7:45 am on Friday 17 April 2015, water was observed to be flowing from a pipe at the Dam 15N pumping station into a tributary of Farrell's Creek at Hunter Valley Operations.

Dam 15N is utilised as a flood protection dam for Dam 16N. Dam 16N captures runoff from HVO's Coal Handling and Preparation Plant (CHPP) and Maintenance facilities. Water from the Dam 15N pumping station was observed to be flowing from an open ended pipe between the dam and the pump (on the downstream or pump-side of the pipe). A small section of the pipe had been removed to facilitate removal and repair of the pump. The section of pipe was removed on 14 April 2015; no water was observed to be flowing from the pipe at this time. Subsequent daily environmental inspections did not identify any water flowing from the pumping station until 7:45am on 17 April 2015, where it was observed that water was flowing from the removed section of pipe at an estimated rate of 2 L/s. The investigation determined that the source of the water entering the pump station was from the outlet pipeline (not from Dam 15N). So far as we have been able to determine, the most likely cause of the water flowing from the pipe was a failed or inoperative non-return valve.

The actions taken in respect of the incident included:

- Sourced and installed a blanking plate to stop the flow of water from the pipe. The blanking plate was installed at approximately 9:45 am. Once the blanking plate was installed the flow of water ceased immediately. Between 7:45 am and 9:45 am staff investigated the source of the leak, attempting to close a number of interconnecting valves in the water network to cease flow.
- A vacuum truck was brought to site at 10:50 am 17 April 2015 to recover leaked water in the vicinity of the pumping station. Approximately 50 m3 was recovered.
- Water sampling was undertaken to characterise potential impact upon receiving waters.
- An incident investigation was undertaken to determine the cause of the incident

The incident notification was made to the EPA at 10:55 am (Reference C053922015) on 17 April 2015, in accordance with Part 5.7 of the Protection of the Environment Operations Act 1997 (POEO Act). The following agencies were also notified of the event, between 10:55 am and 11:47 am, in line with the Coal & Allied Pollution Incident Response Management Plan: Singleton Council, Ministry of Health, Workcover, Fire and Rescue NSW. The NSW Department of Planning and Environment were also notified.

11.3.2 21 April 2016

A rain event of approximately 126 mm was received on site over a three day period, from Monday 20th to Wednesday 22nd April 2015. The rain was associated with a significant regional event as a result of an east coast low, which persisted over the Lower Hunter during this period.

Newdell Sump 060: Identified to be overtopping during a daily environmental inspection on 21st April 2015 at approximately 8am. Overtopping ceased prior to 9am on 22nd April 2015, when a subsequent inspection was undertaken. Newdell Sump 060 receives runoff water from a rehabilitated clean catchment west of the disused Newdell CHPP site. Stormwater from this catchment is directed to the east through the rail loop by an existing diversion bund and open drain, where it flows into Sump 060 and is pumped back to Dam 14W for storage.

Any water that overtopped Sump 060 was caused by the rainfall event exceeding the pump-out rate. The permanent pontoon pump failed on 17th April 2015 and a temporary pump was installed on that day and used prior to and during the overtopping event. Waters reporting to the sump were observed to display some brown discoloration, likely associated with suspended sediment with potential for coal contact. Sump waters were sampled on 21st April 2015 and analysed for Electrical Conductivity; a field measurement of ~400 µS/cm was recorded. A sample was also taken from Bayswater Creek approximately 700 m downstream; a field measurement of ~600 µS/cm was recorded. Given the nature of the sump and receiving catchment any volume of water that flowed from site is primarily rainfall runoff associated with the storm event. The volume of water discharged is unable to be determined.

Pump-out of the sump occurred on the 20th April 2015 following initial rainfall runoff and recommenced on the morning of the 21st April 2015 following identification of overtopping during the daily environmental inspection. Pumping continued over several days given ongoing rainfall runoff to the sump. The permanent pump was subsequently repaired.

Glider pit sediment dam: Identified to be overtopping for approximately one hour on the morning of Tuesday 21st April 2015, from 10am until 11am. The sediment dam receives rainfall runoff from a clean catchment ahead of mining at the Glider pit.

The sediment dam is designed for an 85th percentile, 5-day rainfall event, in accordance with the 'Blue Book': Managing Urban Stormwater: soils and construction (Volume 1 and 2E – Mines and Quarries). This standard provides containment for a nominal 31 mm rainfall event, before spilling. In this case the rainfall event exceeded the design criteria for the sediment dam, resulting in it spilling to United Dam 14 (which collects runoff from clean catchment). The dam was empty prior to the rainfall event commencing. Abstraction of water from the sediment dam continued throughout the rainfall event; for a brief period the pump out rate was exceeded by the dam inflow rate. The dam has been dewatered following the rainfall event.

Planning & Environment were notified of the event on 21 April 2015, with a follow up incident report prepared and sent to both regulators on 13 May 2015. Investigations indicated no actual harm or potential for harm to the environment.

11.3.3 3 July 2015

At the commencement of day shift on 3 July 2015 at approximately 8am, an operator tasked to work on the Howick ROM pad Loader observed water pooling/bubbling from the north western extent of the ROM pad. The loader operator contacted the CHPP control room. It was identified that a buried tailings line that runs from the Howick CHPP to the Dam 6 Tailings Facility had been punctured by a loader bucket, resulting in tailings discharging on the ROM pad and subsequently flowing out a break in the western windrow into a clean water diversion drain on the western boundary of HVO that directs runoff water to Parnells Creek. Tailings affected water was observed to be pooling in the clean water diversion drain approximately 900m downstream from the discharge point, where it had ceased to flow due to a section of the drain being dammed. Due to a partially dammed section of the drain no tailings or tailings affected water left the mine premise.

Recovery of the water in the drain by pumping commenced at approximately 1pm on 3 July 2015 and continued for approximately 3 days, with intermittent water recovery ongoing (to 15 July 2015). To prevent a re-occurrence the tailings pipeline has been relocated away from the ROM pad area and demarcated via signage. Both Planning & Environment and the EPA were notified of the incident on 3 July 2015.

12 ACTIVITIES TO BE COMPLETED IN THE NEXT REPORTING PERIOD

12.1 Noise

Noise management improvements identified for implementation in 2016 include:

- Staged introduction of additional sound suppressed (attenuated) haul trucks;
- Implementation of an Environmental Noise Compass (directional noise monitor) in Jerrys Plains, and associated revision to the Trigger, Action, Response Plan (TARP);
- Commencement of daily public reporting, including information on noise management for the previous night shift (reporting undertaken on business days only); and
- Revision of the HVO Noise Management Plan.

12.2 Blasting

Blasting management improvements identified for implementation in 2016 include:

- Revision of the HVO Blast Management Plan; and
- Roll-out of a revised blasting permission process following comprehensive review completed in 2015, incorporating a number of changes including:
    - Revision of wind speed / direction triggers, taking account of historical data, changes in land ownership, and progression of mining;
    - Introduction of additional permissions pages (Glider Pit, Riverview West, Wilton Pits); and
    - Incorporation of blast plume prediction data.

12.3 Air Quality

Air Quality management improvements identified for implementation in 2016 include:

- Re-configuration of real-time PM_{10} monitoring locations, in consultation with EPA and DP&E, and in accordance with varied requirements on EPL640, and revision of HVO's Air Quality Trigger, Action, Response Plan (TARP) in line with these changes;
- Commencement of daily public reporting, including information on air quality management for the previous day (reporting undertaken on business days only); and
- Revision of the HVO Air Quality & Greenhouse Gas Management Plan.

12.4 Cultural heritage

12.4.1 Aboriginal Cultural Heritage Activities

Ongoing Aboriginal archaeological and cultural heritage management activities will occur in 2016 at HVO in accordance with the ACHMPs, to inform ongoing land management and development planning. Condition monitoring of those sites both within and peripheral to authorised disturbance areas will be conducted at regular intervals to ensure operational compliance with the ACHMPs. The AHIMS sites database audit will continue in 201.

12.4.2 Historic Heritage Activities

The Stage One Chain of Ponds Stabilisation works were completed in 2015. Further maintenance and structural repair works are planned for 2016. Coal & Allied will continue to consult with the neighbouring Liddell Coal Operations on any future mining plans that may interact with the Inn complex to ensure appropriate protective management measures are implemented where required.

12.5 Waste and Hazard Management

Site documents and procedures for hazardous materials and contaminated sites management will be reviewed in 2016 to assess potential for improvements in line with industry best practice.

12.6 Water

Improvements to mine water management in 2016 will focus on water security and surface water management. This includes:

- Increasing capacity for stormwater runoff from the Hunter Valley Load Point. This work is due for completion in2016.
- Improving secondary containment of pipelines and a review of the design containment criteria for water storage facilities on site.

A consultant has been engaged to develop a hydraulic testing programme and review the conceptual hydrogeological model for the alluvial lands area. This will be undertaken in 2016.

The Water Management Plan will be reviewed in 2016 to reflect updated water quality triggers incorporating 2015 data for the surface water and groundwater monitoring programmes.

12.7 Rehabilitation

12.7.1 Performance Criteria and Rehabilitation Monitoring

The rehabilitation monitoring programme will continue in 2016 for both grazing and native vegetation rehabilitation areas. Results from this and previous year's monitoring of reference sites and rehabilitation sites will be used to determine suitable target levels for the rehabilitation performance criteria. Target levels for MOP performance criteria will be determined by the end of 2016.

12.7.2 Performance Criteria and Rehabilitation Monitoring

An air-assisted boom sprayer (Figure 110) will be trialled to control weeds on rehabilitation areas and topsoil stockpiles. The spray nozzles are enclosed within a shroud and air is used to direct the herbicide out through the bottom of the shroud and onto the target weeds. The air-assist design helps to minimise spray drift onto off-target areas and results in better leaf coverage with herbicide for a more effective kill of target species.

Figure 110: Spray rig boom fitted with air-assist shroud

12.7.3 Habitat Augmentation

Guidelines for fauna habitat augmentation in rehabilitation areas will be developed during 2016. Data on the number of trees containing hollows and length of logs on the ground has been collected for the native vegetation reference sites established during the recent rehabilitation monitoring program. This information will be used to set targets for the habitat-related MOP performance criteria. Habitat augmentation measures, such as the construction of habitat ponds and the placement of salvaged logs in rehabilitation areas, will be undertaken during 2016.

12.7.4 Native Grass Harvest Areas

The native grass seed harvesting properties at Mt Pleasant will not be available to C&A for future harvests due to the impending sale of the Mt Pleasant assets. Over the next couple of years C&A will prepare native grass pasture areas in rehabilitation areas to provide replacement harvest sites. In the interim, C&A have an inventory of harvested native grass seed from the Mt Pleasant properties to provide seed for rehabilitation activities while the native pastures in rehabilitation areas are being prepared.

12.7.5 Native Grass Cover Crops

Trials will be undertaken in new rehabilitation areas that have been spread with topsoil to use native grasses as a cover crop rather than using exotic cereal and legume crops. The current use of annual exotic cover crops results in regular spraying out and replacing through re-sowing. Alternatively, the use of a perennial native pasture as a cover crop is planned to reduce this requirement and will begin the establishment of a component of the desired vegetation community. The weed wiper will provide a means of removing quick-growing exotic grasses from the native grass pasture during the early establishment phase.

12.7.6 Grazing Trial

The current steers will be turned off the trial in April and replacement weaners will be sourced that will remain on the trial paddocks until the end of the trial in mid-2017. The DPI personnel managing the trial believe that the rehabilitation paddocks are capable of supporting more cattle than the 10 steers that have been in place to date, due to the high amount of feed on offer. It is planned that the number of cattle on the rehabilitation paddocks be increased to between 15-20 steers while the number of cattle on the unmined paddocks will be maintained at 10 steers. Monitoring on the unmined paddocks has indicated that the current number of cattle installed on these paddocks is well matched to the available feed levels while still maintaining sufficient pasture cover levels.

12.8 Community Development

Priority areas for community development in 2015 included education, economic, environment and social/cultural. Coal and Allied currently support numerous foundations, programmes and scholarships in relation to these priority areas with continuation and commencement of these into 2016.

Appendix 1

2015 Complaints Summary

Hunter Valley Operations Complaints 2015

Type	Month	Date	Time	Method Received	Location
Noise	January	1/01/2015	22:25	Complaints Hotline	Jerrys Plains
Blast	January	6/01/2015	13:01	Complaints Hotline	Jerrys Plains
Blast	January	30/01/2015	08:10	Via DP&E*	Maison Dieu
Blast	March	4/03/2015	11:09	Complaints Hotline	Jerrys Plains
Noise	March	4/03/2015	21:45	Complaints Hotline	Jerrys Plains
Noise	March	7/03/2015	21:13	Complaints Hotline	Jerrys Plains
Lighting	March	17/03/2015	19:26	Complaints Hotline	Maison Dieu
Noise	April	2/04/2015	20:47	Complaints Hotline	Jerrys Plains
Noise	April	2/04/2015	21:22	Complaints Hotline	Jerrys Plains
Noise	April	2/04/2015	22:41	Complaints Hotline	Jerrys Plains
Lighting	April	5/04/2015	21:23	Complaints Hotline	Glider Club
Noise	April	5/04/2015	21:24	Complaints Hotline	Glider Club
Blast	April	10/04/2015	09:50	Complaints Hotline	Jerrys Plains
Blast	April	16/04/2015	11:17	Complaints Hotline	Jerrys Plains
Blast	April	16/04/2015	11:27	Complaints Hotline	Jerrys Plains
Blast	May	1/05/2015	12:55	Complaints Hotline	Jerrys Plains
Blast	May	8/05/2015	19:32	Complaints Hotline	Hebden
Blast	June	2/06/2015	11:05	Telephone	Jerrys Plains
Noise	June	3/06/2015	11:50	Telephone	Jerrys Plains
Blast	June	30/06/2015	13:20	Complaints Hotline	Jerrys Plains
Blast	July	22/07/2015	13:13	Complaints Hotline	Jerrys Plains
Blast	August	21/08/2015	11:24	Complaints Hotline	Jerrys Plains
Blast	September	9/09/2015	13:15	Complaints Hotline	Jerrys Plains
Noise	September	13/09/2015	23:06	Complaints Hotline	Jerrys Plains
Dust	October	2/10/2015	12:48	Complaints Hotline	Jerrys Plains
Blast	October	9/10/2015	16:00	Via DP&E*	Jerrys Plains
Noise	October	24/10/2015	21:05	Complaints Hotline	Jerrys Plains
Blast	October	29/10/2015	10:37	Complaints Hotline	Jerrys Plains
Noise	October	29/10/2015	22:22	Complaints Hotline	Jerrys Plains
Blast	October	30/10/2015	08:12	Complaints Hotline	Jerrys Plains
Blast	October	30/10/2015	08:21	Complaints Hotline	Jerrys Plains
Noise	October	30/10/2015	21:03	Complaints Hotline	Jerrys Plains
Noise	November	5/11/2015	21:42	Complaints Hotline	Jerrys Plains
Blast	December	10/12/2015	12:04	Complaints Hotline	Jerrys Plains
Blast	December	15/12/2015	11:52	Complaints Hotline	Jerrys Plains
Noise	December	18/12/2015	08:02	Complaints Hotline	Unknown

* DP&E - Department of Planning and Environment

Appendix 2

2015 Groundwater Impacts Reports

Australasian
Groundwater
and Environmental
Consultants Pty Ltd
(AGE)

Report on

HVO North

2015 Annual Groundwater Impacts Review

Prepared for

Coal and Allied Operations Pty Ltd

Project No. G1809   March 2016

www.ageconsultants.com.au   ABN 64 080 238 642

Document details and history

Document details

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Report on

HVO North
2015 Annual Groundwater Impacts Review

1 Introduction

The Hunter Valley Operations (HVO) mining complex is located approximately 20 km north-west of Singleton, NSW. The complex is divided into its HVO North and HVO South components by the Hunter River (refer Figure 1). This report focuses on HVO North (the Project area), located approximately 500 m to the north of the Hunter River. The mine is owned by Rio Tinto Coal Australia (RTCA) and operated by Coal and Allied Operations Pty Ltd (Coal & Allied).

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) was commissioned by Coal & Allied to review the impacts of mining on groundwater systems contained within the Project area for 2015. The assessment has included:

- preparation of water quality tables and graphs and assessed the results for compliance with trigger values adopted in the site Water Management Plan (WMP);
- preparation of water table and piezometric contours from monitoring data pertaining to the Project area;
- assessment of alluvial sediments and Permian strata groundwater flows over the 2015 monitoring period; and
- assessments of groundwater take from the Hunter River Alluvium.

Furthermore, this report presents the assessment of existing consent comittments for Alluvial Lands Bore licence 20BL173587-89 & 20BL173847, specifically conditions 10 and 11. The majority of the requirments are assessed as part of the annual Groundwater Impact Report.

2 Project setting

2.1 Mining

HVO North has been extensively mined since 1979, with several open-cut operations that have since been backfilled with spoil and rehabilitated. The rehabilitated pits include:

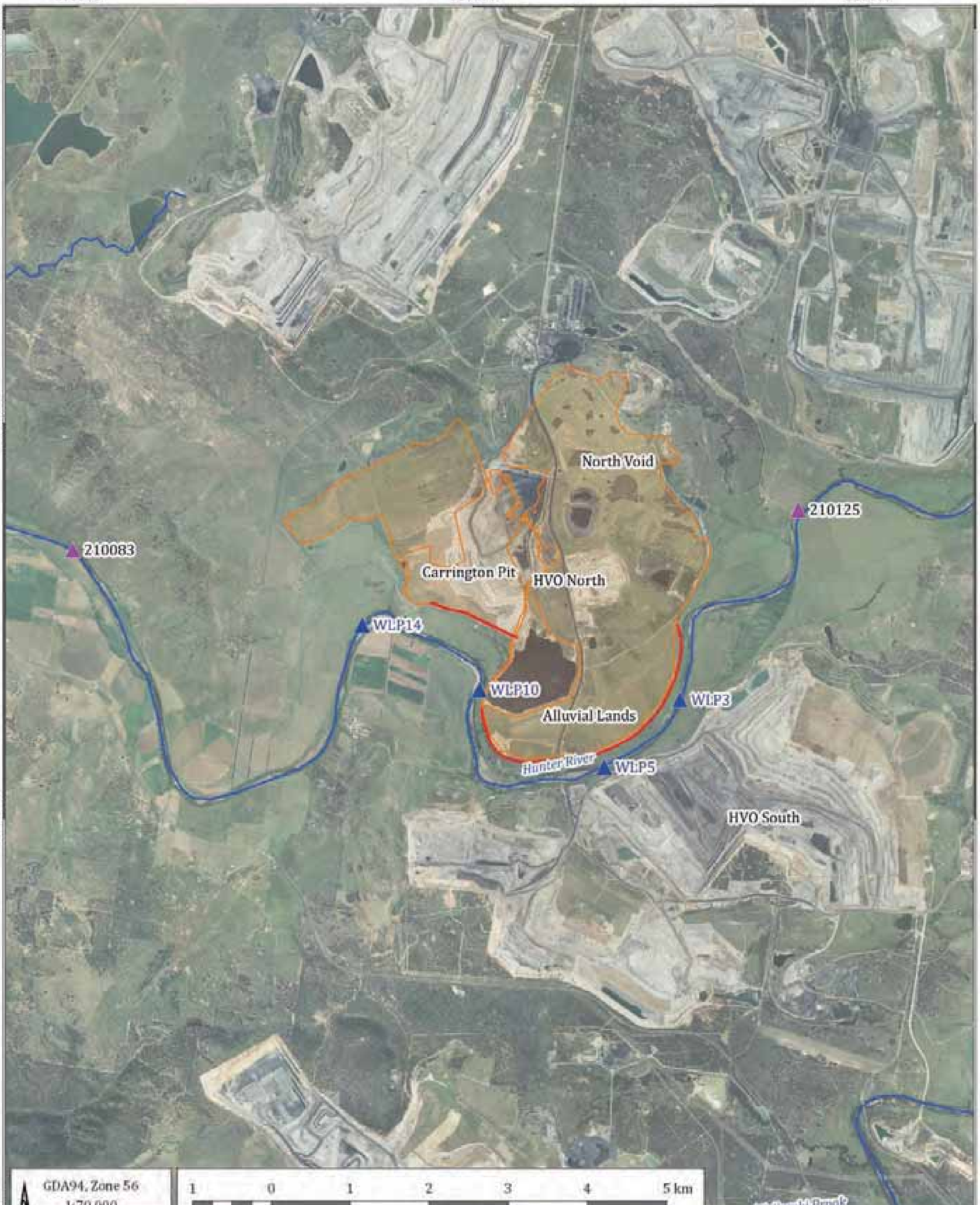
- North Void, which was mined from 1979 to around 2008 to the base of the Vaux Seam; and
- Alluvial Lands, which was the southern extension of North Void, mined from 1993 to 2003 to the base of the Vaux Seam.

The HVO North Carrington Pit commenced operations in August 2000. Mining in the Carrington Pit during 2015 was limited with previously mined areas largely backfilled with spoil (Figure 1). Several other mines operated by Coal & Allied surround the Project area, including HVO South, located south of the Hunter River, and West Pit which forms part of HVO North Consent, located north of the Project area. Other surrounding mines include the Ravensworth Operations open-cut and underground mines, located north-east of the Project area.

The Carrington Pit is located approximately 500 m to the north of the Hunter River. In 2010 a barrier wall constructed between the Carrington Pit and the Hunter River alluvium to:

- enable continued mining at Carrington Pit;
- conserve the Carrington Billabong, which contains groundwater dependent vegetation;
- minimise leakage from the alluvium to the open-cut; and
- contain groundwater within the mine, following mine closure.

The barrier wall was constructed as a compacted clay buttress wall, against an existing levee that extended across the eastern limb of a Tertiary palaeochannel. The wall was constructed to the base of the Vaux Seam. The extent of the barrier wall and the location of the Carrington Billabong are shown in Figure 1.



LEGEND

- Barrier wall
- Spoil
- WHO gauge station
- HVO gauge station
- Major drainage

HVO North - 2015 Annual Groundwater Impacts Review (G1809)

Project area

DATE 27/01/2016

FIGURE No. **1**

2.2 Climate

The climate of the HVO area is mostly temperate, and characterised by hot, wet summers and mild, dry winters. Climate monitoring data collected by Coal and Allied at the HVO Corp Meteorological Weather Station during 2015 is summarised in Table 1.

Table 1 Climate averages: HVO Corp. Meteorological Data 2015

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean max temp (°C)	30.7	30.3	30.1	23.7	19.9	17.9	16.7	19.0	22.0	30.9	31.2	29.8	n/a
Mean min temp (°C)	18.3	17.6	16.1	13.1	10.2	7.2	5.7	7.4	9.5	8.7	17.8	15.4	n/a
Mean monthly rainfall since 2007(mm)	67.5	82.4	72.1	52.4	33.8	70.4	29.0	39.5	33.1	34.0	99.4	77.5	696.8 *
Total monthly rainfall 2015 (mm)	176.8	37.6	19.2	169.0	50.2	25.8	23.8	48.6	19.4	30.8	101.0	111.4	813.6

Note: *Mean Annual average (2007-2015)*

The total annual rainfall for 2015 was 813.6 mm with the wettest month in January (176.8 mm). On average, 2015 was wetter than the previous eight years with 116.8 mm cumulative rainfall above the average.

Monthly Cumulative Rainfall Departure (CRD) using available rainfall data has been calculated for the period 2007 to December 2015 using rainfall data from the Singleton monitoring station and the HVO Corp. Meteorological data. The CRD method is a summation of the monthly departure of rainfall from the long-term average monthly rainfall. A rising trend in the CRD plot indicates periods of above average rainfall, whilst a falling slope indicates periods when rainfall is below average.

The CRD graph for the period 2007 to 2015 is shown in Figure 2. The CRD indicates that the site experienced intermittent periods of above average rainfalls between November 2014 to January 2015 and March 2015 to May 2015. Between June and November 2015 the periods of rainfall is similar to the average.

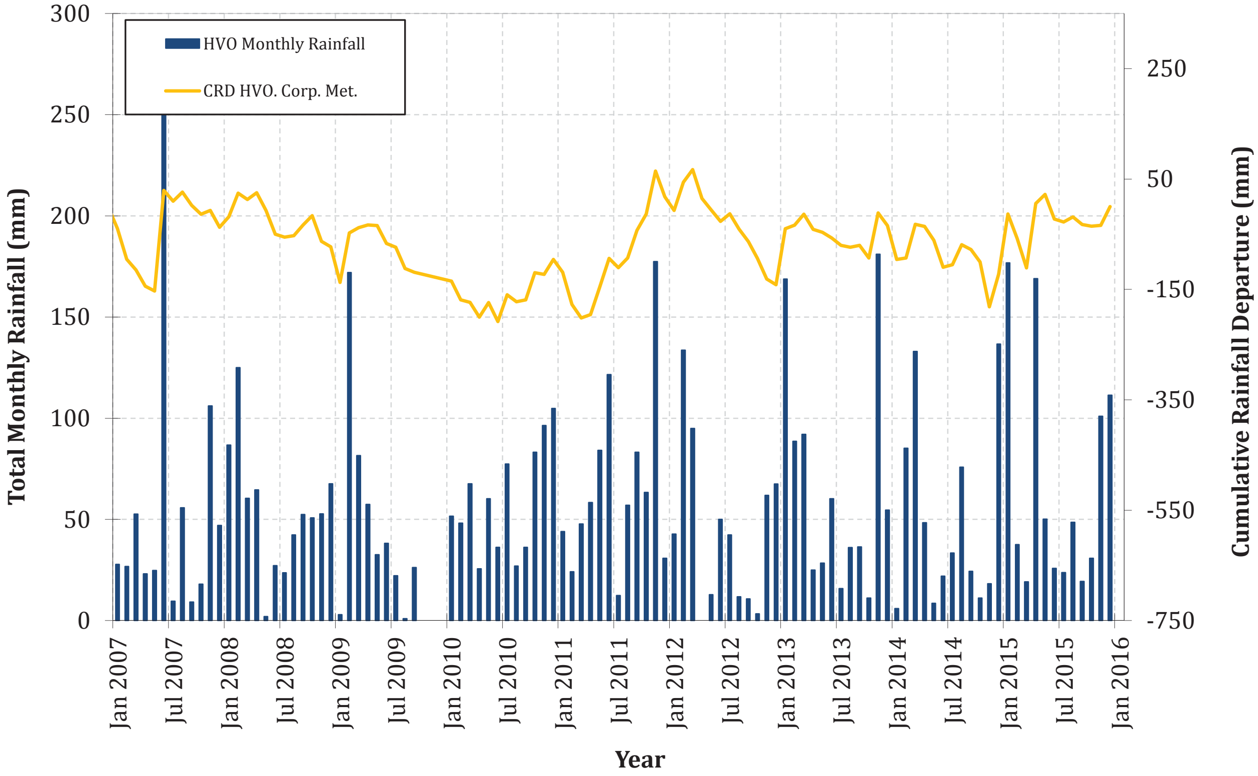


Figure 2 Cumulative rainfall departure comparison - HVO & Singleton data

2.3 Surface water

At HVO, monthly stream elevation data was collected from four stations along the Hunter River during 2015 (WLP3, WLP5, WLP10 and WLP14). The locations of the NOW and HVO stream sites are shown in Figure 1. The stream levels were relatively stable over 2015 with a downstream average level of 54.9 m (at WLP3) and an average upstream level of 60.4 m (at WLP14). The highest monthly water level was recorded during August. The data are summarised in Table 2.

Table 2 Water elevation monitoring Hunter River_HVO

Station ID	Easting	Northing	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WLP3	312613	6401505	54.8	54.9	54.9	54.9	55.0	55.1	55.0	55.1	55.1	54.8	54.9	54.8
WLP5	311655	6400647	55.8	55.8	55.8	55.9	56.0	56.0	56.0	56.2	56.1	55.8	55.9	55.8
WLP10	310080	6401634	58.5	58.5	58.5	58.6	58.9	58.7	58.7	58.9	58.7	58.5	58.5	58.2
WLP14	308598	6402453	60.4	60.5	60.4	60.4	60.4	60.4	60.5	60.6	60.4	60.4	60.3	60.3

In order to monitor the daily variation and flooding after major rainfall events, data are collected from two New South Wales Office of Water (NOW) gauging stations, located on the Hunter River adjacent to HVO North. The NOW gauging stations collect real time stream flow data via the Hunter Integrated Telemetry System (HIT). The nearest NOW gauging stations to the Project area are:

- Station 210083 upstream of HVO North at Liddell (gauge zero at 60.951 mRL); and
- Station 210125 downstream of HVO North (gauge zero at 50.331 mRL).

There were four main peak flow events recorded on both gauging station during 2015:

- the main peak flow was recorded on 23 April after a major rainfall event on 21 April (68.4 mm). The water level returned to the average elevation in ten days;
- 26 August after a rainfall event between 23 and 24 August;
- 17 November after a rainfall event between 12 and 13 November; and
- 27 December after a major rainfall event between the 21 and 22 December.

The Hunter River is a stream that is regulated by release from Glenbawn Dam; however, the Hunter River water level rises generally very quickly after a main rainfall event and reaches the peak level(s) after two to three days. The water level generally falls within the ten days following peak flow.

The temporal distribution of stream flow levels since 2012, for both the NOW stream gauges and HVO gauges, are shown in Appendix A.

2.4 Geology

The stratigraphic sequence of part of the Hunter Region Permian coal measures is shown in Figure 3. The regional geology is shown on the 1:100,000 scale geological map, published by the Department of Mineral Resources (Glen & Beckett, 1993) and reproduced in Figure 4.

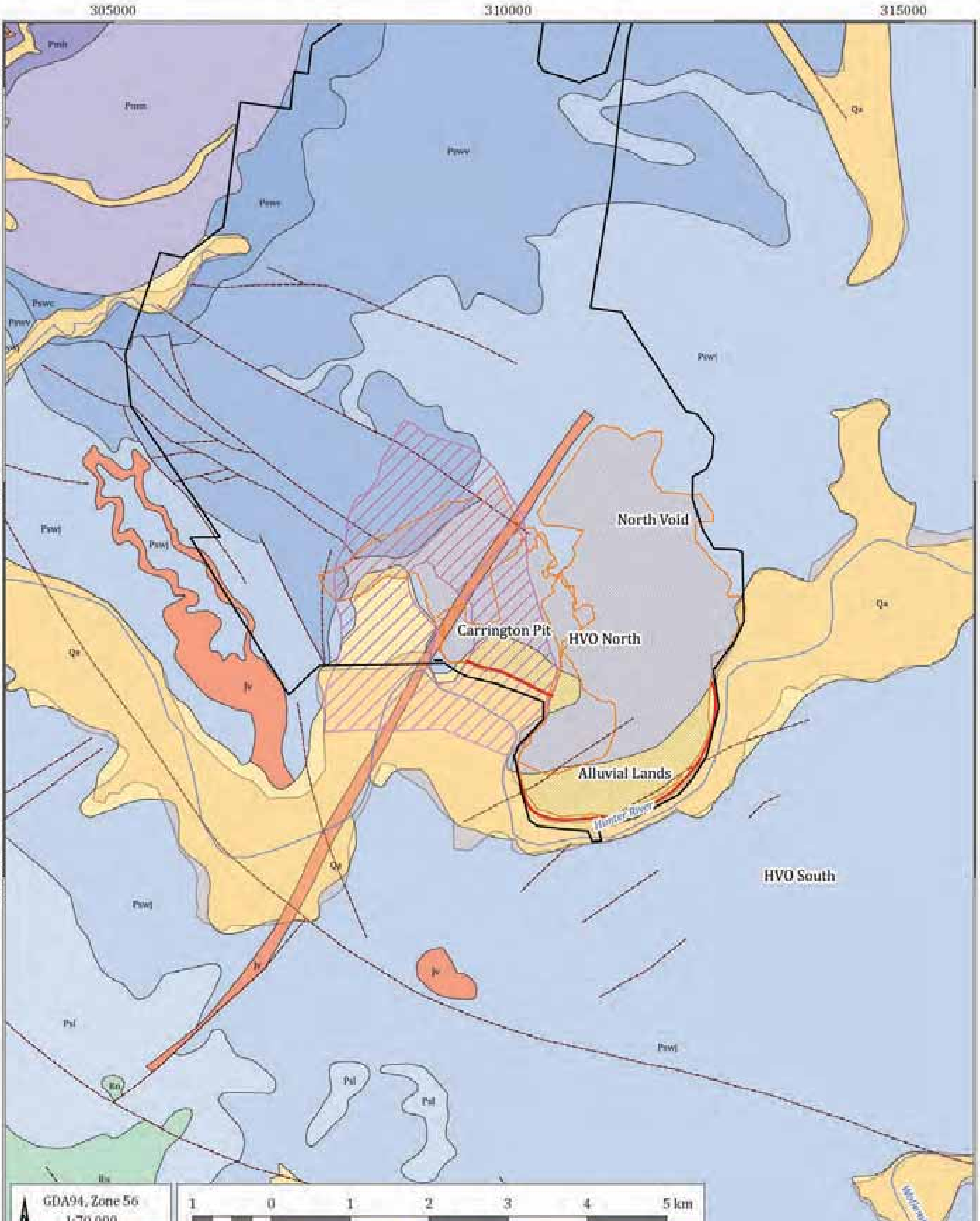
The stratigraphic sequence in the region comprises two distinct units, Quaternary Alluvium and the Permian sediments:

- The ***Quaternary Alluvium*** along the Hunter River contains two main deposital units, a surficial fine grained sediment (clay, silt and sand) overlying a coarser basal material (sand and gravel). Palaeochannel deposits are contained within an ancient river meander carved into the underlying Permian sediments north of the Hunter River (Figure 4). Palaeochannel alluvial sediments consist of silt, sand and gravel.
- The ***Permian units*** underlying the Quaternary alluvium and comprise coal seam sequences with overburden and interburden consisting of sandstone, siltstone, tuffaceous mudstone, and conglomerate. It is a regular layered sedimentary sequence that dip south-west. The Wittingham Coal Measures contains the main economic coal seams of the Project area, including the Burnamwood Formation which is the sequence being mined at Carrington Pit (Figure 4). The Archerfield Sandstone and the Vane Subgroup underlie the Jerrys Plains Subgroup.

SINGLETON SUPER GROUP	WITTINGHAM COAL MEASURES	**DENMAN FORMATION**		
		JERRYS PLAINS SUBGROUP	MOUNT LEONARD FORMATION	WHYBROW SEAM
			ALTHORPE FORMATION	
			MALABAR FORMATION	REDBANK CREEK SEAM
				WAMBO SEAM
				WHYNOT SEAM
				BLAKEFIELD SEAM
			SAXONVALE MBR	
			MOUNT OGILVIE FORMATION	GLEN MUNRO SEAM
				WOODLANDS HILL SEAM
			MILBRODALE FORMATION	
			MOUNT THORLEY FORMATION	ARROWFIELD SEAM
				BOWFIELD SEAM
				WARKWORTH SEAM
			FAIRFORD FORMATION	
			BURNAMWOOD FORMATION	MOUNT ARTHUR SEAM
				PIERCEFIELD SEAM
				VAUX SEAM
				BROONIE SEAM
				BAYSWATER SEAM
		ARCHERFIELD SANDSTONE		

Figure 3 Wittingham Coal Measures Stratigraphic Table

Note: *Carrington Pit – target coal seams* (green-shaded cells: Burnamwood Formation and its seams)



LEGEND

- Mine lease
- Spoil
- Paleochannel (MER, 2005)
- Quaternary alluvium (1:25k AGE)
- Barrier wall
- Regional fault
- Major drainage

Geology - Hunter Coalfield Regional 100k

- Qa - Quaternary alluvium
- Jv - Jurassic volcanics
- Rn - Narrabeen Group
- Psl - Newcastle Coal Measures
- Pswj - Jerrys Plains Subgroup
- Pswv - Archerfield Ss., Vane Subgroup
- Pswc - Saltwater Creek Formation
- Pmm - Mulbring Siltstone
- Pmb - Braxton Formation

HVO North - 2015 Annual Groundwater Impacts Review (G1809)

Geology

DATE 27/01/2016

FIGURE No. **4**

2.5 Hydrogeology

The hydrogeological setting of the Project area comprises three main groundwater systems including, the Hunter River alluvium; the palaeochannel alluvium; and the Permian coal measures. The Project area also includes several mined-out areas that have been backfilled with spoil which can be considered to be a water receiving formation due to recharge from rainfall, surface water / run-off, pit inflows and in some cases, seepage from dams and tailings facilities. The hydrogeological characteristics of the alluvium, palaeochannel alluvium and Permian coal measures are detailed in Section 2.5.1 to Section 2.5.3 below.

2.5.1 Hunter River Alluvium

The Hunter River alluvial aquifer refers to groundwater within the Quaternary alluvium located along the Hunter River. The extent of the Quaternary alluvium is shown in Figure 4. The alluvium is generally comprised of 10 m to 20 m of unconsolidated gravels, sands, silts and clays. The alluvium typically includes two to three main stratigraphic units (Mackie, 2005) as follows:

- surface layer comprising of sands, gravels and minor clay;
- middle layer of silty gravels and sands interbedded with silt and clay layers; and a
- coarse cobble-gravel basal section.

Recharge to the alluvium is by direct infiltration of rainfall, with a lesser contribution from upward leakage from the underlying coal measures. Localised recharge also occurs via lateral seepage through the banks of the Hunter River during periods of high flows. Mackie (2005) found that the Hunter River shallow alluvium, downstream of Muswellbrook, was of sodium-chloride type-water.

2.5.2 Palaeochannel

The alluvial palaeochannel is located north of the Hunter River and west of the existing Carrington Pit (Figure 4). The alluvial palaeochannel is generally 12 m to 20 m thick and comprises of unconsolidated gravels, silts and clays. The depositional environment of the palaeochannel appears to have been dominated by flood surge events, resulting in deposition of gravels contiguously with silts and clays. The alluvial palaeochannel comprises three main layers (MER, 2010a):

- upper layer, comprising thin bands of sand, silt and clay;
- middle layer, which is approximately 3 m to 8 m thick that consists of stiff clays; and a
- basal layer, which is approximately 3 m to 8 m thick comprising of fine to coarse-grained silty clay gravels and cobbles or in some areas, sandy gravels.

2.5.3 Permian coal measures

The Permian coal measures can be categorised into the following hydrogeological units:

- the majority of the Permian comprises interburden / overburden, consisting of very low to low permeability and very low yielding sandstone, siltstone and conglomerate units; and
- low to moderately permeable coal seams, each typically ranging in thickness from 2.5 m to 10 m, which are the prime water bearing strata within the Permian sequence.

3 Monitoring programme

The Water Management Plan (WMP) defines the groundwater monitoring programme for HVO, North and South. The summary of the monitoring bore construction and details is provided in Appendix B.

3.1 Monitoring bore network

The groundwater monitoring network at HVO North (excluding West Pit area), consists of 60 monitoring locations (including vibrating wire piezometers [VWP]) of which there are:

- 29 in the Carrington Pit area;
- 23 in the North Void and Alluvial Lands; and
- 8 VWP installations.

A summary of the bore target formations is included in Table 3 below. Monitoring bore locations are shown in Figure 5 and bore construction details are included in Appendix B

Table 3 Monitoring bore network lithology

Location	Lithology	No. of bores
Alluvial Lands	Alluvium	6
	Permian Coal Seam	1
	Spoil	15
	Unknown	1
Carrington	Alluvium	13
	Permian Coal Seam	9
	Permian Interburden	4
	Spoil	3
	VWP	8

The groundwater monitoring programme records the following parameters quarterly, biannually and / or annually:

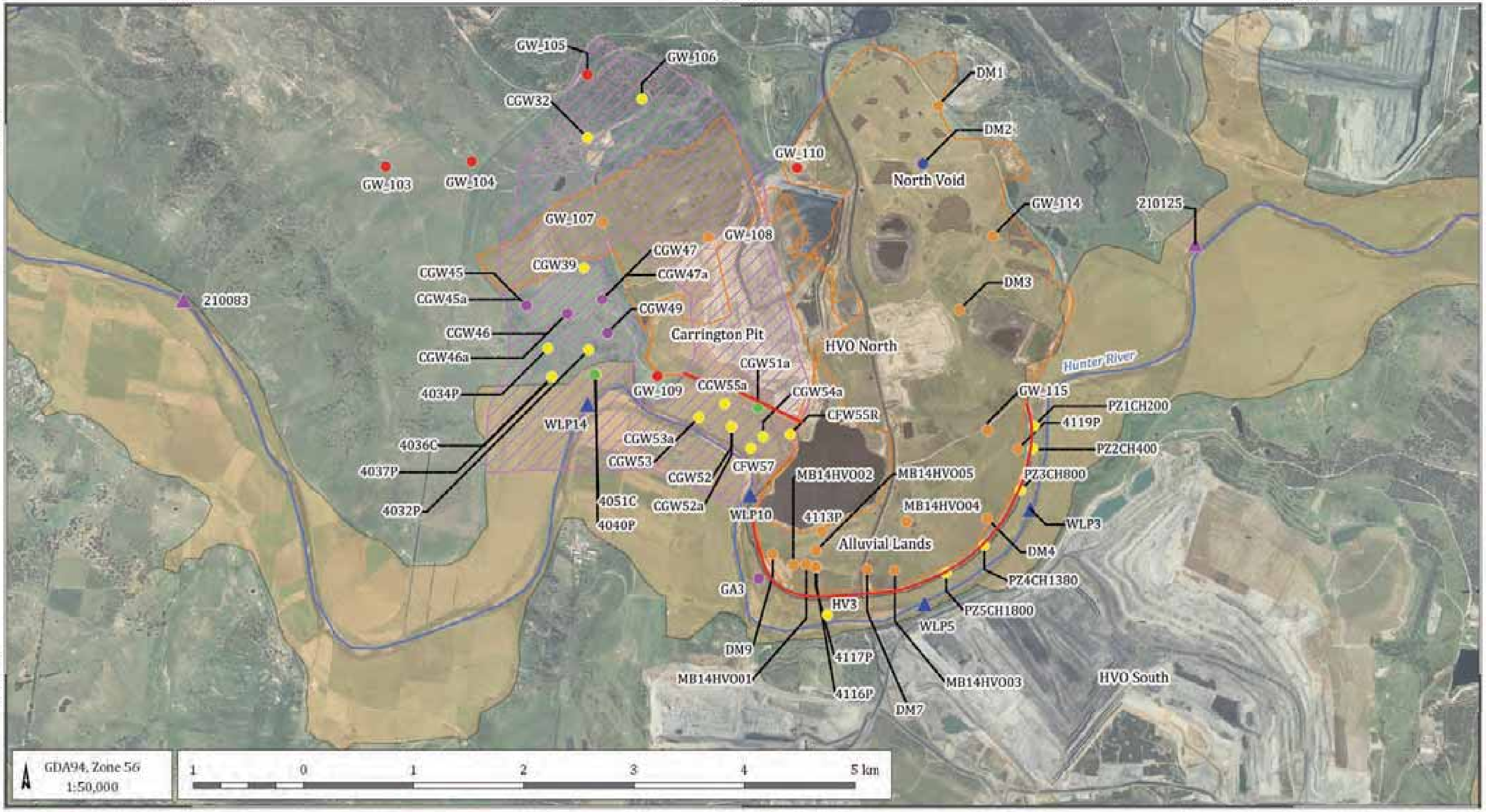
- groundwater level (manual measurements and some bores are equipped with data loggers);
- field water quality, electrical conductivity (EC), pH ; and
- comprehensive analysis.

3.2 Trigger levels

Trigger levels from 95th percentile were assigned for maximum value to a list of relevant borehole for EC and pH. Additionally, 5th percentile minimum value was assigned to the pH.

Site specific investigation is initiated when:

- three consecutive measurements of EC or pH exceed trigger values; and
- professional judgement to determine that a single deviation or a developing trend could result in environmental harm.



LEGEND

- Spoil
- Paleochannel (MER, 2005)
- Quaternary alluvium (1:25k AGE)
- Barrier wall
- HVO gauge station
- WHO gauge station
- Major drainage

Monitoring bore type

- Alluvium
- Permian Coal Seam
- Permian Interburden
- Spoil
- Unknown
- VWP

HVO North - 2015 Annual Groundwater Impacts Review (G1809)

Monitoring bores location

DATE
27/01/2016

FIGURE No:
5

4 Groundwater quality

Electrical conductivity (EC) and pH were measured in 50 bores in 2015 with a total of 146 individual measurements of pH and EC. These measurements were undertaken quarterly or bi-annually. In addition, at 30 of these bore locations groundwater samples were obtained for laboratory analysis of major ions and selected metals. Either one or two sampling rounds were undertaken during 2015.

4.1 Field water quality measurements

Available 2015 EC and pH field values are graphed and tabulated in Appendix C. These graphs and tables are used to identify trends throughout the year and assess compliance with the WMP. Table 4 below summarises the field EC and pH measurements for 2015.

Table 4 Summary of EC and pH data

Location	Lithology	Total bores sampled	Number of measure -ments	Mean EC (µS/cm)	Min. EC (µS/cm)	Max. EC (µS/cm)	Mean pH	Min pH	Max pH
Alluvial Lands	alluvium	6	22	785	127	1,703	6.8	6.3	7.2
	Coal Seam	1	3	746	730	769	7.1	7.0	7.2
	Spoil	15	42	7,194	1,677	12,830	7.0	6.5	7.5
Carrington	Alluvium / palaeochannel	16	45	3,607	935	9,490	7.3	6.8	8.1
	Bayswater Seam	3	9	2,265	384	3,010	7.2	6.5	7.5
	Broonies Seam	3	10	7,281	5,420	8,670	7.1	6.8	7.7
	Interburden	4	11	5,534	2,440	10,800	7.2	7.0	7.4
	Regolith / alluvium	1	1	27,900	27,900	27,900	7.1	7.1	7.1
	Spoil	1	3	4,017	2,120	7,640	7.2	6.9	7.5

Groundwater on site is brackish to saline with the lowest EC measured within the Hunter River alluvium in the Alluvial Lands area. pH results range from 6.3 to 8.1.

The recorded EC values were generally stable during 2015, with the exception of:

- CGW45 (Bayswater seam), CFW57 (palaeochannel), CGW51A (interburden), 4116P (spoil), CGW52 and CGW53 (Broonie seam) which have recorded EC values decreasing from April to October 2015. Theses bores are localised near the Carrington Billabong; except for bores 4116P and CGW45 which are on the Alluvial Lands and on Carrington West Wing, respectively.
- GW_114 and GW_115, both screened in the spoil and located in the east of the Project area, have had their EC increase by approximately 3,000 and 6,000 µS/cm, respectively, since April / July 2015.

Two bores were observed with three consecutives values above the trigger level defined in the WMP:

- CFW55R, near Carrington Billabong. EC concentration increased in May 2015 and subsequently decreased slowly. Concurrently, the pH values decreased and were below the lower trigger value for three consecutive measurements (refer Figure 6).
- GW_106, within the palaeochannel on the north west of the Project area. There were no data available for the previous monitoring year. The three measurements of EC were stable above the trigger level for 2015 (Figure 7).

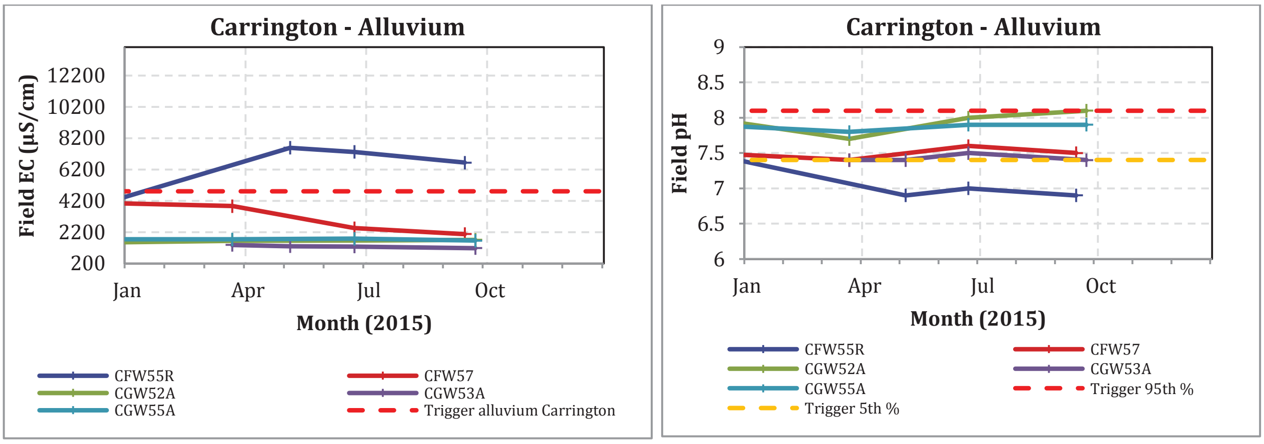


Figure 6 Carrington - alluvium pH and EC,

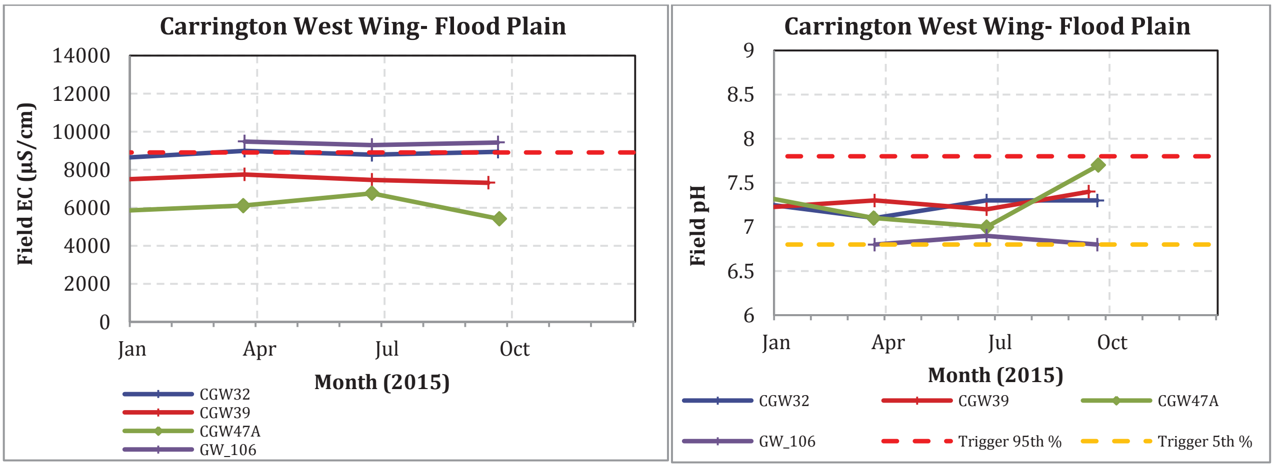
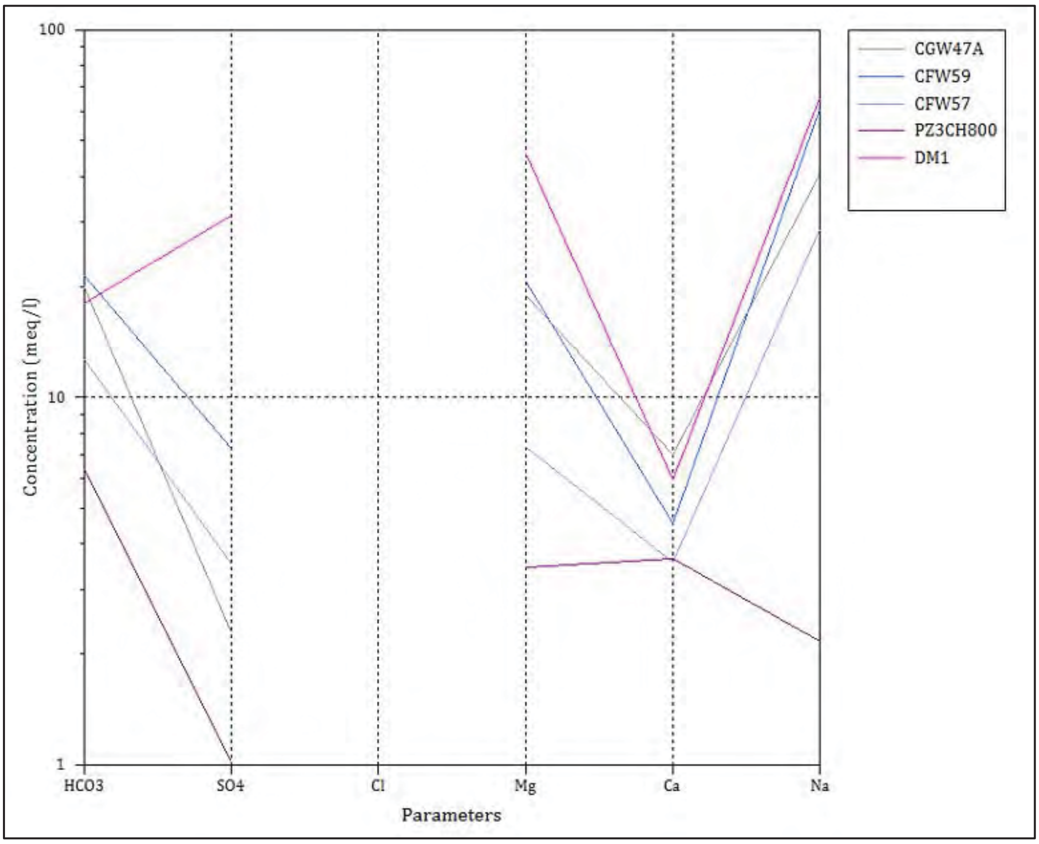


Figure 7 Carrington West Wing – Flood Plain, EC and pH,

4.2 Laboratory analysis

Schoeller plots have been created in order to compare major ion chemistry of groundwater samples. Groundwater type comparison is possible even if some of the major ions were not analysed; as is the case at HVO North, where chloride (Cl) was not included in the whole sample analyses in 2015. Schoeller plots compare the normalised concentration of ions (in milliequivalents / litre) on a vertical logarithmic axis with the analytes identified on the horizontal axis. Points for each ion are then connected to form a line. Similar shaped lines from multiple samples indicate a similarity in origin and vertical displacement of similar lines indicates dilution with fresh water (resulting in downward shift in the line) or concentration / evaporation (resulting in an upward shift).

Schoeller plot analyses have been prepared for Carrington palaeochannel and alluvium, Permian sediment and spoil. Figure 8 shows a representative Schoeller plot from each of these lithological units for 2015. Detailed Schoeller plots for all the bores with sufficient water quality data are in included in Appendix C and regrouped both analyses from early and late 2015 for the same bore.



Note: *CGW47A (Broonie Seam); CFW59 (Interburden); CFW57 (Palaeochannel); PZ3CH800 (Alluvium), DM1 (Spoil)*

Figure 8 Schoeller plot of typical spoil, interburden and alluvium chemistry

The results of the above Schoeller plot analysis are that the chemistry appears similar in the palaeochannel and Permian sediment. Sodium (Na) is the most dominant ion except for the alluvium in the Alluvial Lands where bicarbonate (HCO_3) is the major ion.

The observations, per major geological, units are as follows:

- Elevated sulphate (SO_4) in the spoil samples, with the exception of bores 4119P and 4117P. These bores have chemistry consistent with the palaeochannel groundwater.
- Elevated Calcium (Ca) concentration within the alluvium samples, in contrast to the palaeochannel.
- Groundwater from the palaeochannel bores had similar chemistry, with the exception of bore CFW55R, which showed elevated concentration of SO_4 in March and September 2015. The Schoeller plots show comparable line trend to spoil and may indicate leaching from the spoil. The results differ from the previous reporting years but are consistent with the EC and pH values observed from CFW55R in 2015.

5 Groundwater levels

Groundwater level data has been collected for the Project area since 2001, with data-loggers installed in 16 locations since 2009 to 2014. This report specifically looks at groundwater trends over the 2015 calendar year; however, the data since 2014 has been used for comparison. The groundwater hydrographs are included in Appendix D, and groundwater contours are included in Appendix E. Observations from the available data are detailed in Section 5.1 and Section 5.2.

The groundwater levels were measured in 55 monitoring bores; 3 bores were dry across the whole of 2015: CGW45A, CGW46A and DM2. The bore DM9 was out of service and no data were collected during 2015.

The groundwater levels were compared against the CRD, Hunter River water levels at NOW Station 210083 – (approximately 4 km west of Carrington Pit), and relevant HVO river stations to better understand the connectivity between surface water and groundwater. Note that the available recorded water level from data loggers were not corrected with the water level measured during the monitoring programme and were graphed to observe the groundwater trend over a short period. Manual measured groundwater level was graphed by plot to assess long term groundwater trend.

5.1 Hunter River / Palaeochannel Alluvium

Long-term groundwater trends from all alluvial bores are shown in Appendix D. Groundwater contours for July 2015 (Appendix E) indicate that groundwater in both western and eastern wing of the alluvial sediments has a low hydraulic gradient in the vicinity of the river. Further from embankment, the groundwater has higher hydraulic gradient with a general flow direction toward Hunter River. Both the western and eastern limbs of the alluvial sediments generally record groundwater levels between 58 mAHD and 60 mAHD.

The alluvium groundwater levels were plotted as hydrographs divided into three areas. These hydrographs are compared with the Hunter River water level and are commented on in the following sections.

5.1.1 Carrington West Wing (west of the project area)

Hydrographs were divided into two zones; less than and greater than 700 m from the Hunter River (Figure 9 and Figure 10, respectively). Both hydrographs show groundwater levels below the HVO surface water station WLP14. This indicates a potential recharge from the Hunter River to the alluvium throughout the year.

Additionally, the data logger installed in bore 4040P, located 150 m from the river, recorded similar water level fluctuation to the Hunter River. However, the data logger within bore 4034P, 600 m from the river, shows little influence from variation in water levels. This suggests high connection between the alluvium and the river within the first 200 m and lower connection further inland.

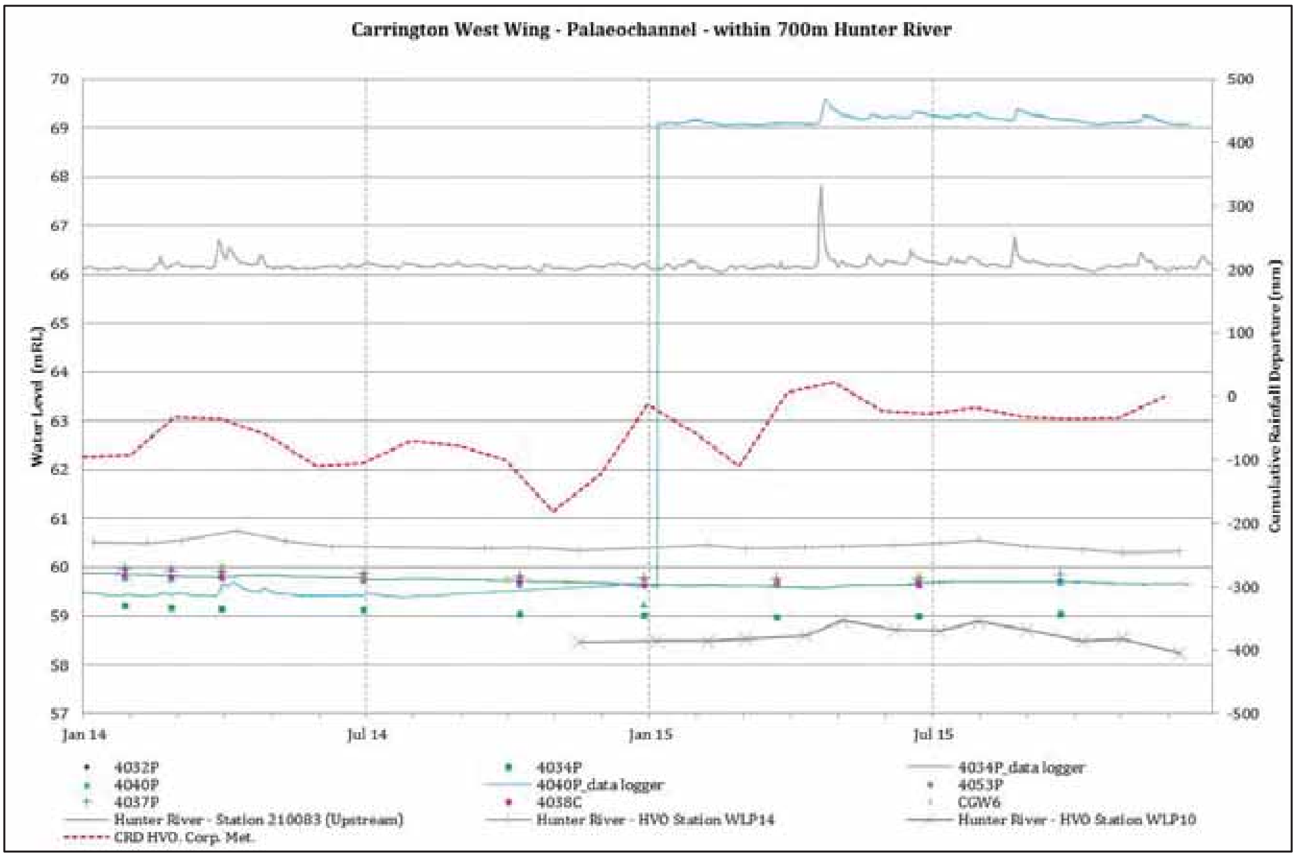


Figure 9 Carrington West Wing hydrographs (less than 700m)

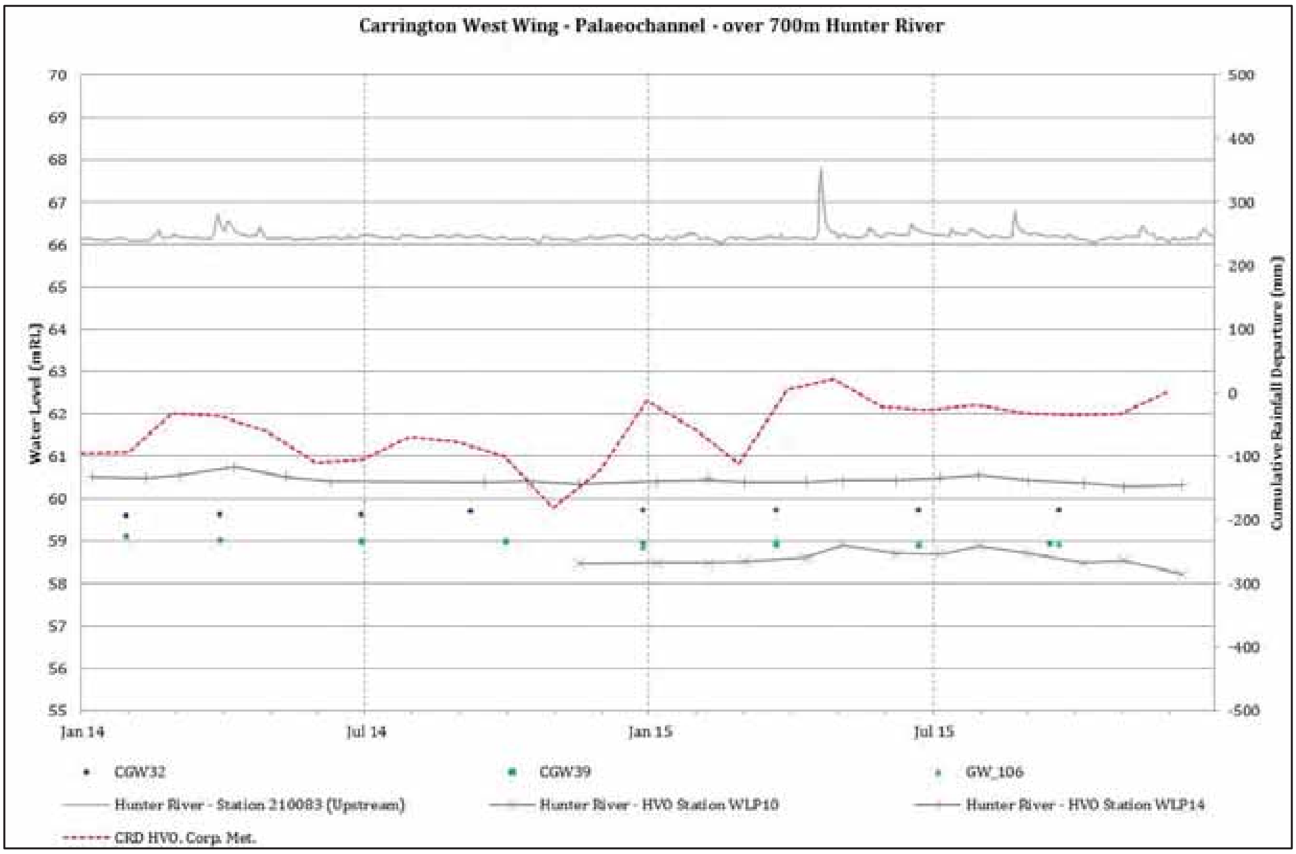


Figure 10 Carrington West Wing hydrographs (greater than 700m)

5.1.2 Carrington East Wing (south west of the Project area)

In March 2010, a barrier (groundwater cut-off) wall was constructed across the eastern limb of the alluvial sediments, approximately 400 m north of the Hunter River.

In general, groundwater levels have similar elevation to the Hunter River. More precisely, when comparing the water level within the bore CGW54A and the HVO Station WLP10, groundwater levels were higher than the surface water except during major peak flows (e.g. 24 April 2015). This indicates an oscillation between potential discharge from groundwater to the river when river levels are low and recharge from the river to the groundwater in high flow periods as a result of reversed differential pressure.

Further from the river, over 250 m, the groundwater level in the vicinity of "The Billabong" (bore CFW55R) is lower than the river for the majority of 2015; however, the water level has been rising since April 2015 and was above the surface water level from September 2015.

The groundwater level recorded in bore CGW55A, located over 250 m from the river west of the Billabong, has been lower than Hunter River for the two last years.

Overall, where data loggers were installed, the observed groundwater levels rose during major river peak flows (April 2014, early May 2015 and August 2015) and decreased for the rest of the year. This implies a connection between the Hunter River and the Alluvium.

5.1.3 Hunter River Alluvium (south of the Project area)

A barrier wall was constructed between the Hunter River and the rehabilitated Alluvial Lands. Six monitoring bores are recording the groundwater level along the wall. Groundwater and river elevations were similar for 2015 and previous years at between 54 mAHD and 56 mAHD; except for monitoring bore HV3 with an average groundwater elevation of 37 mAHD, which is similar to the groundwater within the base of the spoil.

Figure 11 compares the groundwater level elevation between the alluvium and the spoil on the eastern part of the Alluvial Lands and assesses the effectiveness of the barrier wall. Groundwater level within the spoil was continuously lower than the alluvium during the year 2015 which confirms there was no discharge from the spoil in that area.

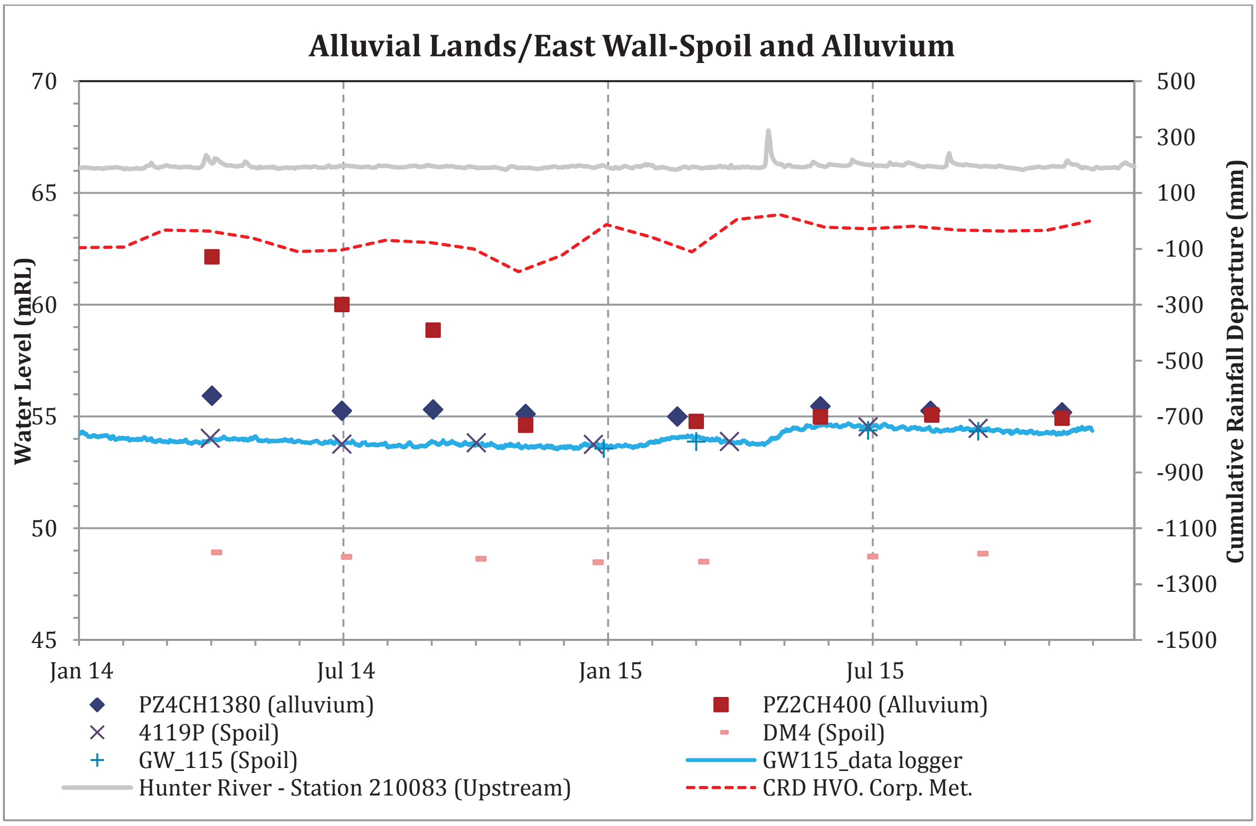


Figure 11 Alluvial Lands (east wall) groundwater elevation comparison between the spoil and alluvium

5.2 Permian coal measures

5.2.1 Permian coal seams

Hydrographs for bores screened within the Permian coal measures are shown in Figure 12 and Appendix D. There is an insufficient number of bores spread across the Project area and intersecting the same coal seam, to display reliable groundwater contours for the Permian coal measures. The groundwater level data indicates:

- Groundwater within the Broonie Seam (BS) is lower in the East Wing of the alluvial sediment (CGW52 and CGW53) than the West Wing (CGW47A and CGW46A). This likely relates to distance from the working Carrington Pit as well as potentially a geological structure.
- Groundwater levels recorded were generally stable for 2015.
- The groundwater level in bore CGW45, screened in the Bayswater Seam, was observed rising to approximately 16 m between March and September 2015.
- The groundwater level in bore CGW53, screened in the east wing of the alluvial plain, was observed to have risen between July 2014 and December 2015.

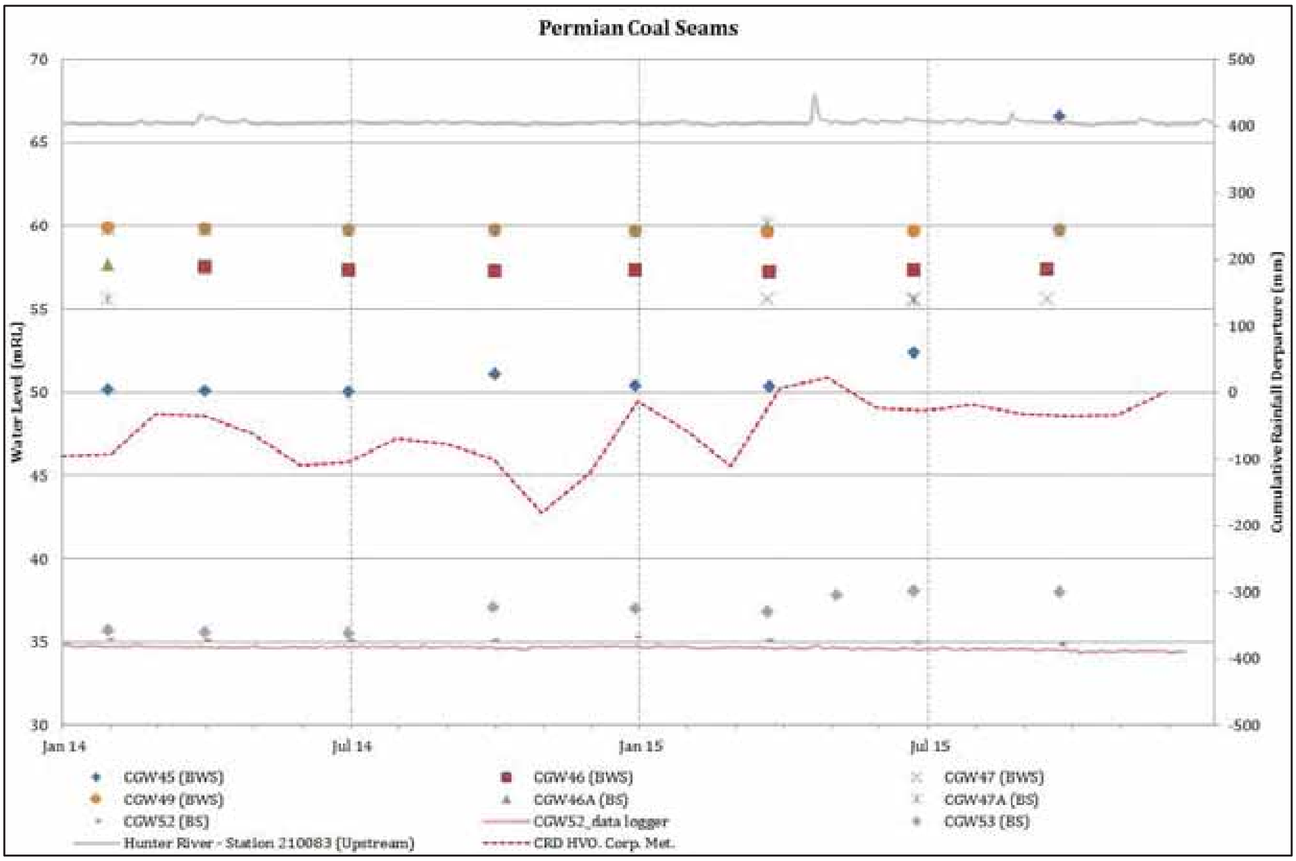


Figure 12 Permian coal seam hydrographs

5.2.2 Permian interburden

Long-term hydrographs for bores screened within the Permian interburden are shown in Figure 13 and Appendix D. There was insufficient data to draw conclusions as to the groundwater flow direction from the 2015 data.

The available 2015 groundwater level data indicates that:

- Bores CFW59 and CGW51A, located in the east wing near the barrier wall, show similar groundwater elevations and trends. The water level is a few metres lower than the alluvium and more than ten metres higher than the Broonie Seam. Water levels within the interburden have been increasing since March 2015.
- Bore 4036C, located in the west wing, displays an average groundwater level lower than the east wing at approximately 38 mAHD. This average groundwater level is lower than the alluvium and the Bayswater Seam in that area. This bore shows a slight decline in groundwater level in 2015, which is indicative of downward leakage in response to depressurisation caused by mining in the Carrington Pit;

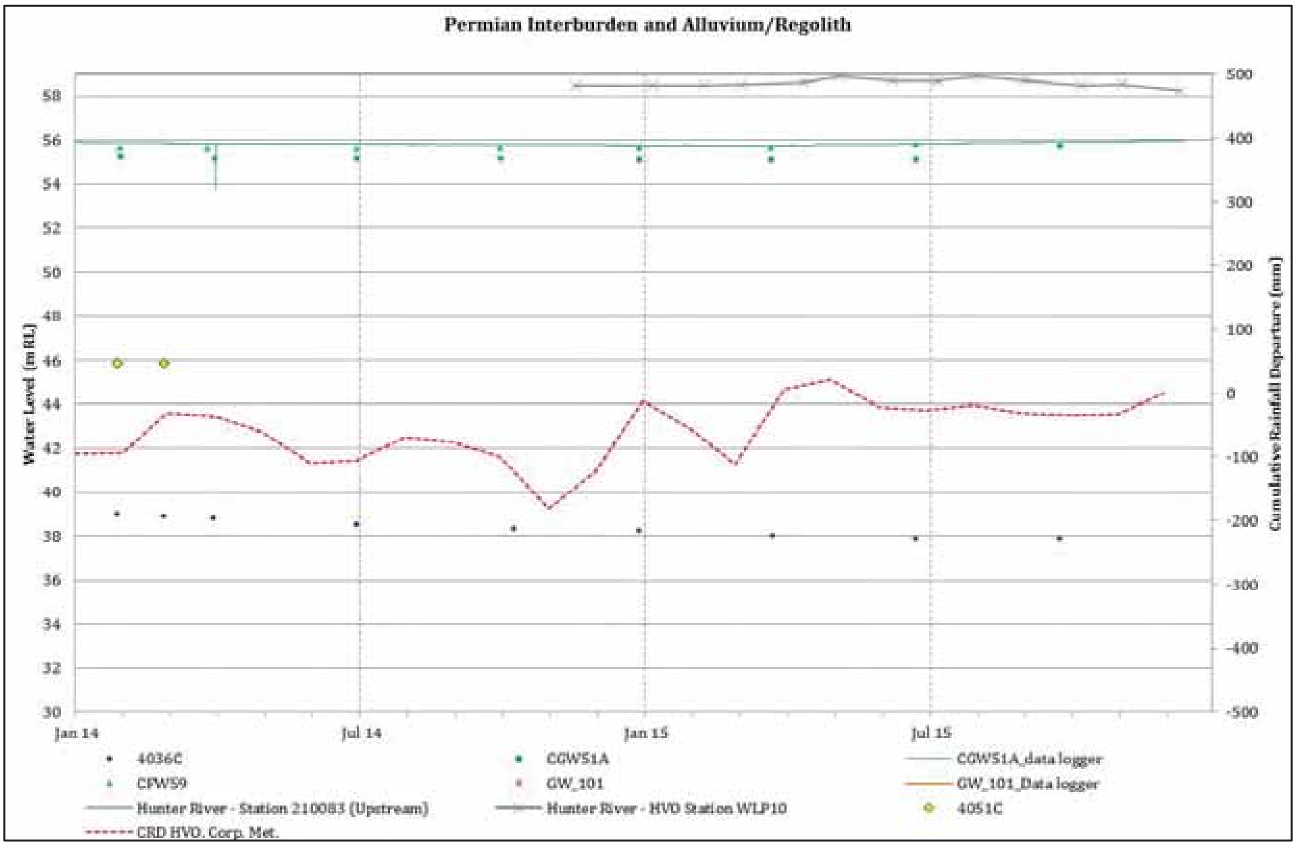


Figure 13 Permian interburden hydrographs

5.3 Spoil

Bores screened in the spoil were plotted in a hydrograph shown in Figure 14 and Appendix D. Groundwater contours for July 2015 in Appendix E indicate that the main flow direction is toward the Dam 29N. A depression was observed within the bore GW_108 with a recorded water level of 23.3 mRL along the Year 2015. Groundwater contours on the east side of the barrier wall at Alluvial Plain are well perpendicular to the wall which confirms the effectiveness of the wall in that area.

The observations during the annual Year 2015 were the following:

- groundwater elevation across the spoil ranges between 23 m RL to 78 m RL and was generally stable throughout the year;
- bores DM7, 4113P and 4117P, located on the western extent of the Alluvial Lands, showed a continued declining trend between 2014 and 2015; and
- bores screened in the upper part of the spoil within the Alluvial Lands, recorded higher groundwater elevations, than the base of the spoil.

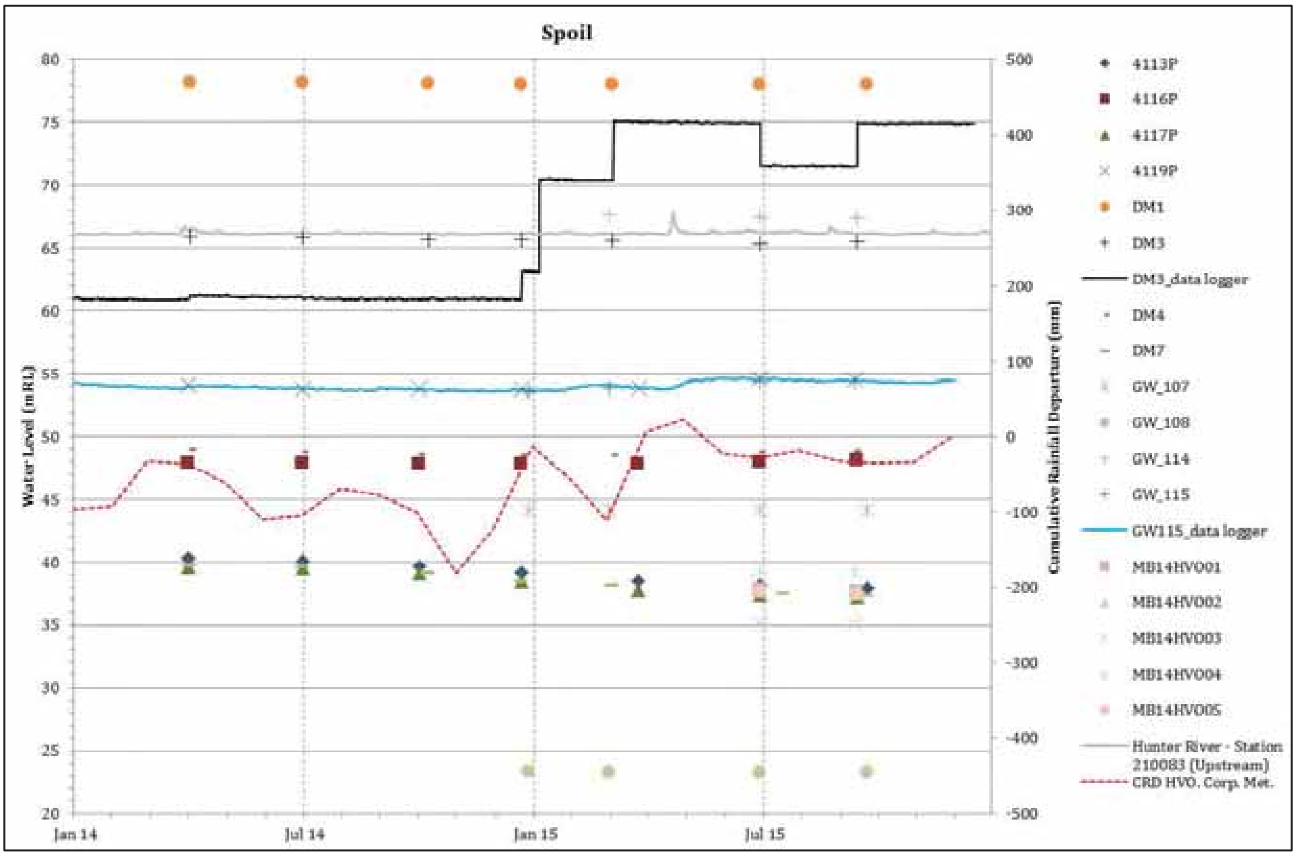


Figure 14 Spoil bore hydrographs

6 Analytical modelling of impacts on Hunter river baseflow

The following section details the estimated loss of alluvial groundwater due to mining operations at the Project area, based on calculations using "snap-shot in time" data. Groundwater leakage from coal seams and alluvium (through the barrier wall) into the pit (Q_{XY}), and vertical leakage of alluvial groundwater into the underlying Permian coal seam (Qz), were calculated by applying Darcy's Law (Equation 1). The calculations and assumptions that were used to estimate the groundwater flow loss (Q_{XY} and Q_Z), are presented in Appendix F and Appendix G. Flow loss calculation results are shown and discussed in Sections 6.1 and 6.2.

Darcy's Law:

$$Q = KiA \qquad (Equation\ 1)$$

where:

Q is the amount of water discharged (m^3/day)

K is the hydraulic conductivity (m/day)

i is the hydraulic gradient (dimensionless)

A is the area (e.g. exposed coal seam) (m^2)

6.1 Horizontal discharge (Q_{xy})

The horizontal leakage of groundwater from the Permian coal measures and alluvium into the Carrington Pit (Qxy) has been calculated using the principles of Darcy's Law. The results, shown in Table 5, indicate that approximately 0.14 ML/day of groundwater from the Permian coal measures potentially enters Carrington Pit and approximately 0.01 ML/day of alluvial groundwater potentially seeps through the barrier wall into Carrington Pit.

Table 5 Estimated leakage of groundwater into pits

Location	Horizontal hydraulic conductivity (MER, 2010) K_{XY} (m/d)	Horizontal hydraulic gradient (i_{XY})	Pit wall length (m)	Exposed face (m)	Horizontal discharge to Pit Q_{XY} (L/s)	Horizontal Discharge from coal seams to Pit Q_{XY} (ML/d)
Carrington Pit	6.0×10^{-3}	0.37	1,100	60	1.68	0.14
Carrington Barrier Wall - South	5.8×10^{-4}	1.54	1,100	10	0.11	0.01

Notes:
K_{xy} *Hydraulic conductivity derived from MER (2010a) and MER (2010b)*
I_{xy} *Horizontal hydraulic gradient*
Q_{xy} *Volume of groundwater discharging into mine pit*

Groundwater related impacts on the palaeochannel alluvium and the Hunter River have been modelled by MER (2010a) since mining commenced at Carrington in 2000, until 2010. The MER (2010a) numerical model predicted long-term baseflow loss from the Hunter River would be up to 0.1 ML/day for both the eastern and western limbs of the palaeochannel. MER (2011) also predicted baseflow loss into the coal measures, as underflow beneath the barrier wall, of about 0.05 ML/day, thus yielding a total leakage loss rate of about 0.15 ML/day.

While the overall baseflow estimates are comparable, the steady state estimate for leakage through the alluvium is lower, compared to MER (2010a), and inflows through the Permian sequences are higher. The analytical calculations presented in this report are a 2D simplification of the hydrogeological system, and therefore only flow through the highwall across the eastern limb of the palaeochannel is reported. The higher estimates for baseflow from the alluvium to the Carrington Pit by MER (2010a) account for flow from the western limb of the palaeochannel, and are considered a more representative estimate of alluvial flow loss.

6.2 Vertical discharge (Qz)

The vertical leakage of alluvial groundwater into the underlying coal measures (Q_Z) was calculated, and the results are shown in Table 6. The results indicate a total baseflow loss into the pit (via the coal measures) of 0.12 ML/day.

Table 6 Estimated leakage of groundwater into coal seams

Location / Pit	K_Z (m/d)	I_z	Pit wall length (m)	Width of Alluvium (m)	Vertical discharge from Alluvium to Broonie Coal Seams Q_Z (L/s)	Vertical discharge from Alluvium to Broonie Coal Seams Q_Z (ML/d)	Percentage of pit inflow from Alluvium Q_Z/Q_{XY} (%)
Alluvial sediments east Limb	2.60E-04	1.34	1100	300	1.34	0.12	80%

Notes:
K_z *Hydraulic conductivity derived from MER (2011) for PCM Layer 2*
I_z *Vertical hydraulic gradient*
Q_z *Is the amount of water discharged*

The vertical leakage rates (Q_z) defining the downward flow of groundwater from the alluvium to the coal seams was divided by the rate of groundwater leakage from target coal seams into the pits (Q_{xy}). The results (% Q_Z/Q_{xy}) indicate that approximately 80% of groundwater seepage is likely to be sourced from the alluvium at Carrington. With the additional 0.01 ML/day predicted flow of alluvial groundwater through the barrier wall, it is predicted that 0.13 ML/day of alluvial groundwater flows into the Carrington Pit.

Real time river flow data and Hunter Integrated Telemetry System (HITS) data is collected by NOW at Station 210083. The time weighted discharge rate duration curve, which is based on historical streamflow data since 1970, shows that the Hunter River (at Station 210083) flows at a rate of around 150 ML/day approximately 75% of the time, and flows at a rate of around 60 ML/day 95% of the time. The total leakage of alluvial groundwater (Q_z) is estimated at 0.13 ML/day, which conservatively equates to a stream flow loss of 0.1% to 0.2% from the Hunter River, based on the 75th and 95th percentile of stream flow rates. It is anticipated that the 0.1% flow loss, based on the 75th percentile, is a more realistic estimate.

7 Alluvial Lands Bore Compliance

Four licences were renewed under Part V of the Water Act 1912 the 14th October 2014 in the Alluvial Lands area:

- 20BL173847 - bore yet to be constructed;
- 20BL173587 - Bore DM9 (in spoil) commissioned but out of service;
- 20BL173588 - Bore DM8 commissioned but out of service; and
- 20BL173589 - Bore DM7 (in spoil) not commissioned.

As mentioned previously, a barrier wall was constructed in 2010 between the Alluvial Lands and the Hunter River alluvium to contain the groundwater within the mine and to protect the Hunter River ecosystem.

The maximum volume of groundwater extracted authorised by the four licences is 2,400 ML from 1 July to 31 June. There was no abstraction from the bores during the reporting period; therefore there was no impact on any aquifers, groundwater dependent ecosystems and stream in the area.

The following paragraph provides a summary of the groundwater elevation in the Alluvial Lands for the reporting period to provide a baseline for the next reporting period.

Hydrographs within spoil and Hunter River alluvium are in Appendix D. When comparing the monitoring bores within the alluvium and the spoil on the west side of the barrier wall, groundwater levels within the spoil are greater than two metres below the alluvium (bore PZ4CH400 and bore 4119P) which indicates there is no leakage from the saturated backfilled mine void to the alluvium. On the southern or river-side of the barrier wall, one monitoring bore is screened within the alluvium (HV3); the groundwater level measured within HV3 is lower than the groundwater within the spoil.

8 Conclusions

The following conclusions for HVO North Project Area are drawn from the data presented in the previous sections:

- Bore CFW55R, near Carrington Billabong, had three consecutive EC values above the trigger level since May 2015 and three pH measurements below the trigger value for the same recording period. Furthermore, Schoeller plots indicate an elevated concentration of sulphates which may indicate leakage from the Dam 29N or that the bore is not screened in the alluvium.
- Bore GW_106, within the palaeochannel has three consecutive EC values above the trigger level and is broadly consistent with other paleochannel bores distal to the river. Paleochannel bores have been grouped separately from the alluvium bores to reflect the target aquifer and trigger levels are reviewed annually as per the WMP requirements.
- Based on 2015 river and groundwater elevations for the alluvium, the Hunter River can be considered to be losing water to the west wing paleochannel alluvium. This is consistent with that reported in the 2014. In the east wing of the paleochannel and in Alluvial lands, recharge from Hunter River within the alluvium occurred mainly during peak flow.
- Groundwater levels within the spoil are a minimum two metres lower than the alluvium water levels. The main flow direction is toward Dam 29N.
- Darcy's Law steady state calculations indicate that approximately 0.14 ML/day of groundwater from the coal measures enter the Carrington Pit, while approximately 0.01 ML/day of alluvial groundwater enters the pit through the barrier wall. These results are comparable with the results presented by MER (2010a) who undertook a three dimensional numerical model for the Carrington mine area.
- Based on Darcy's Law steady state calculations, the total baseflow loss from the Hunter River alluvium into the Carrington Pit is estimated to be around 0.13 ML/day, which is equivalent to between 0.1% and 0.2% of Hunter River baseflows. This estimate is within the volumes predicted by previous modelling.
- Alluvial Lands Bores are in compliance with the terms and conditions of the licences 20BL173847 and 20BL173587-89.

9 References

Glen R.A. and Beckett J., (1993), "*Hunter Coalfield Regional Geology 1:100 000",* 2nd Edition. Geological Society of New South Wales, Sydney.

Mackie Environmental Research, (2005), "*Carrington Extended – Water Management Studies*", prepared for Coal & Allied, in Carrington Pit Extended – Statement of Environmental Effects, Volume 2, Annex D – Groundwater & Surface Water Assessment & Associated Peer Review, September 2005.

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Mackie Environmental Research, (2010b), *"Carrington West Wing Modification – Groundwater Assessment*", prepared for Coal & Allied, in Carrington West Wing Environmental Assessment (EA), Volume 2, Appendix C – Groundwater Study, March 2010.

Rio Tinto Coal Australia, (2015), "*Hunter Valley Operations Water Management Plan*", July 2015

Appendix A Surface water data

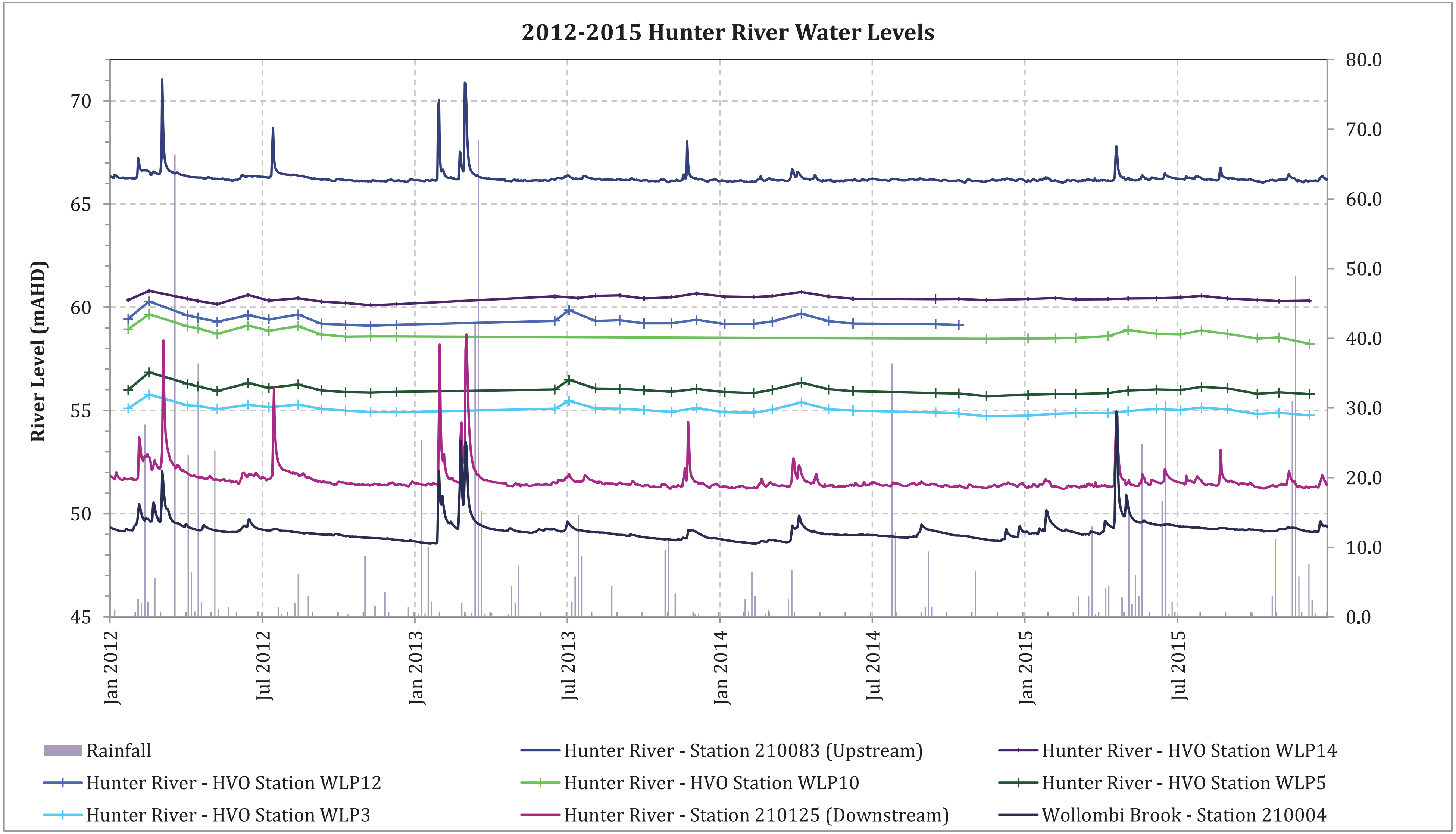


Figure A 1 Hunter River levels

Appendix B Monitoring bore construction details

Bore ID	Type	Status	Easting	Northing	Ground elevation (mAHD)	Collar height (maGL)	Bore depth (mbGL)	Top of screen (mbGL)	Base of screen (mbGL)	VWP sensor (mAHD)	VWP sensor (mbGL)	Bore diameter (mm)	Lithological description	Location
HV3	MB	EX	310776	6400546	67.67	0.5	16.6	-	16.7	-	-	-	Hunter River Alluvium	Alluvial Lands
PZ1CH200	MB	EX	312646	6402256	62.22	0.1	10.5	>8.9	11.1	-	-	50	Alluvium	Alluvial Lands
PZ2CH400	MB	EX	312634.55	6402050.63	62.73	0.05	11.12	>9.9	11.2	-	-	50	Hunter River Alluvium	Alluvial Lands
PZ3CH800	MB	EX	312522.15	6401674.08	64.22	-	10.42	-	-	-	-	50	Hunter River Alluvium	Alluvial Lands
PZ4CH1380	MB	EX	312195.59	6401175.55	65.03	0.08	14.5	-	-	-	-	50	Hunter River Alluvium	Alluvial Lands
PZ5CH1800	MB	EX	311851.97	6400928	66.20	0.08	14.92	-	-	-	-	50	Hunter River Alluvium	Alluvial Lands
GA3	MB	EX	310159.21	6400875.91	65.52	-	-	-	-	-	-	-	Coal	Alluvial Lands
GW_114_extra	MB	AD	312272.1	6403981.3	98.19	-	120	111	114	-	-	50	Bayswater Seam	Alluvial Lands
4113P	MB	EX	310729.27	6401303.83	70.41	1.33	66.54	62.9	65.54	-	-	50	Spoil	Alluvial Lands
4116P	MB	EX	310681.13	6400978.14	71.48	1.31	25.8	20.9	23.54	-	-	50	Spoil	Alluvial Lands
4117P	MB	EX	310670.12	6400979.97	71.43	1.22	91	87	87.64	-	-	50	Spoil	Alluvial Lands
4119P	MB	EX	312500.62	6402047.91	64.74	1.23	20.8	14.9	17.54	-	-	50	Spoil	Alluvial Lands
DM1	MB	EX	311778	6405164	103.05	0.32	28.83	-	-	-	-	50	Spoil (Base)	Alluvial Lands
DM2	MB	AD	311640	6404635	106.81	-	-	-	-	-	-	-	Pit Floor	Alluvial Lands
DM3	MB	EX	311971	6403310	94.97	0.83	40.67	50	-	-	-	50	Spoil (Base)	Alluvial Lands
DM4	MB	EX	312222	6401418	65.69	0.84	-	55	-	-	-	50	Spoil (Base)	Alluvial Lands
DM7	MB	EX	311136	6400961	70.39	1.13	-	32	-	-	-	400	Spoil	Alluvial Lands
DM9	MB	AD	310284.43	6401094.95	70.80	1.2	-	32	-	-	-	400	Spoil	Alluvial Lands

Bore ID	Type	Status	Easting	Northing	Ground elevation (mAHD)	Collar height (maGL)	Bore depth (mbGL)	Top of screen (mbGL)	Base of screen (mbGL)	VWP sensor (mAHD)	VWP sensor (mbGL)	Bore diameter (mm)	Lithological description	Location
GW_114	MB	EX	312272.1	6403981.3	98.19	-	33	27	30	-	-	50	Spoil	Alluvial Lands
MB14HVO01	MB	AU	310587	6401003	71.29	-	90	-	-	-	-	-	Spoil	Alluvial Lands
MB14HVO02	MB	AU	310469	6401001	70.90	-	90	-	-	-	-	-	Spoil	Alluvial Lands
MB14HVO03	MB	AU	311387	6400950	67.14	-	80	-	-	-	-	-	Spoil	Alluvial Lands
MB14HVO04	MB	AU	311491	6401392	67.06	-	55	-	-	-	-	-	Spoil	Alluvial Lands
MB14HVO05	MB	AU	310675	6401127	71.67	-	85	-	-	-	-	-	Spoil	Alluvial Lands
4032P	MB	EX	308608.87	6402944.75	70.29	0.94	14.4	7.44	13.44	-	-	50	Palaeochannel alluvium	Carrington
4034P	MB	EX	308238.86	6402958.62	71.46	0.31	15	5.6	14.6	-	-	50	Palaeochannel alluvium	Carrington
4037P	MB	EX	308276.59	6402701.7	71.77	1.03	15.4	8.28	14.28	-	-	50	Palaeochannel alluvium	Carrington
4040P	MB	EX	308675	6402723.76	70.13	0.97	12.91	5.9	11.9	-	-	50	Palaeochannel alluvium	Carrington
CFW55R	MB	EX	310438.96	6402179.73	70.28	0.5	16.4	9.4	16.4	-	-	50	Palaeochannel alluvium	Carrington
CFW57	MB	EX	310083.7	6402052.62	70.75	0.7	16.44	8.44	15.44	-	-	50	Palaeochannel alluvium	Carrington
CGW32	MB	EX	308598	6404872	79.18	-	-	-	-	-	-	-	Palaeochannel alluvium	Carrington
CGW52a	MB	EX	309901.62	6402249.47	71.36	0.75	18.55	-	-	-	-	50	Alluvium	Carrington
CGW53a	MB	EX	309606	6402333	70.53	0.7	14.74	-	-	-	-	50	Alluvium	Carrington
CGW54a	MB	EX	310196.21	6402158.88	70.00	0.79	17.1	-	-	-	-	50	Alluvium	Carrington
CGW55a	MB	EX	309840	6402457	71.04	0.48	18.46	-	-	-	-	50	Alluvium	Carrington
GW_101	MB	EX	304373.64	6406727.78	100.54	-	12	9	12	-	-	50	Regolith, alluvium	Carrington
GW_106	MB	AU	309091.86	6405223.99	82.26	0.84	30	24	27	-	-	50	Palaeochannel alluvium or weathered sandstone?	Carrington
CGW39	MB	EX	308566	6403694	70.17	0.53	13.45	5	14	-	-	-	Alluvium?	Carrington
CGW45	MB	EX	308042	6403349	72.51	0.33	14.44	-	-	-	-	25	Bayswater Seam	Carrington

Bore ID	Type	Status	Easting	Northing	Ground elevation (mAHD)	Collar height (maGL)	Bore depth (mbGL)	Top of screen (mbGL)	Base of screen (mbGL)	VWP sensor (mAHD)	VWP sensor (mbGL)	Bore diameter (mm)	Lithological description	Location
CGW45a	MB	AD	308044	6403349	72.65	0.47	-	-	-	-	-	65	Broonie Seam	Carrington
CGW46	MB	EX	308413	6403276	71.95	-	13.64	-	-	-	-	25	Bayswater Seam	Carrington
CGW46a	MB	EX	308415	6403276	71.95	-	-	-	-	-	-	65	Broonie Seam	Carrington
CGW47	MB	EX	308729	6403406	70.83	0.44	16.47	-	-	-	-	25	Bayswater Seam	Carrington
CGW47a	MB	EX	308731	6403405	70.83	0.44	-	-	-	-	-	50	Broonie Seam	Carrington
CGW49	MB	EX	308778	6403098	69.57	0.49	13.3	-	-	-	-	80	Bayswater Seam	Carrington
CGW52	MB	EX	309905.73	6402255.4	71.40	0.7	45.25	-	-	-	-	25	Broonie Seam	Carrington
CGW53	MB	EX	309605.51	6402332.71	70.48	0.61	43	-	-	-	-	25	Broonie Seam	Carrington
GW_103	VWP	AU	306769.16	6404610.08	103.18	-	120	-	-	-	25.5 64.5 119.5	-	Coal - undifferentiated and weathered Siltstone and coal Sandstone - mg, fresh	Carrington
GW_105	VWP	AU	308597	6405442.41	93.10		154	-	-		33 103.5 154	-	Coal - undifferentiated Coal - tuffaceous Coal	Carrington
GW_109	VWP	AU	309232.07	6402705.86	85.16	-	-	-	-		31.5 65 89.5	-	Coal - slightly weathered Coal - tuffaceous Bayswater Seam	Carrington
4036C	MB	EX	308272.36	6402687.62	71.78	1.08	35.2	33.1	34.1		-	50	Interburden (Siltstone/Sandstone)	Carrington
4051C	MB	EX	308664	6402721	69.90	0.98	31.51	31.75	32.75		-	50	Interburden (Siltstone/Sandstone)	Carrington
CGW51a	MB	EX	310148.93	6402419.17	70.21	0.17	17.18	-	-	-	-	50	Interburden (Siltstone/Sandstone)	Carrington
GW_100a	VWP	EX	303721.7	6406444.63	89.38	-	60	-	-	-	51	-	Barrett Seam and Interburden	Carrington
GW_101a	VWP	AU	304362.4	6406720.58	100.55	-	52	-	-	-	51	-	Interburden (Siltstone/Sandstone)	Carrington
GW_102	VWP	AU	305279.82	6406667.69	114.60	-	60.5	-	-	-	60.5	-	Interburden (Sandstone with minor coal)	Carrington

Bore ID	Type	Status	Easting	Northing	Ground elevation (mAHD)	Collar height (maGL)	Bore depth (mbGL)	Top of screen (mbGL)	Base of screen (mbGL)	VWP sensor (mAHD)	VWP sensor (mbGL)	Bore diameter (mm)	Lithological description	Location
GW_104	VWP	AU	307548.87	6404657.16	86.75	-	136	-	-	-	59 107 135	-	Lower Pikes Gully Seam Sandstone IB (near Upper Liddell Seam) Sandstone (above Barret)	Carrington
GW_110	VWP	AU	310502.8	6404597.56	124.64	-	-	-	-	-	38 63 93	-	Sandstone - fresh Sandstone Bayswater Seam	Carrington
GW_107	MB	EX	308737.77	6404102.81	73.47		28.63	24.2	27.2		-	50	Carrington Spoil	Carrington
GW_108	MB	EX	309695.01	6403970.7	84.39	-	61.5	52.5	58.5	-	-	50	Carrington Spoil	Carrington
GW_115	MB	EX	312227.24	6402216	68.32		28.7	22.2	28.2		-	50	Spoil	Carrington

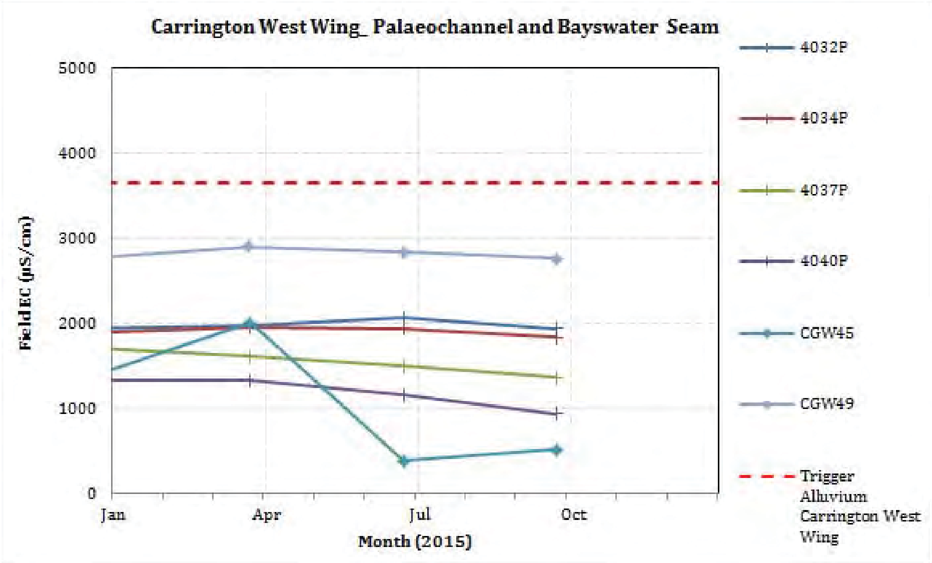
Appendix C **Groundwater quality**

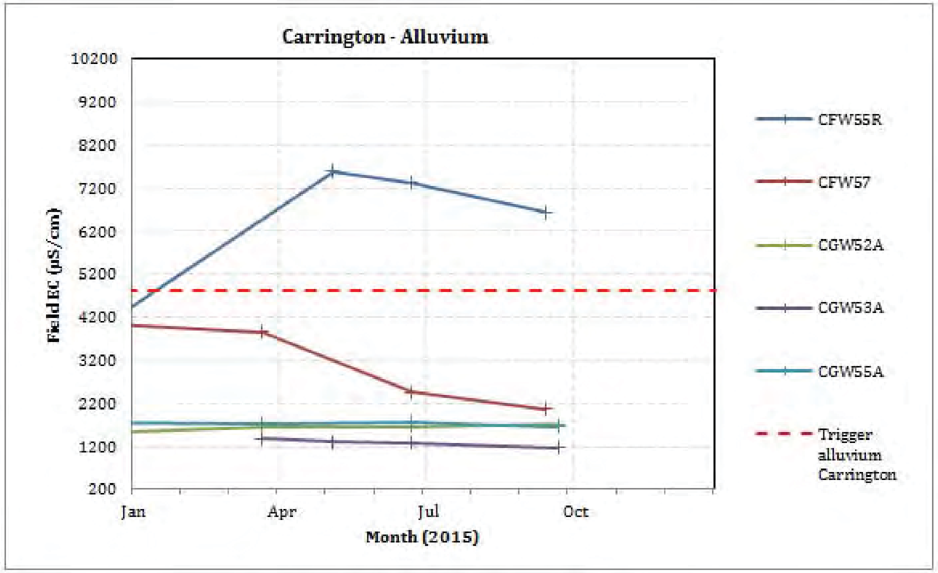
2015 Groundwater Field EC (µS/cm)															
Bore ID	Target lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trigger 95th %ile
GA3	Coal	Alluvial Lands			738				769		730				7440
HV3	Hunter River Alluvium	Alluvial Lands			1703				1438						7440
PZ1CH200	Alluvium	Alluvial Lands		190			185			1130			974		7440
PZ2CH400	Hunter River Alluvium	Alluvial Lands		856			705			845			725		7440
PZ3CH800	Hunter River Alluvium	Alluvial Lands		897			883			878			891		7440
PZ4CH1380	Hunter River Alluvium	Alluvial Lands		801			878			895			999		7440
PZ5CH1800	Hunter River Alluvium	Alluvial Lands		276			127			782			204		7440
DM2	Pit Floor	Alluvial Lands													n/a
4113P	Spoil	Alluvial Lands				7590			7500		7270				12505
4116P	Spoil	Alluvial Lands				12830			11990		11290				12505
4117P	Spoil	Alluvial Lands				7210			7120		7090				12505
4119P	Spoil	Alluvial Lands				1820			1970		1677				12505
DM7	Spoil	Alluvial Lands			7240				7620		7620				12505
DM9	Spoil	Alluvial Lands													n/a
GW_114	Spoil	Alluvial Lands			5690				7230		8890				12505
MB14HVO0 1	Spoil	Alluvial Lands				7220			7170		7060				12505
MB14HVO0 2	Spoil	Alluvial Lands				6970			6820		6940				12505
MB14HVO0 3	Spoil	Alluvial Lands				6030			5650		5860				12505
MB14HVO0 4	Spoil	Alluvial Lands				5760			5750		5520				12505
MB14HVO0 5	Spoil	Alluvial Lands				7490			7370		7210				12505

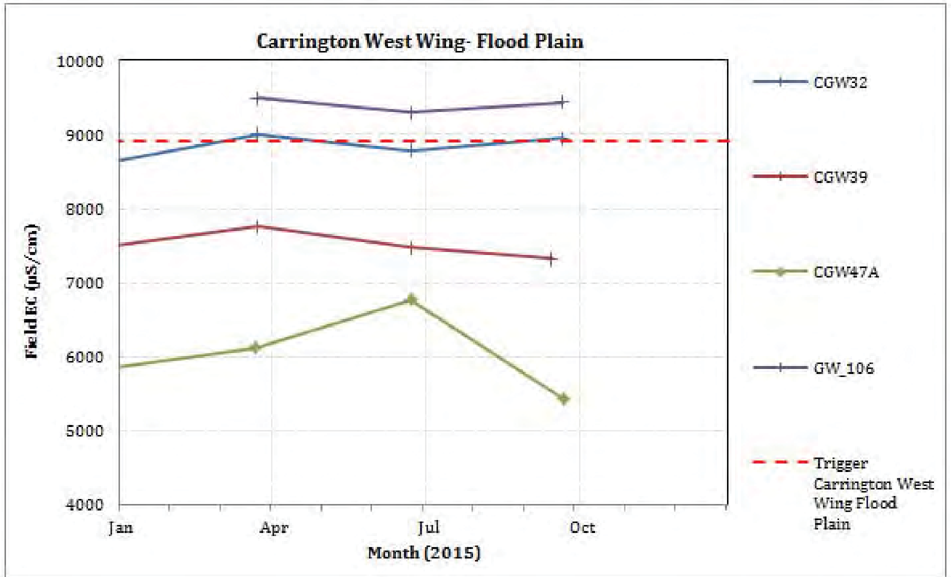
2015 Groundwater Field EC (µS/cm)															
Bore ID	Target lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trigger 95th %ile
DM1	Spoil (Base)	Alluvial Lands			9180				9920		9560				12505
DM3	Spoil (Base)	Alluvial Lands			8610				9320		9150				12505
DM4	Spoil (Base)	Alluvial Lands			5850				6100		6010				12505
CGW52A	Alluvium	Carrington				1642		1654			1706				4802
CGW53A	Alluvium	Carrington				1380	1301	1277			1176				4802
CGW54A	Alluvium	Carrington				3290		3090							n/a
CGW55A	Alluvium	Carrington				1740		1776			1660				4802
CGW6	Alluvium	Carrington				1745		1440							n/a
CGW39	Alluvium?	Carrington				7760		7470			7320				8914
CGW45	Bayswater Seam	Carrington				2000		384			513				3648
CGW46	Bayswater Seam	Carrington				3010		2990			3000				n/a
CGW47	Bayswater Seam	Carrington													10877
CGW49	Bayswater Seam	Carrington				2900		2830			2760				3648
CGW45A	Broonie Seam	Carrington													n/a
CGW46A	Broonie Seam	Carrington													3648
CGW47A	Broonie Seam	Carrington				6120		6770			5420				8914
CGW52	Broonie Seam	Carrington				8670		8320			8000				8608
CGW53	Broonie Seam	Carrington				7650	7430	7250			7180				8608
4036C	Interburden (Siltstone/Sandstone)	Carrington				3370		3420			3350				10877
4051C	Interburden (Siltstone/Sandstone)	Carrington				2470		2520			2440				10877
CFW59	Interburden (Siltstone/Sandstone)	Carrington				7960		6760							n/a
CGW51A	Interburden (Siltstone/Sandstone)	Carrington				10800		8830			8950				10877

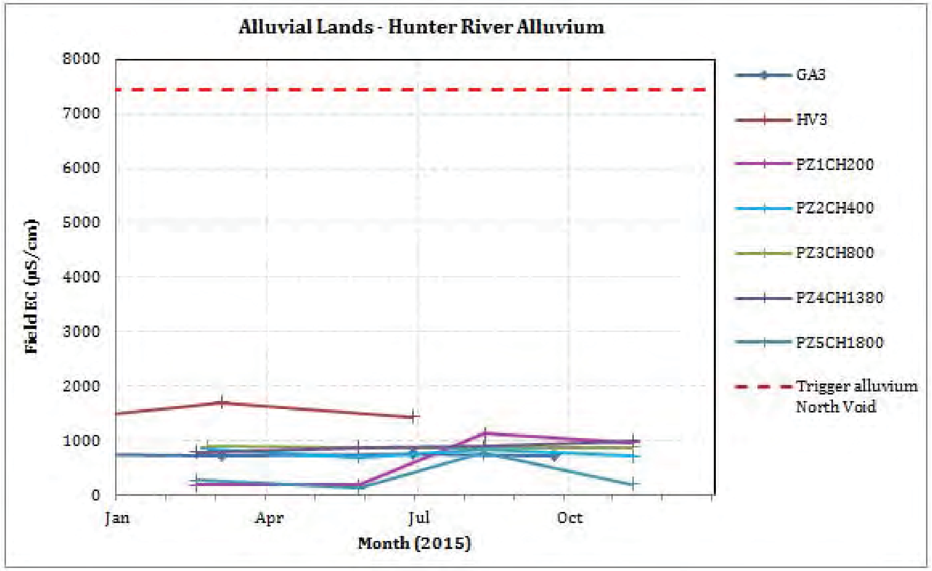
2015 Groundwater Field EC (µS/cm)															
Bore ID	Target lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trigger 95th %ile
4032P	Palaeochannel alluvium	Carrington				1970		2060			1940				3648
4034P	Palaeochannel alluvium	Carrington				1960		1940			1830				3648
4037P	Palaeochannel alluvium	Carrington				1605		1499			1360				3648
4038C	Palaeochannel alluvium	Carrington				3400		3290							n/a
4040P	Palaeochannel alluvium	Carrington				1322		1158			935				3648
4053P	Palaeochannel alluvium	Carrington				1870		1850							n/a
CFW55R	Palaeochannel alluvium	Carrington					7580	7320			6640				4802
CFW57	Palaeochannel alluvium	Carrington				3860		2450			2070				4802
CGW32	Palaeochannel alluvium	Carrington				9000		8790			8950				8914
GW_106	Palaeochannel alluvium or weathered sandstone?	Carrington				9490		9300			9440				8914
GW_107	Carrington Spoil	Carrington													n/a
GW_108	Carrington Spoil	Carrington													n/a
GW_101	Regolith, alluvium	Carrington						27900							n/a
GW_115	Spoil	Carrington			2120				2290		7640				12505

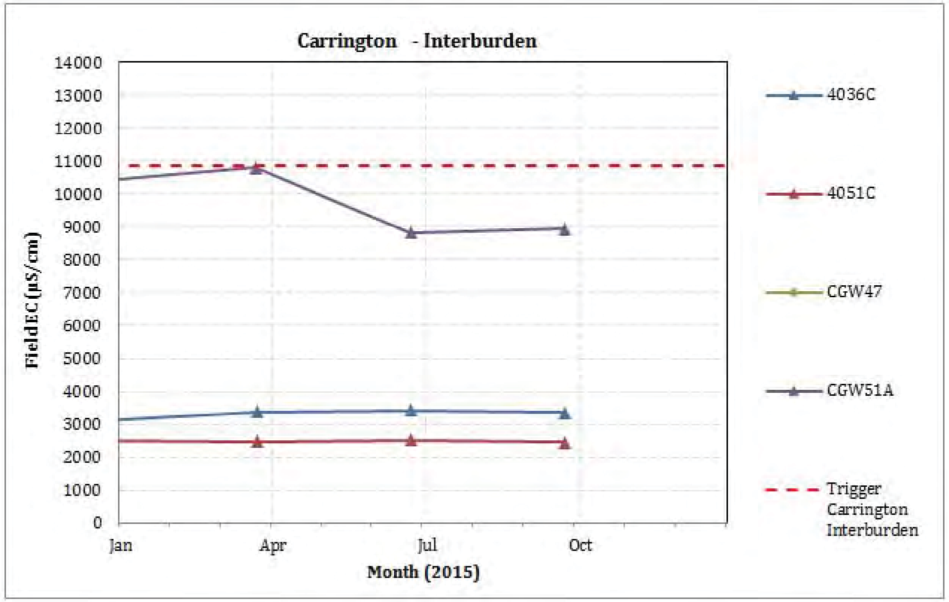
2015 Field Electrical Conductivity (EC)

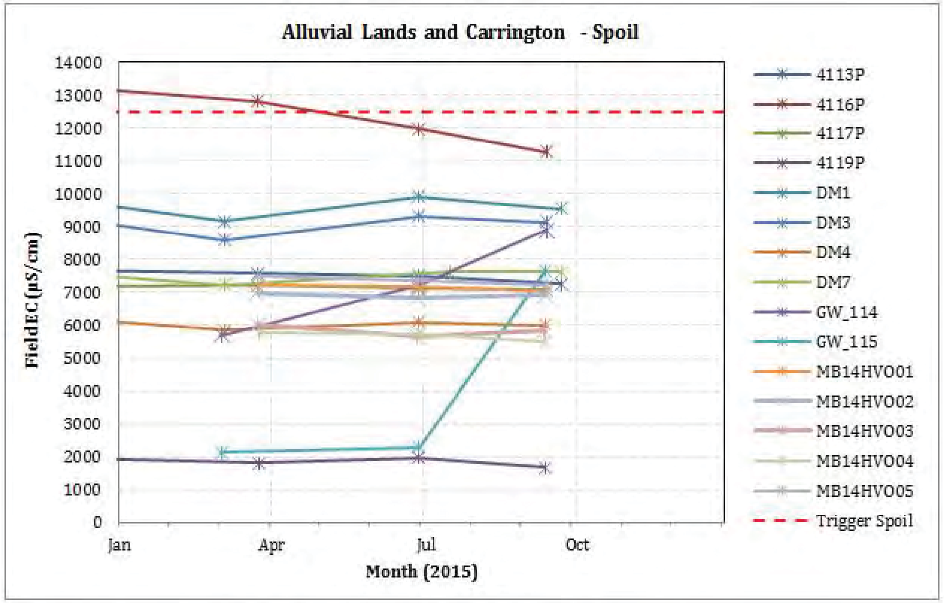


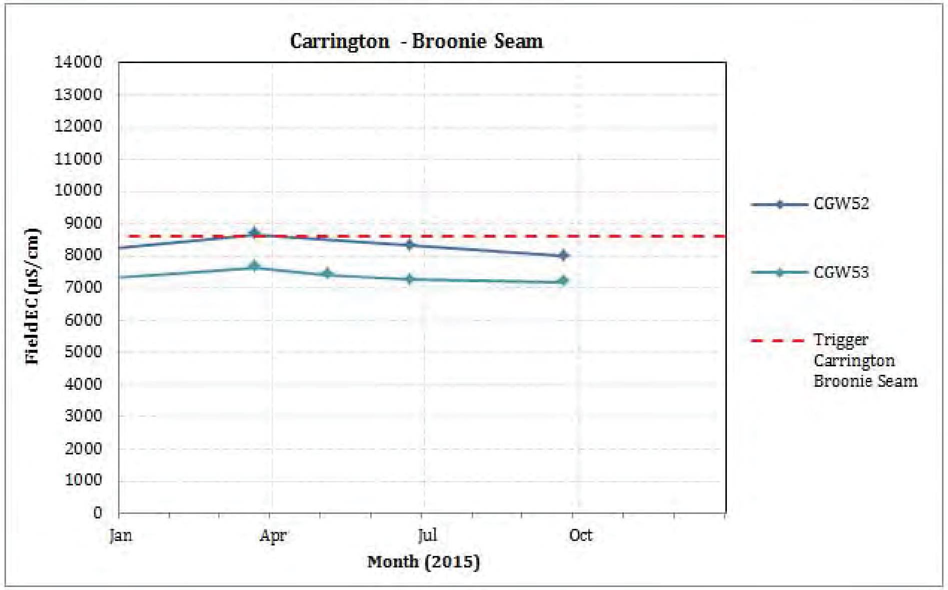


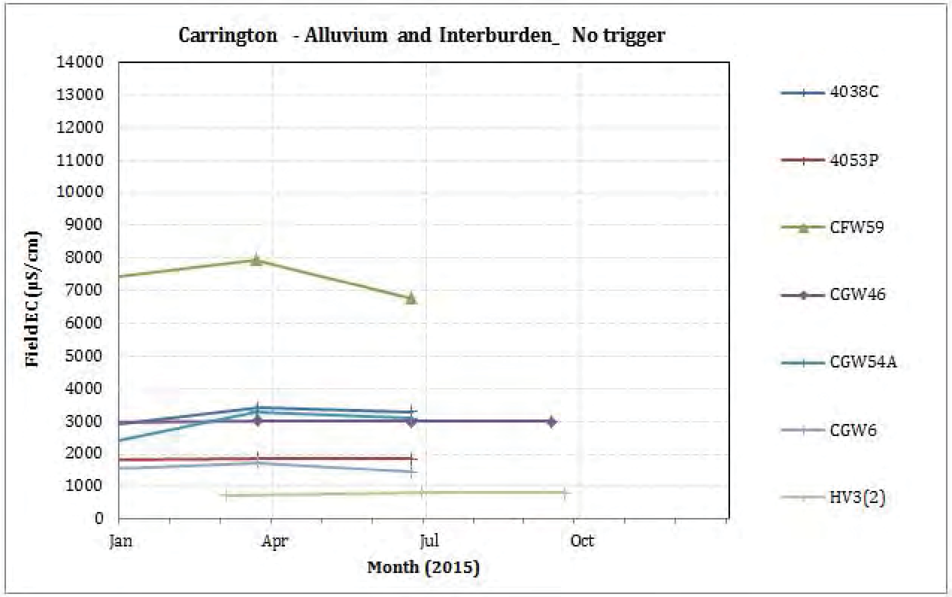





Carrington - Interburden
Field EC (µS/cm)
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Jan
Apr
Jul
Oct
Month (2015)
4036C
4051C
CGW47
CGW51A
Trigger Carrington Interburden


Alluvial Lands and Carrington - Spoil
Field EC (µS/cm)
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Jan
Apr
Jul
Oct
Month (2015)
4113P
4116P
4117P
4119P
DM1
DM3
DM4
DM7
GW_114
GW_115
MB14HVO01
MB14HVO02
MB14HVO03
MB14HVO04
MB14HVO05
Trigger Spoil


Carrington - Broonie Seam
Field EC (µS/cm)
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Jan
Apr
Jul
Oct
Month (2015)
CGW52
CGW53
Trigger Carrington Broonie Seam

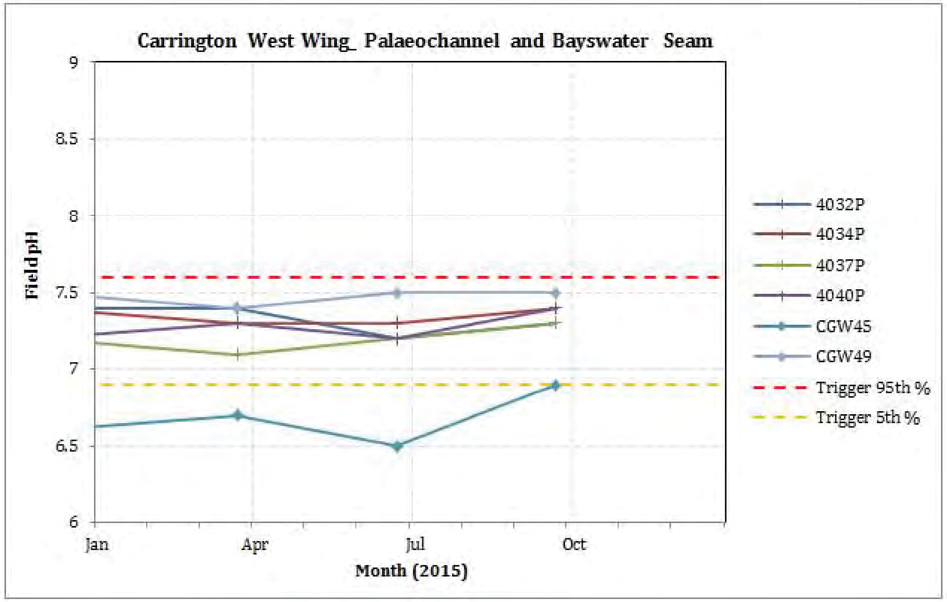

Carrington - Alluvium and Interburden_ No trigger
Field EC (µS/cm)
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Jan
Apr
Jul
Oct
Month (2015)
4038C
4053P
CFW59
CGW46
CGW54A
CGW6
HV3(2)

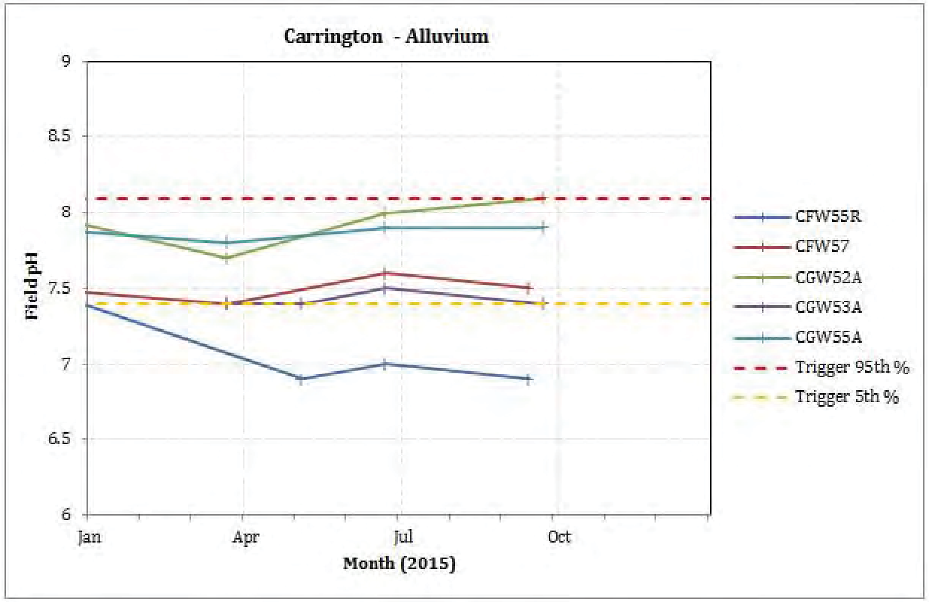
2015 Groundwater Field pH																
Bore ID	Lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	trigger pH 95th%	trigger pH 5th%
GA3	Coal	Alluvial Lands			7				7.2		7.1				7.5	6.6
HV3	Hunter River Alluvium	Alluvial Lands			7				7.2						7.5	6.6
PZ1CH200	Alluvium	Alluvial Lands		6.6			6.5			6.8			6.6		7.5	6.6
PZ2CH400	Hunter River Alluvium	Alluvial Lands		6.9			6.6			6.6			6.4		7.5	6.6
PZ3CH800	Hunter River Alluvium	Alluvial Lands		6.9			6.7			6.9			6.9		7.5	6.6
PZ4CH1380	Hunter River Alluvium	Alluvial Lands		6.9			6.9			6.7			6.3		7.5	6.6
PZ5CH1800	Hunter River Alluvium	Alluvial Lands		7			6.9			7.1			6.7		7.5	6.6
DM2	Pit Floor	Alluvial Lands													n/a	n/a
4113P	Spoil	Alluvial Lands				6.6			7		7				8.1	6.6
4116P	Spoil	Alluvial Lands				7			7.1		7.1				8.1	6.6
4117P	Spoil	Alluvial Lands				7.3			7.4		7.4				8.1	6.6
4119P	Spoil	Alluvial Lands				6.7			7.2		7.3				8.1	6.6
DM7	Spoil	Alluvial Lands			7.5				7		7.4				8.1	6.6
DM9	Spoil	Alluvial Lands													n/a	n/a
GW_114	Spoil	Alluvial Lands			6.6				6.8		6.6				8.1	6.6
MB14HVO01	Spoil	Alluvial Lands				6.8			7.1		6.8				8.1	6.6
MB14HVO02	Spoil	Alluvial Lands				6.8			7.5		6.8				8.1	6.6
MB14HVO03	Spoil	Alluvial Lands				6.8			7.5		7				8.1	6.6
MB14HVO04	Spoil	Alluvial Lands				6.9			7		7				8.1	6.6
MB14HVO05	Spoil	Alluvial Lands				6.8			7		6.8				8.1	6.6
DM1	Spoil (Base)	Alluvial Lands			6.5				6.5		6.6				8.1	6.6
DM3	Spoil (Base)	Alluvial Lands			6.5				6.6		6.6				8.1	6.6
DM4	Spoil (Base)	Alluvial Lands			6.9				7		7.1				8.1	6.6
CGW52A	Alluvium	Carrington				7.7		8			8.1				8.1	7.4

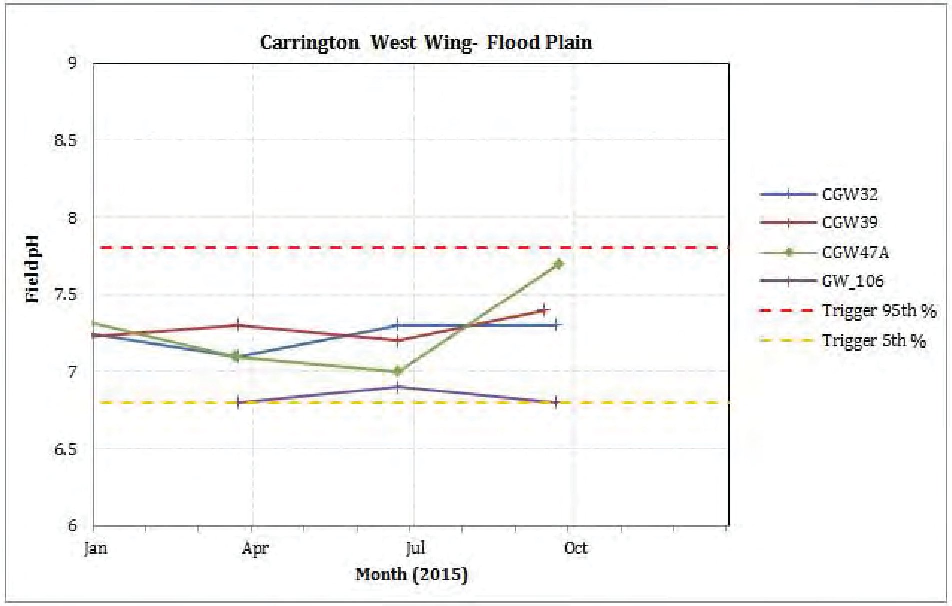
2015 Groundwater Field pH															
Bore ID	Lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	trigger pH 95th%	trigger pH 5th%
CGW53A	Alluvium	Carrington				7.4	7.4	7.5			7.4				8.1	7.4
CGW54A	Alluvium	Carrington				7.6		7.7							n/a	n/a
CGW55A	Alluvium	Carrington				7.8		7.9			7.9				8.1	7.4
CGW6	Alluvium	Carrington				7.3		7.2							n/a	n/a
CGW39	Alluvium?	Carrington				7.3		7.2			7.4				7.8	6.8
CGW45	Bayswater Seam	Carrington				6.7		6.5			6.9				7.6	6.9
CGW46	Bayswater Seam	Carrington				7.2		7.5			7.5				n/a	n/a
CGW47	Bayswater Seam	Carrington													7.4	6.6
CGW49	Bayswater Seam	Carrington				7.4		7.5			7.5				7.6	6.9
CGW45A	Broonie Seam	Carrington													n/a	n/a
CGW46A	Broonie Seam	Carrington													7.6	6.9
CGW47A	Broonie Seam	Carrington				7.1		7			7.7				7.8	6.8
CGW52	Broonie Seam	Carrington				7		6.9			6.9				7.1	6.8
CGW53	Broonie Seam	Carrington				6.9	6.8	7.1			7.1				7.1	6.8
4036C	Interburden (Siltstone/Sandstone)	Carrington				7.1		7			7				7.4	6.6
4051C	Interburden (Siltstone/Sandstone)	Carrington				7.1		7.1			7.2				7.4	6.6
CFW59	Interburden (Siltstone/Sandstone)	Carrington				7.2		7.3							n/a	n/a
CGW51A	Interburden (Siltstone/Sandstone)	Carrington				7.3		7.3			7.4				7.4	6.6
4032P	Palaeochannel alluvium	Carrington				7.4		7.2			7.3				7.6	6.9
4034P	Palaeochannel alluvium	Carrington				7.3		7.3			7.4				7.6	6.9
4037P	Palaeochannel alluvium	Carrington				7.1		7.2			7.3				7.6	6.9
4038C	Palaeochannel alluvium	Carrington				7.4		7							n/a	n/a

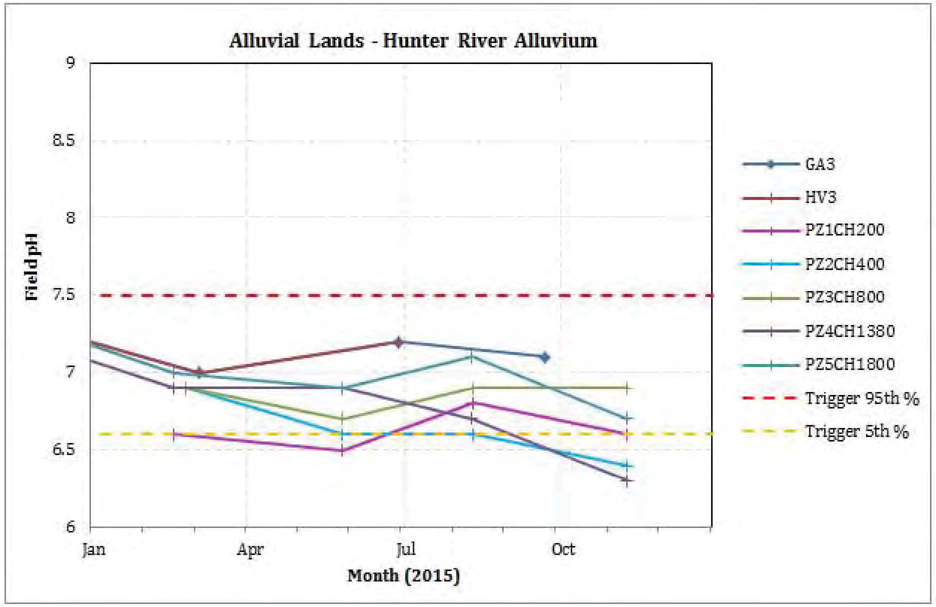
2015 Groundwater Field pH																
Bore ID	**Lithology**	**Location**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**trigger pH 95th%**	**trigger pH 5th%**
4040P	Palaeochannel alluvium	Carrington				7.3		7.2			7.4				7.6	6.9
4053P	Palaeochannel alluvium	Carrington				7.1		6.9							n/a	n/a
CFW55R	Palaeochannel alluvium	Carrington					6.9	7			6.9				8.1	7.4
CFW57	Palaeochannel alluvium	Carrington				7.4		7.6			7.5				8.1	7.4
CGW32	Palaeochannel alluvium	Carrington				7.1		7.3			7.3				7.8	6.8
GW_106	Palaeochannel alluvium or weathered sandstone?	Carrington				6.8		6.9			6.8				7.8	6.8
GW_107	Carrington Spoil	Carrington													n/a	n/a
GW_108	Carrington Spoil	Carrington													n/a	n/a
GW_101	Regolith, alluvium	Carrington						7.1							n/a	n/a
GW_115	Spoil	Carrington			7.3				7.5		6.9				8.1	6.6

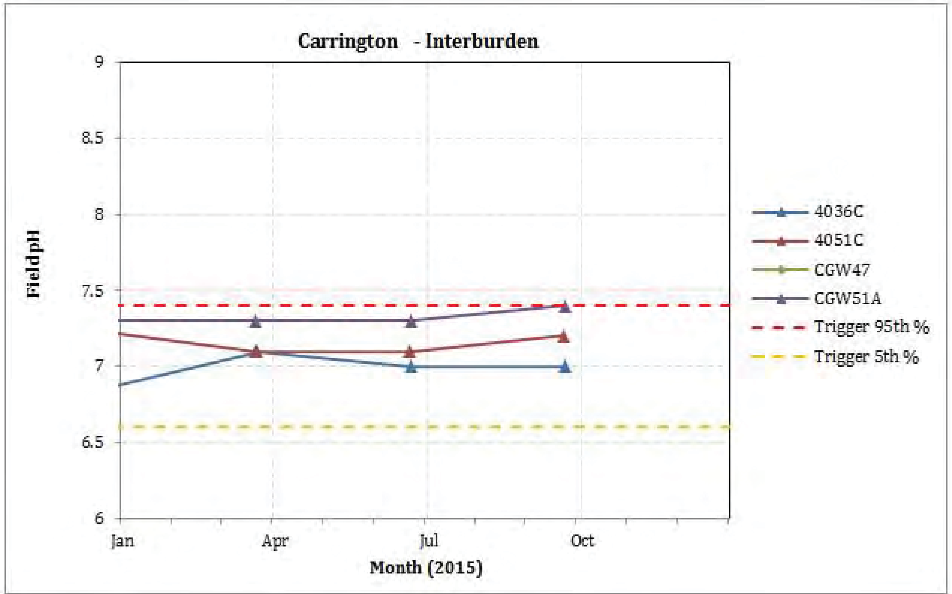
2015 Field pH



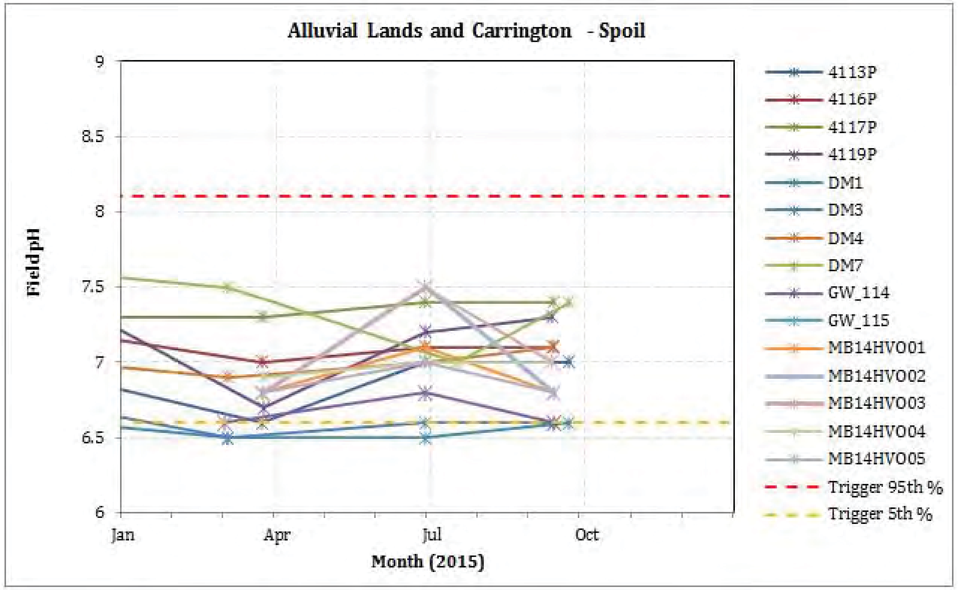




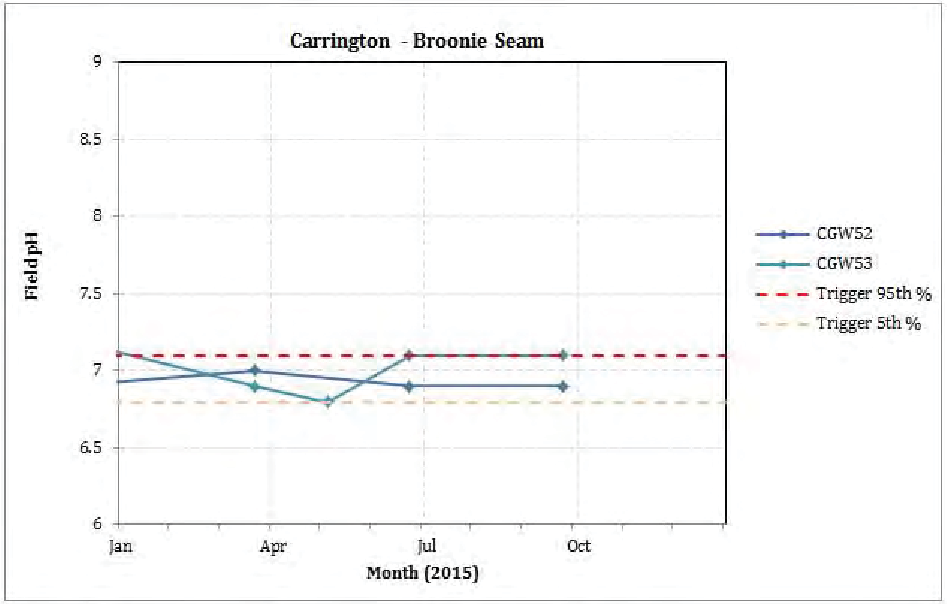




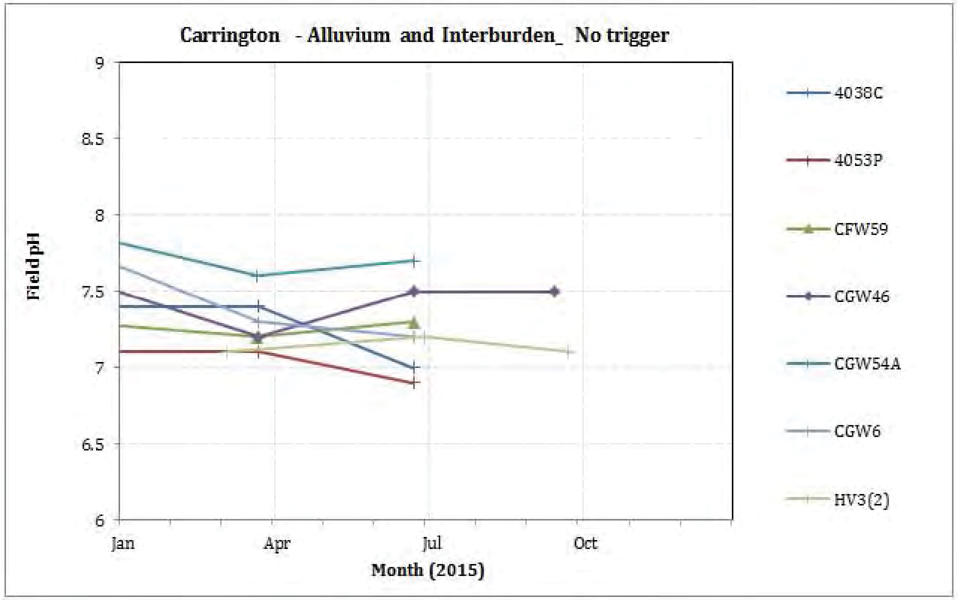
Carrington - Interburden
Field pH
9
8.5
8
7.5
7
6.5
6
Jan
Apr
Jul
Oct
Month (2015)
4036C
4051C
CGW47
CGW51A
Trigger 95th %
Trigger 5th %



Alluvial Lands and Carrington - Spoil
Field pH
9
8.5
8
7.5
7
6.5
6
Jan
Apr
Jul
Oct
Month (2015)
4113P
4116P
4117P
4119P
DM1
DM3
DM4
DM7
GW_114
GW_115
MB14HVO01
MB14HVO02
MB14HVO03
MB14HVO04
MB14HVO05
Trigger 95th %
Trigger 5th %



Carrington - Broonie Seam
Field pH
9
8.5
8
7.5
7
6.5
6
Jan
Apr
Jul
Oct
Month (2015)
CGW52
CGW53
Trigger 95th %
Trigger 5th %

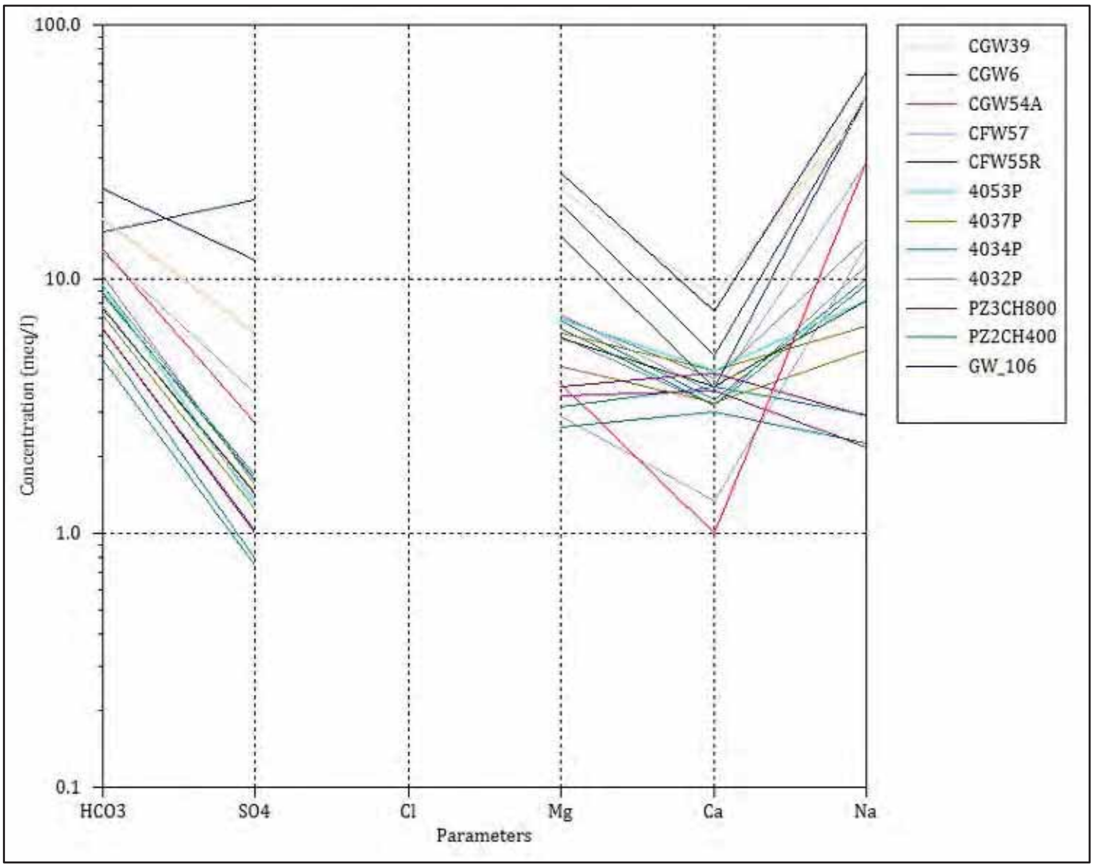


Carrington - Alluvium and Interburden_ No trigger
Field pH
9
8.5
8
7.5
7
6.5
6
Jan
Apr
Jul
Oct
Month (2015)
4038C
4053P
CFW59
CGW46
CGW54A
CGW6
HV3(2)

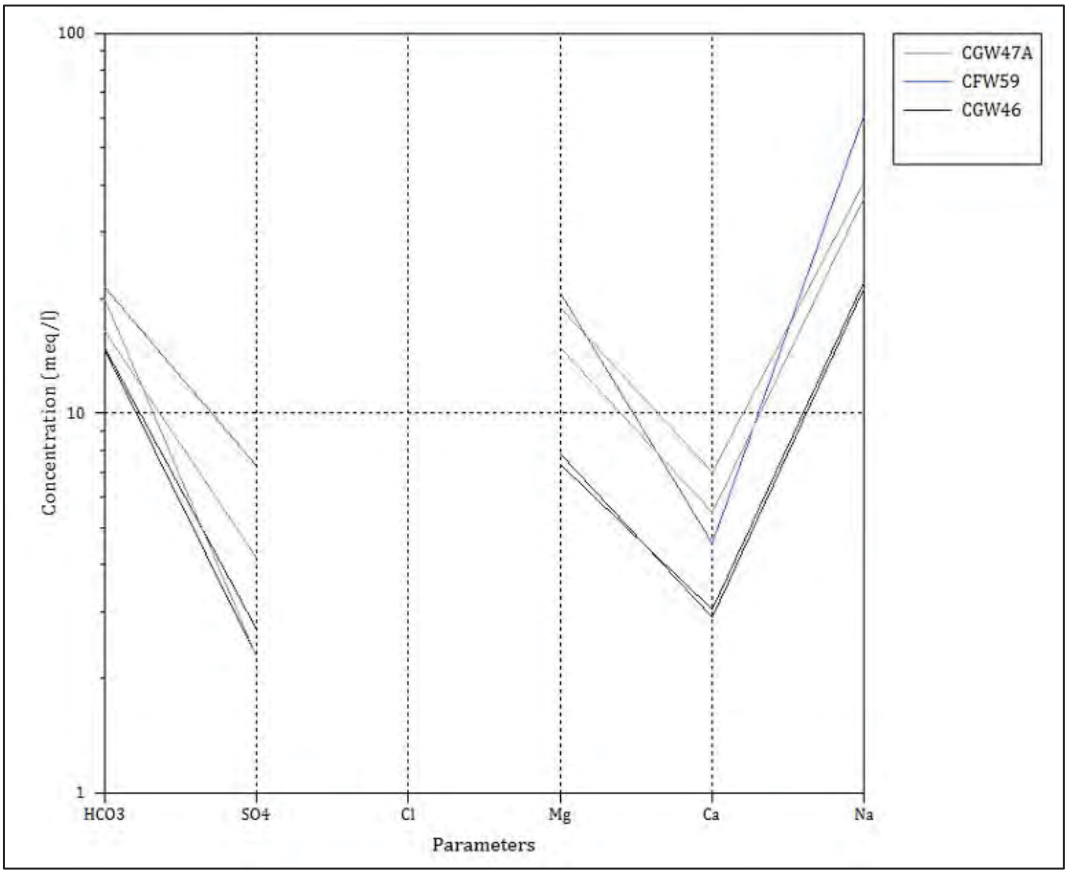
Station	Lithology	Location	Date	Al - Total (mg/l)	Alk - Total (mg/l)	As - Total (mg/l)	B (mg/l)	Ba (mg/l)	Ca - Total (mg/l)	CaCO3 - Total Hard (mg/l)	Fe - Filtered (mg/L)	Hydroxide Alk (mg/l)	K - Total (mg/l)	Li (mg/l)	Mg - Total (mg/l)	Mn - Total (mg/l)	Na - Total (mg/l)	Nitrogen Ammonia (mg/l)	P - Total (mg/l)	Rb - Total (mg/l)	Se (mg/l)	Si (mg/l)	SO4 - Total (mg/l)	Sr - Total (mg/l)	TDS - Total (mg/l)	Zn - Total (mg/l)
PZ2CH400	Hunter River Alluvium	Alluvial Lands	26/2/15	0.41	242	0.001	0.025		60		0.011	0	4.4	0.005	1/2/00	0.2	52	2.5	0.18	0.003	0/1/00	25	36	0.5	472	0.011
PZ2CH400	Hunter River Alluvium	Alluvial Lands	14/8/15	4.2	285	0.002	0.037		76		0.008		4.2	0.005	7/2/00	0.31	67	3.1	0.56	0.004	0/1/00	25	38	0.54	486	0.1
PZ3CH800	Hunter River Alluvium	Alluvial Lands	26/2/15	0.63	319	0.001	0.024		73		0.038	0	2.5	0.005	42	0.033	50	0.05	0.25	0.003	0.001	29	49	0.58	547	0.027
PZ3CH800	Hunter River Alluvium	Alluvial Lands	14/8/15	1.4	319	0.001	0.034		85		0.031		2.7	0.005	46	0.089	66	0.16	0.34	0.003	0.001	28	48	0.55	427	0.082
4113P	Spoil	Alluvial Lands	25/9/15	0.68	727	0.007	0.19		200				37		240		1300				0.001		1300		5840	0.1
4113P	Spoil	Alluvial Lands	26/3/15	1.9	712	0.011	0.17		200			0	35		250		1200				0.001		1400		4980	0.21
4116P	Spoil	Alluvial Lands	26/3/15	1.2	716	0.011	0.18		140			0	48		530		2000				0.001		900		7630	0.026
4116P	Spoil	Alluvial Lands	16/9/15	21	785	0.017	0.16		130				47		470		1800				0.012		820		7890	0.22
4117P	Spoil	Alluvial Lands	16/9/15	1.1	1220	0.051	0.17		100				29		140		1300				0.001		410		4480	0.22
4117P	Spoil	Alluvial Lands	26/3/15	0.37	1177	0.049	0.15		150			0	36		210		1400				0.001		390		10790	0.049
4119P	Spoil	Alluvial Lands	27/3/15	0.033	533	0.064	0.1		57			0	14		44		290				0.001		180		1320	0.009
4119P	Spoil	Alluvial Lands	15/9/15	0.021	521	0.07	0.075		50				13		38		270				0.001		160		1060	0.01
DM7	Spoil	Alluvial Lands	25/9/15	0.057	444	0.001	0.1		120				47		250		1300				0.001		1500		5440	0.008
DM7	Spoil	Alluvial Lands	6/3/15		349					1251		0														
GW_114	Spoil	Alluvial Lands	16/9/15	0.006	851	0.001	0.001		170				63		470		1300				0.001		1900		6740	0.005
MB14HVO01	Spoil	Alluvial Lands	26/3/15	0.005	851	0.061	0.18		190			0	31		220		1200				0.001		1100		4720	0.007
MB14HVO01	Spoil	Alluvial Lands	16/9/15	0.01	863	0.076	0.16		190				40		220		1200				0.001		1200		4770	0.005
MB14HVO02	Spoil	Alluvial Lands	26/3/15	0.03	716	0.27	0.15		180			0	33		220		1100				0.001		1100		4490	0.016
MB14HVO02	Spoil	Alluvial Lands	16/9/15	0.008	731	0.24	0.14		190				36		250		1100				0.001		1200		4740	0.009
MB14HVO03	Spoil	Alluvial Lands	27/3/15	0.023	792	0.15	0.16		190			0	30		190		960				0.001		1000		4030	0.009
MB14HVO03	Spoil	Alluvial Lands	15/9/15	0.027	798	0.18	0.14		190				33		190		950				0.001		990		3990	0.007

Station	Lithology	Location	Date	Al - Total (mg/l)	Alk - Total (mg/l)	As - Total (mg/l)	B (mg/l)	Ba (mg/l)	Ca - Total (mg/l)	CaCO3 - Total Hard (mg/l)	Fe - Filtered (mg/L)	Hydroxide Alk (mg/l)	K - Total (mg/l)	Li (mg/l)	Mg - Total (mg/l)	Mn - Total (mg/l)	Na - Total (mg/l)	Nitrogen Ammonia (mg/l)	P - Total (mg/l)	Rb - Total (mg/l)	Se (mg/l)	Si (mg/l)	SO4 - Total (mg/l)	Sr - Total (mg/l)	TDS - Total (mg/l)	Zn - Total (mg/l)
MB14HVO04	Spoil	Alluvial Lands	27/3/15	2.3	723	0.069	0.15		270			0	32		220		780				0.001		1200		4050	0.021
MB14HVO04	Spoil	Alluvial Lands	15/9/15	0.43	815	0.09	0.13		280				33		220		750				0.001		1200		3980	0.013
MB14HVO05	Spoil	Alluvial Lands	26/3/15	0.005	689	0.035	0.15		190			0	30		290		1100				0.001		1300		4560	0.012
MB14HVO05	Spoil	Alluvial Lands	16/9/15	0.005	693	0.036	0.13		190				31		280		1100				0.001		1300		4770	0.007
DM1	Spoil (Base)	Alluvial Lands	25/9/15	19	903	0.022	0.19		120				66		560		1500				0.01		1500		6900	0.37
DM1	Spoil (Base)	Alluvial Lands	6/3/15		837					2502		0														
DM3	Spoil (Base)	Alluvial Lands	16/9/15	0.32	849	0.003	0.085		220				32		500		1300				0.001		1800		6720	0.22
DM3	Spoil (Base)	Alluvial Lands	6/3/15		818					2562		0														
DM4	Spoil (Base)	Alluvial Lands	6/3/15		898					1069		0														
DM4	Spoil (Base)	Alluvial Lands	15/9/15	0.3	912	0.23	0.15		160				40		150		1100				0.001		1200		4350	0.038
CGW54A	Alluvium	Carrington	24/3/15	0.033	652	0.001	0.16		20			0	6.1		47		660				0.004		130		1840	0.001
CGW6	Alluvium	Carrington	25/3/15	0.005	381	0.001	0.084		76			0	2.4		71		190				0.007		68		948	0.006
CGW39	Alluvium?	Carrington	25/3/15	1.1	862	0.001	0.1		170			0	10		270		1200				0.011		300		4260	0.019
CGW39	Alluvium?	Carrington	17/9/15	3.6	854	0.005	0.082		170				11		270		1100				0.014		290		4470	0.017
CGW46	Bayswater Seam	Carrington	25/3/15	1.1	734	0.002	0.12		61			0	5.1		89		510				0.027		110		1840	0.081
CGW46	Bayswater Seam	Carrington	17/9/15	2.8	743	0.002	0.095		58				6		95		490				0.03		130		1770	0.15
CGW47A	Broonie Seam	Carrington	25/9/15	1.1	824	0.002	0.094		110				9.3		180		850				0.032		200		3440	0.052
CGW47A	Broonie Seam	Carrington	24/3/15	0.39	996	0.001	0.11		140			0	13		230		930				0.003		110		3460	0.033
CFW59	Interburden (Siltstone/Sand stone)	Carrington	24/3/15	0.3	1076	0.001	0.2		91			0	31		250		1400				0.005		350		4490	0.006
4032P	Palaeochannel alluvium	Carrington	25/3/15	7.3	468	0.002	0.11		64			0	2		72		260				0.008		78		1160	0.13
4032P	Palaeochannel alluvium	Carrington	25/9/15	2.9	512	0.002	0.1		81				2.7		86		330				0.012		74		1200	0.039

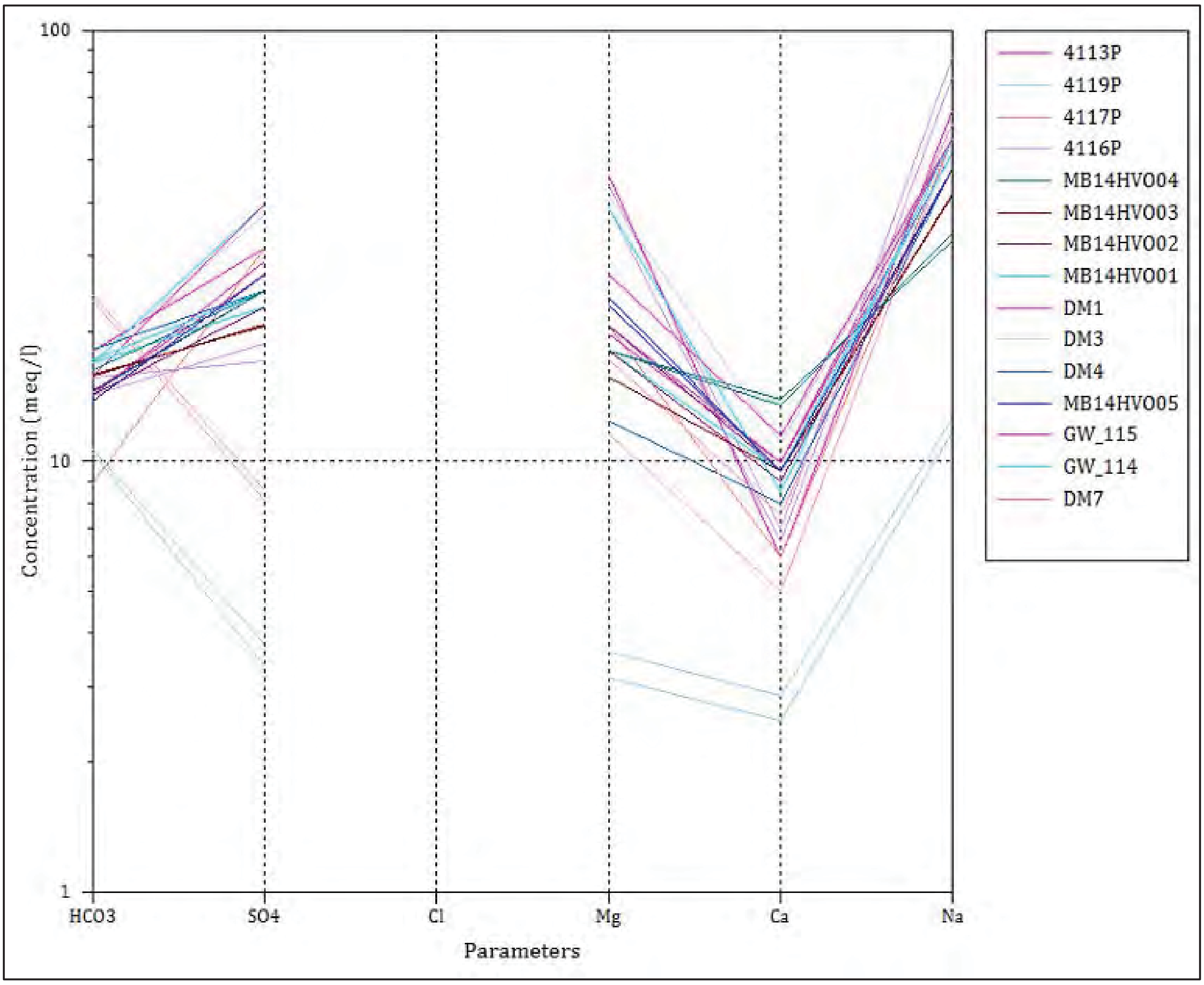
Station	Lithology	Location	Date	Al - Total (mg/l)	Alk - Total (mg/l)	As - Total (mg/l)	B (mg/l)	Ba (mg/l)	Ca - Total (mg/l)	CaCO3 - Total Hard (mg/l)	Fe - Filtered (mg/L)	Hydroxide Alk (mg/l)	K - Total (mg/l)	Li (mg/l)	Mg - Total (mg/l)	Mn - Total (mg/l)	Na - Total (mg/l)	Nitrogen Ammonia (mg/l)	P - Total (mg/l)	Rb - Total (mg/l)	Se (mg/l)	Si (mg/l)	SO4 - Total (mg/l)	Sr - Total (mg/l)	TDS - Total (mg/l)	Zn - Total (mg/l)
4034P	Palaeochannel alluvium	Carrington	25/3/15	1.1	431	0.002	0.11		67			0	2.6		83		230				0.009		81		1040	0.024
4034P	Palaeochannel alluvium	Carrington	25/9/15	0.59	442	0.002	0.094		64				2.7		77		220				0.011		77		1140	0.03
4037P	Palaeochannel alluvium	Carrington	25/3/15	1.3	383	0.002	0.077		88			0	1.6		75		150				0.003		69		916	0.08
4037P	Palaeochannel alluvium	Carrington	25/9/15	0.43	359	0.001	0.065		65				1.1		55		120				0.004		60		833	0.018
4053P	Palaeochannel alluvium	Carrington	25/3/15	1.8	470	0.002	0.077		88			0	2.2		84		190				0.006		62		1030	0.053
CFW55R	Palaeochannel alluvium	Carrington	24/3/15	0.29	856	0.001	0.17		100			0	33		240		1200				0.001				4080	0.006
CFW55R	Palaeochannel alluvium	Carrington	17/9/15	3.5	766	0.003	0.14		75				31		180		1200				0.004		980		4520	0.014
CFW57	Palaeochannel alluvium	Carrington	24/3/15	0.2	636	0.001	0.13		71			0	5.4		89		660				0.001		170		2140	0.011
CFW57	Palaeochannel alluvium	Carrington	17/9/15	0.11	393	0.002	0.073		27				3		35		310				0.001		65		1130	0.005
GW_106	Palaeochannel alluvium	Carrington	24/9/15	0.011	1128	0.001	0.21		150				46		320		1500				0.003		570		6410	0.007
GW_115	Spoil	Carrington	15/9/15	0.033	788	0.015	0.14		230				38		330		1300				0.001		1900		5970	0.049



Schoeller plot_Alluvium and Palaeochannel

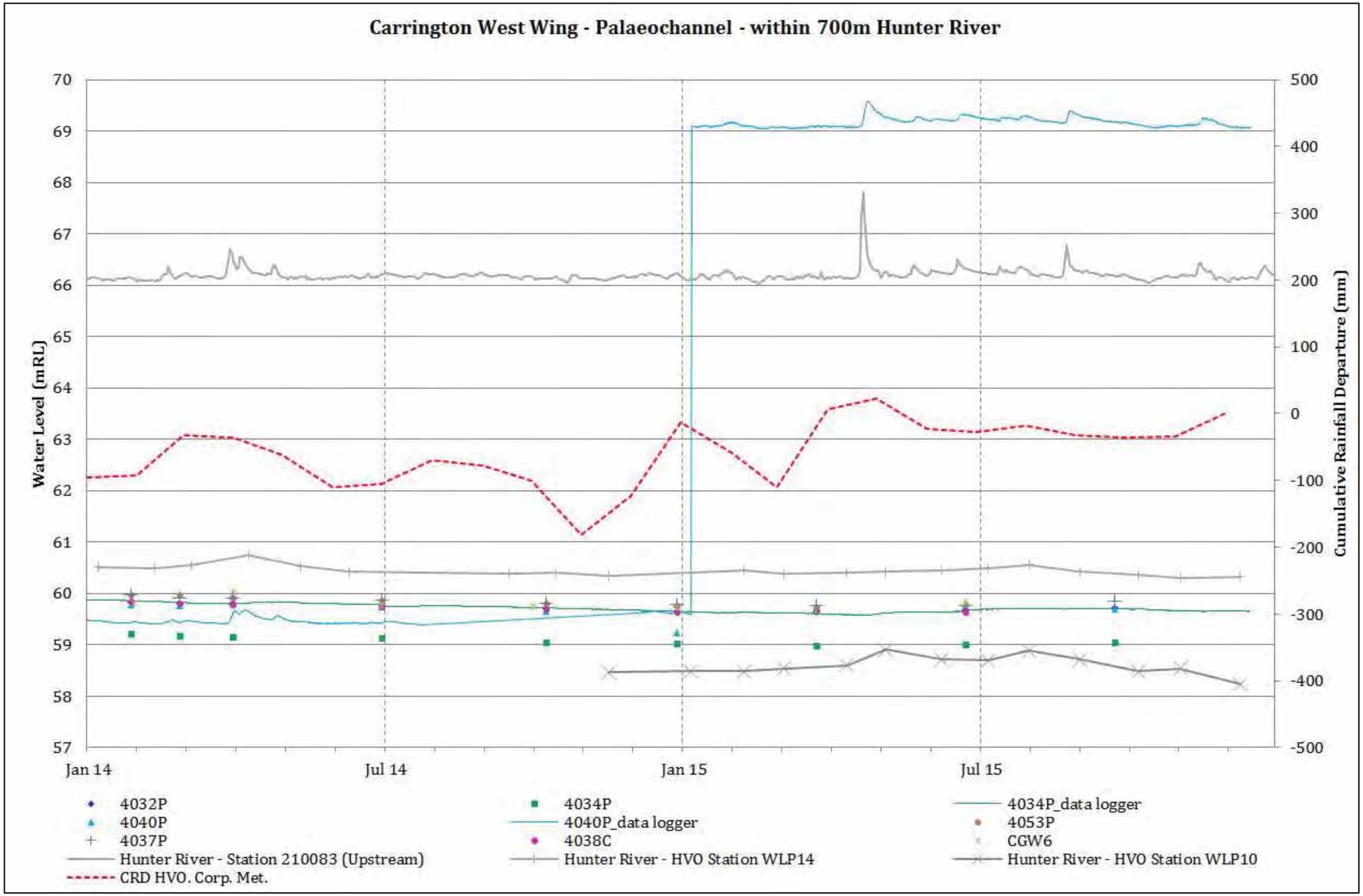


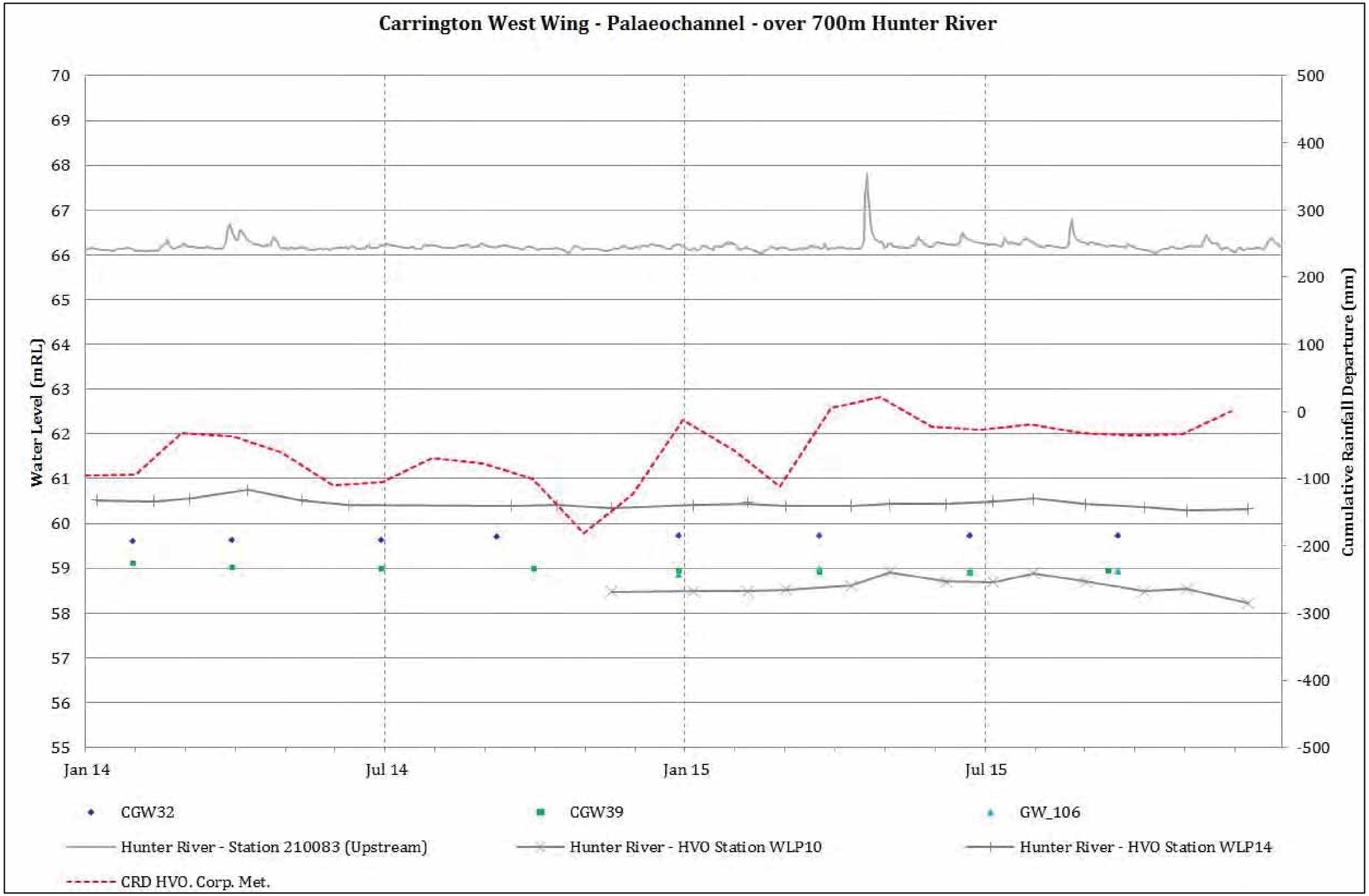
Schoeller plot_Coal Measure and Interburden



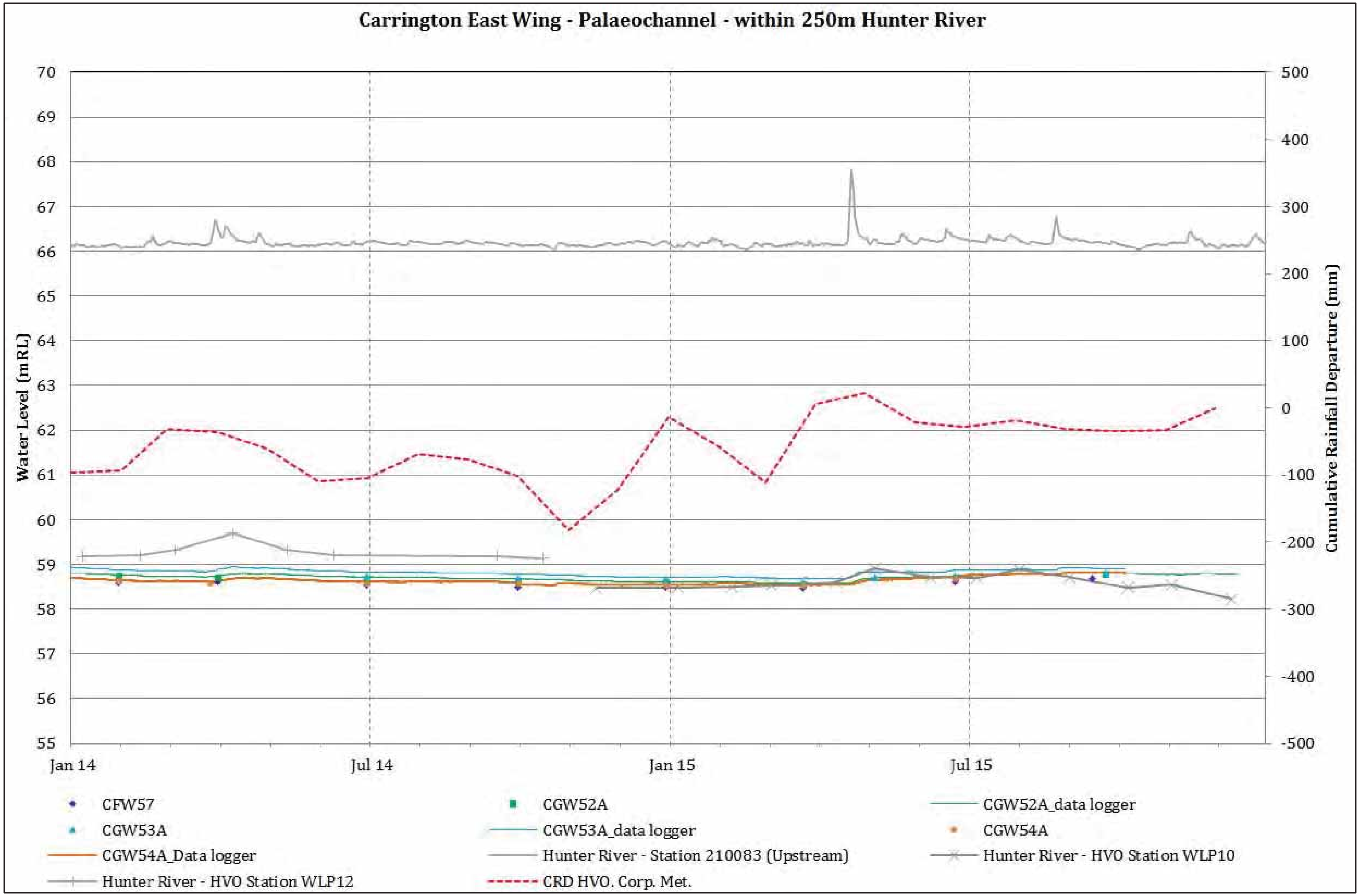
Schoeller plot_Spoil

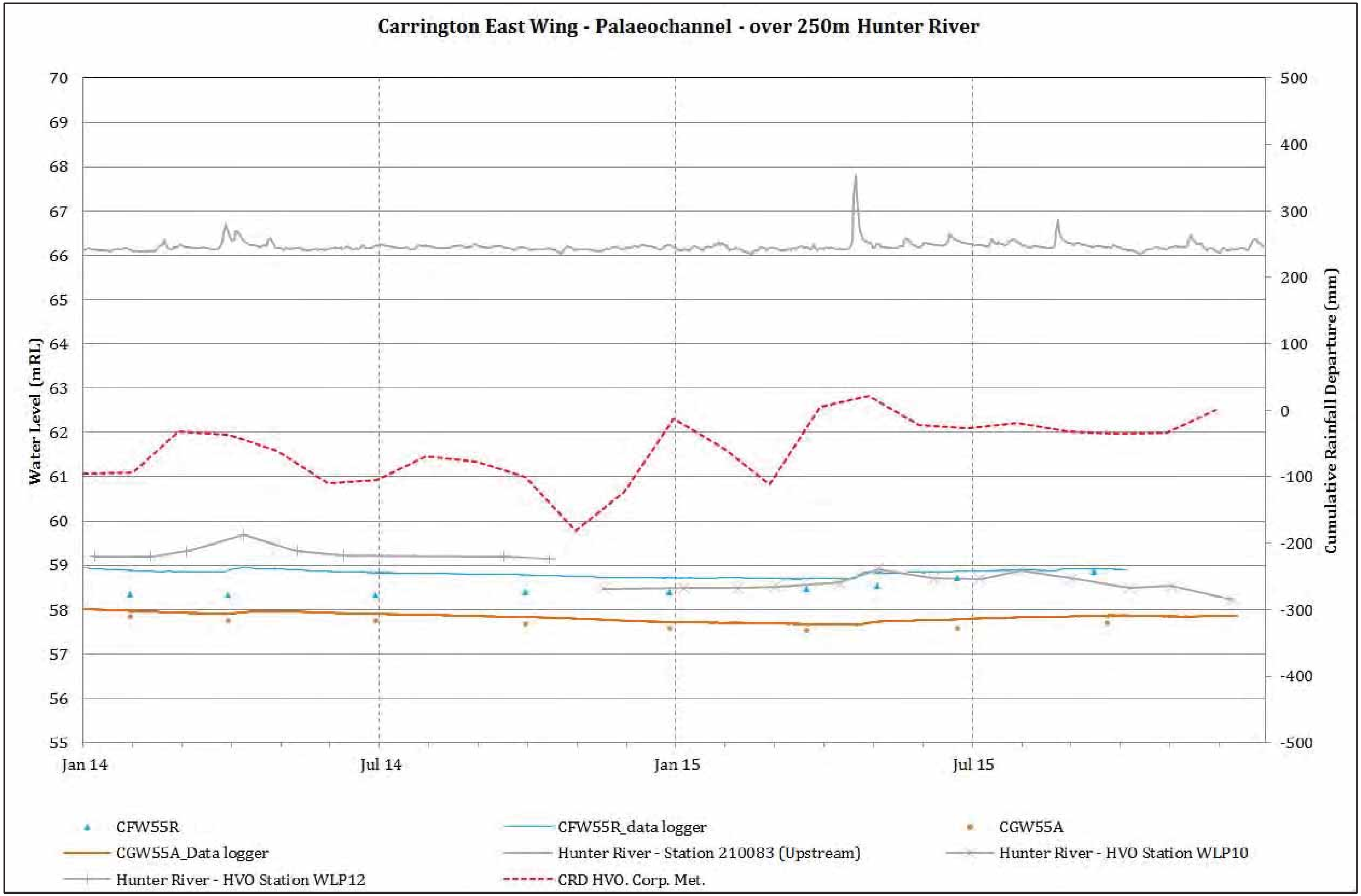
Appendix D Hydrographs


Carrington West Wing - Palaeochannel - within 700m Hunter River
Water Level (mRL)
Cumulative Rainfall Departure (mm)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
4032P
4040P
4037P
Hunter River - Station 210083 (Upstream)
CRD HVO. Corp. Met.
4034P
4040P_data logger
4038C
Hunter River - HVO Station WLP14
4034P_data logger
4053P
CGW6
Hunter River - HVO Station WLP10

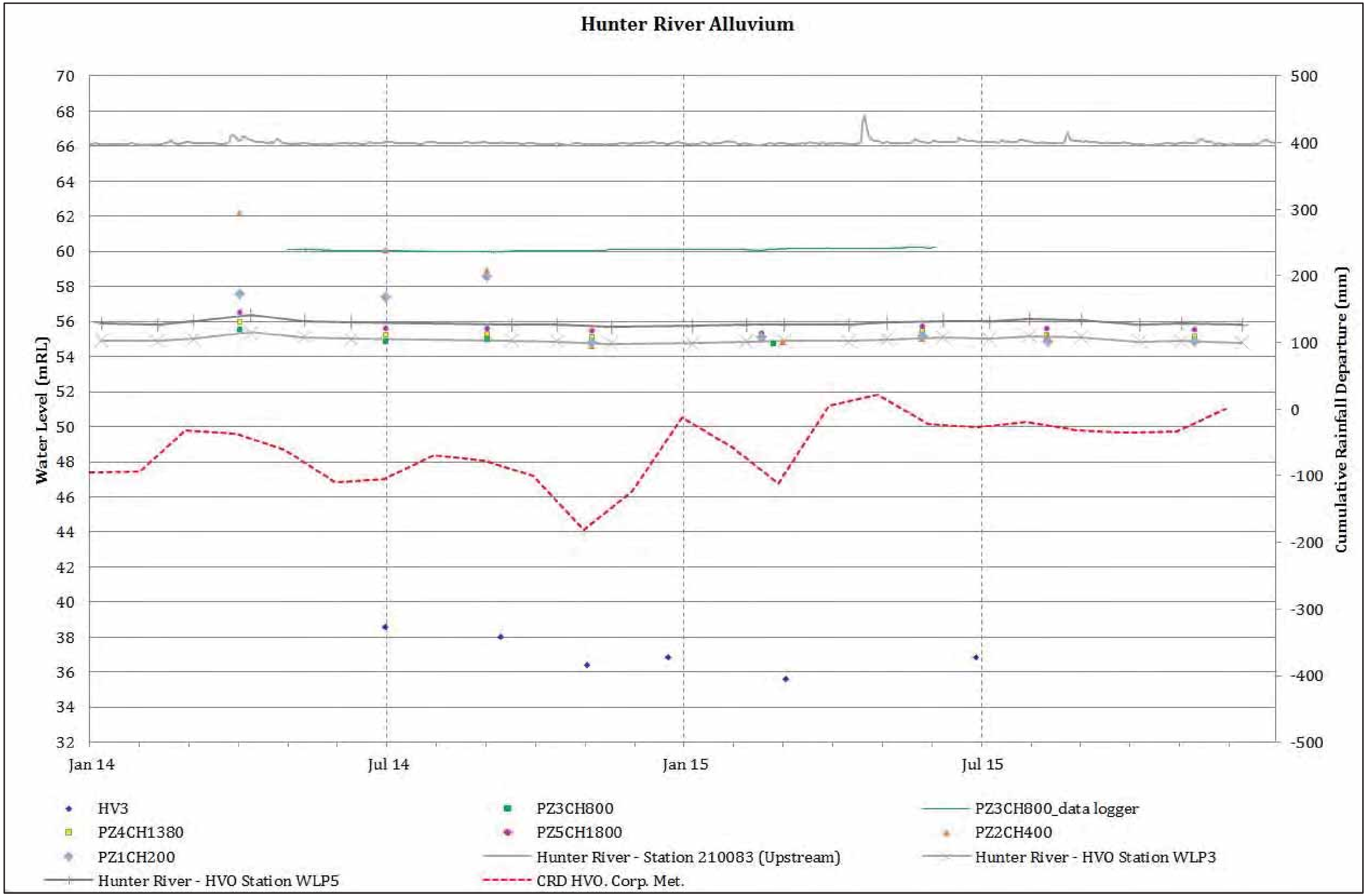


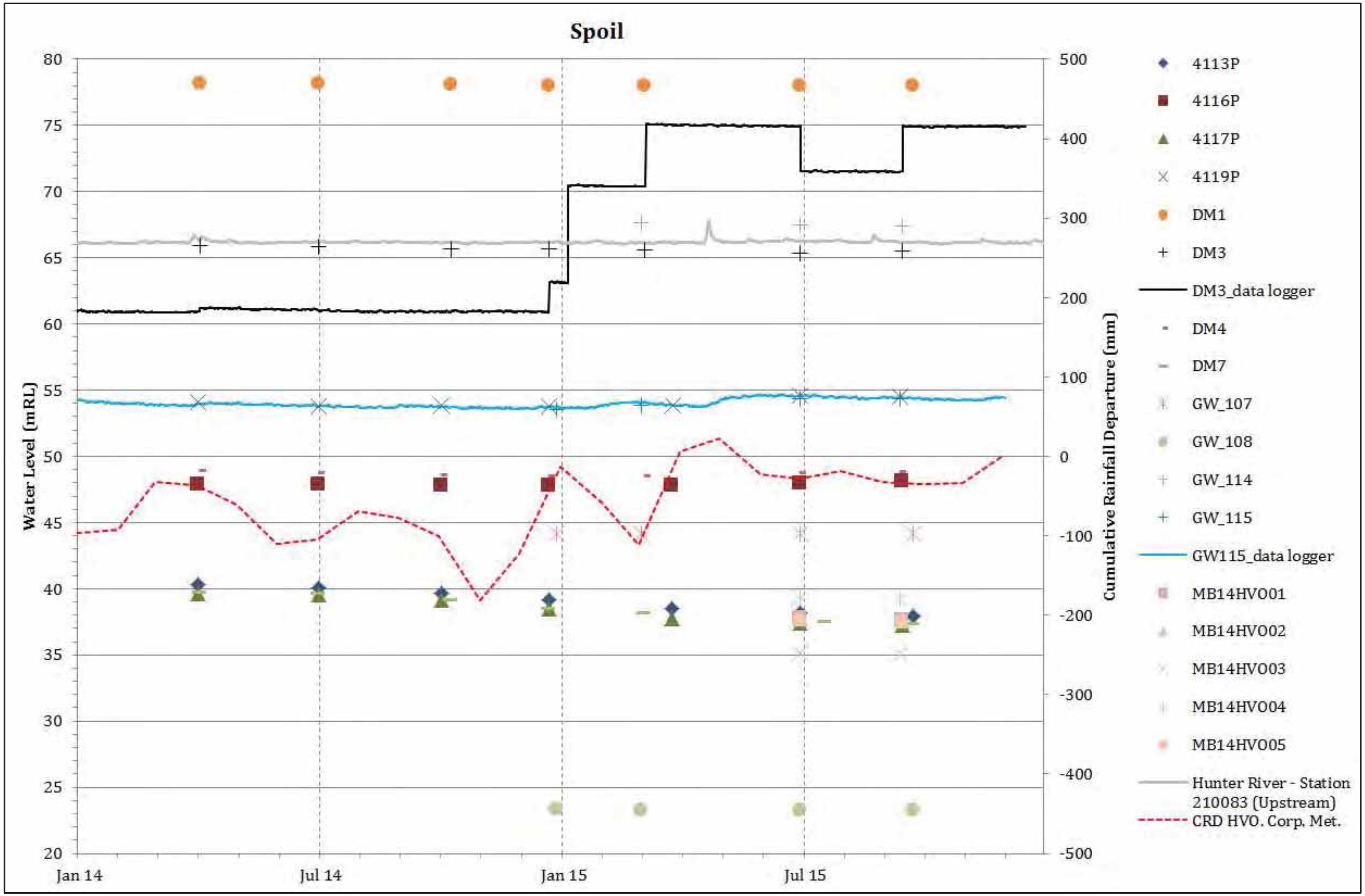
Carrington West Wing - Palaeochannel - over 700m Hunter River
Water Level (mRL)
Cumulative Rainfall Departure (mm)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
CGW32
CGW39
GW_106
Hunter River - Station 210083 (Upstream)
Hunter River - HVO Station WLP10
Hunter River - HVO Station WLP14
CRD HVO. Corp. Met.

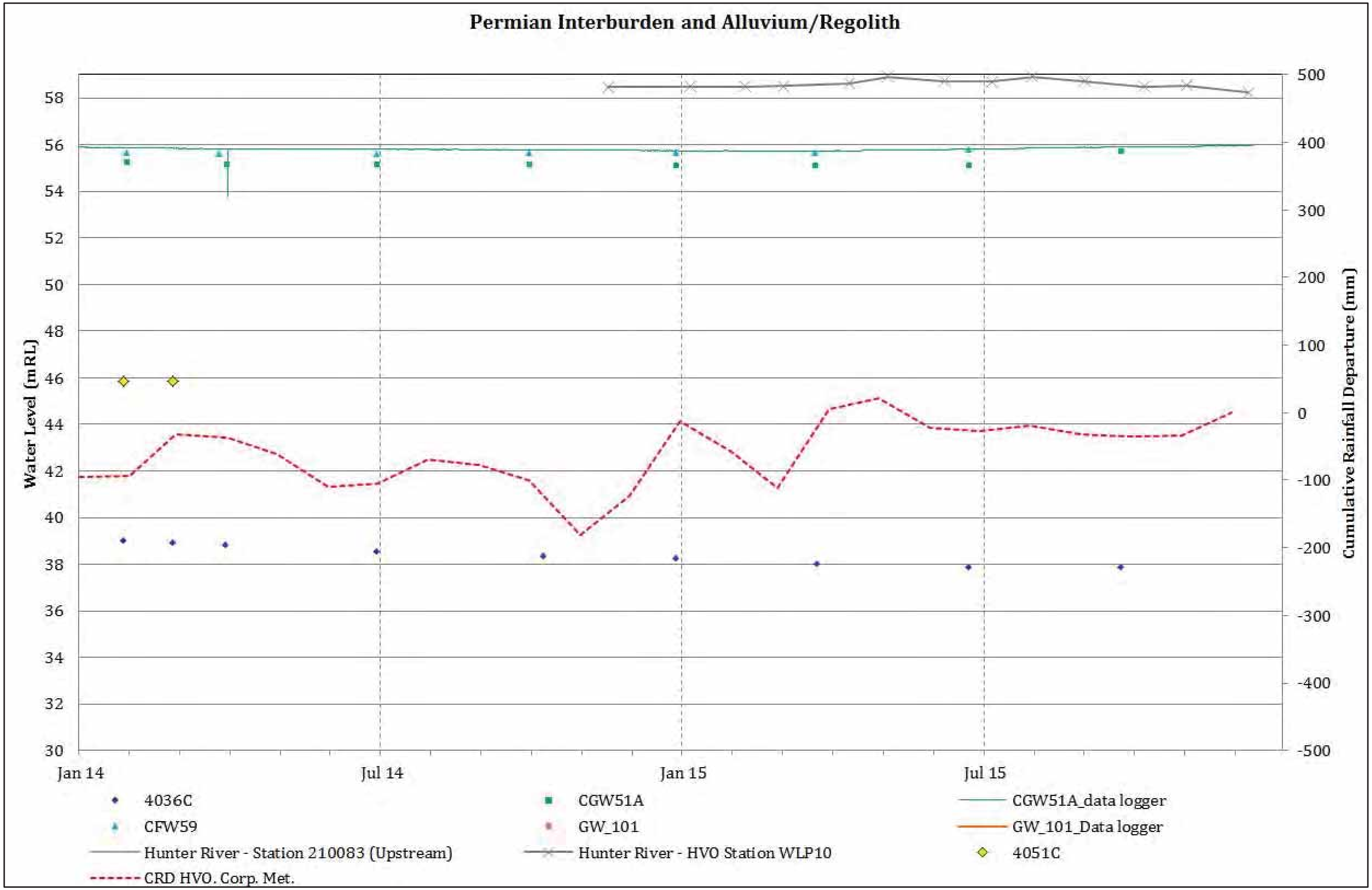

Carrington East Wing - Palaeochannel - within 250m Hunter River
Water Level (mRL)
Cumulative Rainfall Departure (mm)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
CFW57
CGW52A
CGW52A_data logger
CGW53A
CGW53A_data logger
CGW54A
CGW54A_Data logger
Hunter River - Station 210083 (Upstream)
Hunter River - HVO Station WLP10
Hunter River - HVO Station WLP12
CRD HVO. Corp. Met.

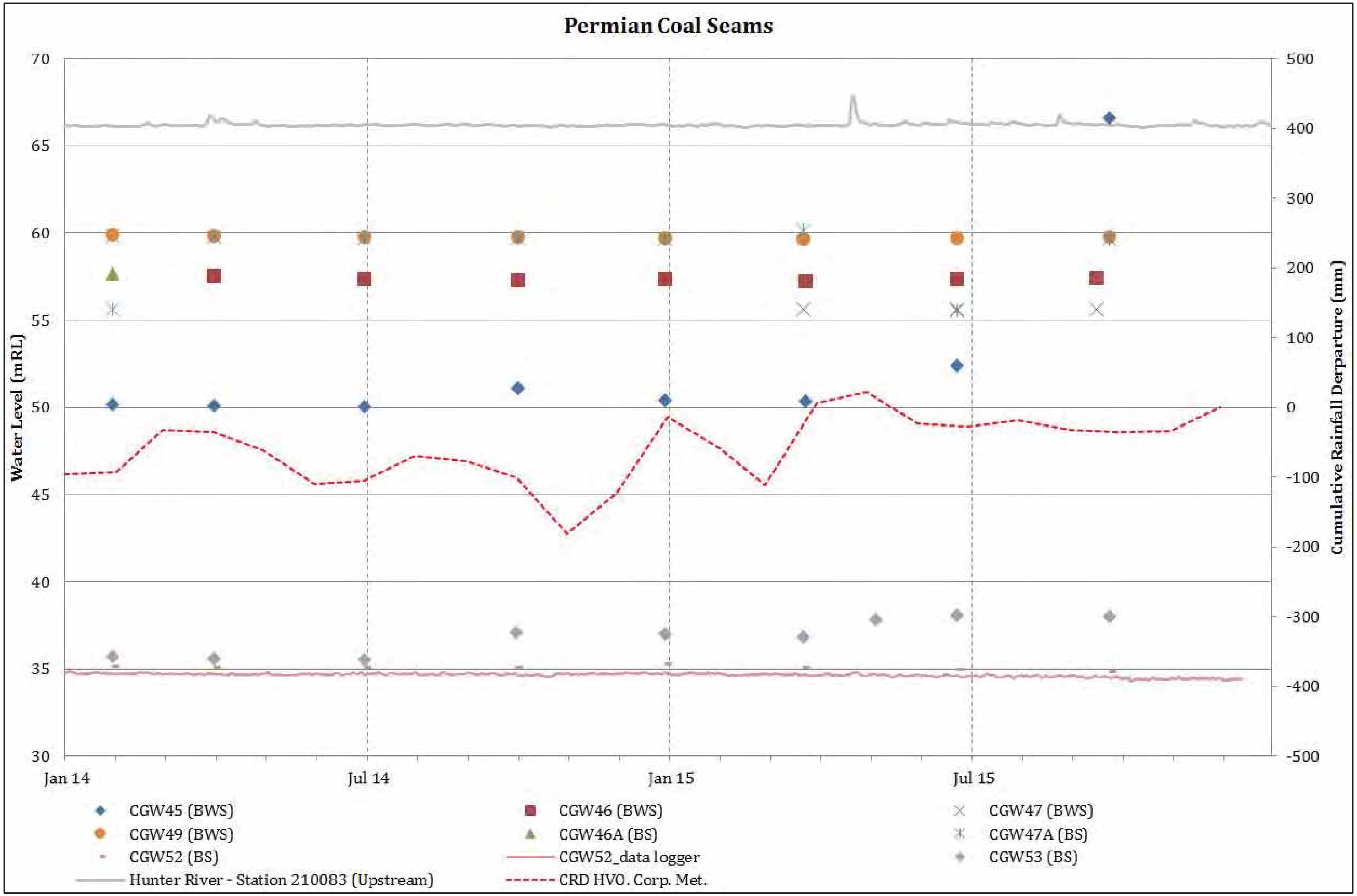


Carrington East Wing - Palaeochannel - over 250m Hunter River
Water Level (mRL)
Cumulative Rainfall Departure (mm)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
CFW55R
CFW55R_data logger
CGW55A
CGW55A_Data logger
Hunter River - Station 210083 (Upstream)
Hunter River - HVO Station WLP10
Hunter River - HVO Station WLP12
CRD HVO. Corp. Met.

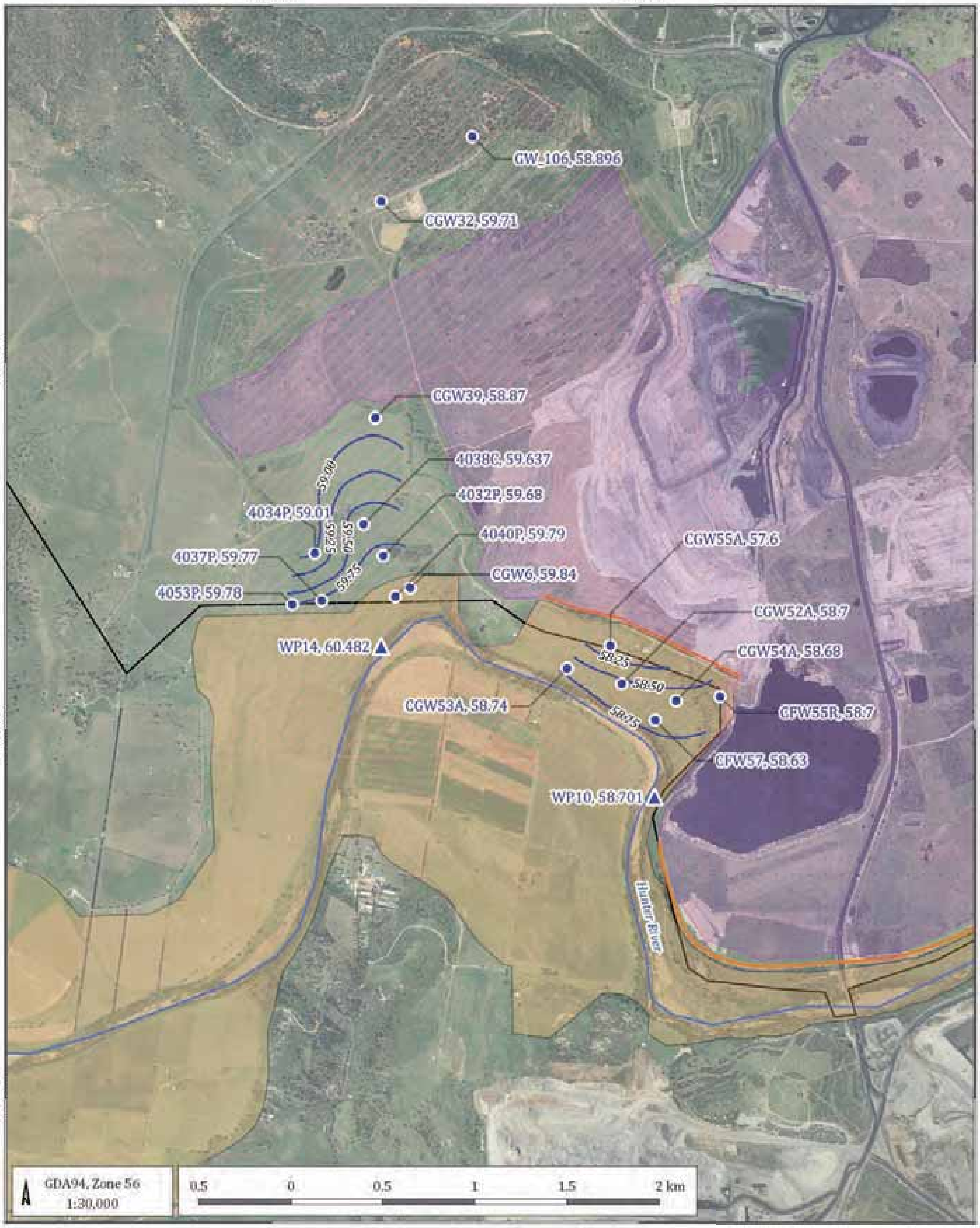

Hunter River Alluvium
Water Level (mRL)
Cumulative Rainfall Departure (mm)
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
HV3
PZ3CH800
PZ3CH800_data logger
PZ4CH1380
PZ5CH1800
PZ2CH400
PZ1CH200
Hunter River - Station 210083 (Upstream)
Hunter River - HVO Station WLP3
Hunter River - HVO Station WLP5
CRD HVO. Corp. Met.


Spoil
Water Level (mRL)
Cumulative Rainfall Departure (mm)
80
75
70
65
60
55
50
45
40
35
30
25
20
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
4113P
4116P
4117P
4119P
DM1
DM3
DM3_data logger
DM4
DM7
GW_107
GW_108
GW_114
GW_115
GW115_data logger
MB14HVO01
MB14HVO02
MB14HVO03
MB14HVO04
MB14HVO05
Hunter River - Station 210083 (Upstream)
CRD HVO. Corp. Met.


Permian Interburden and Alluvium/Regolith
Water Level (mRL)
Cumulative Rainfall Departure (mm)
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
4036C
CFW59
Hunter River - Station 210083 (Upstream)
CRD HVO. Corp. Met.
CGW51A
GW_101
Hunter River - HVO Station WLP10
CGW51A_data logger
GW_101_Data logger
4051C


Permian Coal Seams
Water Level (mRL)
Cumulative Rainfall Derparture (mm)
70
65
60
55
50
45
40
35
30
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
CGW45 (BWS)
CGW49 (BWS)
CGW52 (BS)
Hunter River - Station 210083 (Upstream)
CGW46 (BWS)
CGW46A (BS)
CGW52_data logger
CRD HVO. Corp. Met.
CGW47 (BWS)
CGW47A (BS)
CGW53 (BS)

Appendix E **Groundwater flow contours**



LEGEND

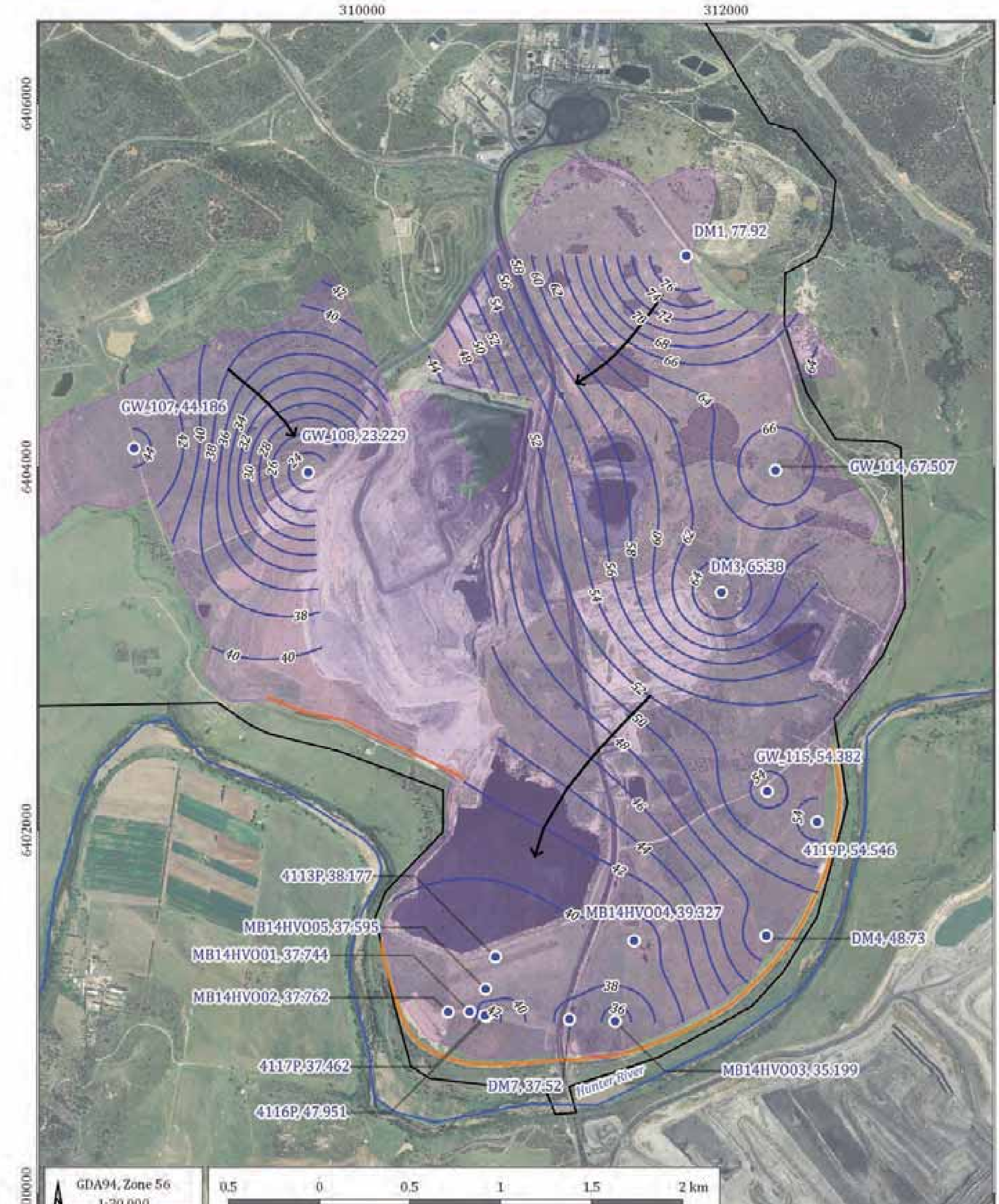
- ▲ Surface water monitoring sites
- ● Groundwater monitoring bore, Observed water level (mAHD)
- Groundwater contour, Interpolated water level (mAHD)
- Mine lease
- Quaternary alluvium (1:25k AGE)
- Spoil
- Paleochannel (MER, 2005)
- Major drainage
- Barrier wall

HVO North - 2015 Annual Groundwater Impacts Review (G1809)

Carrington alluvium groundwater contours

DATE: 07/03/2016

FIGURE No: **E-1**



LEGEND

- Groundwater monitoring bore, Observed water level (mAHD)
- Groundwater contour, Interpolated water level (mAHD)
- Groundwater flow direction
- Spoil
- Mine lease
- Major drainage
- Barrier wall

HVO North - 2015 Annual Groundwater Impacts Review (G1809)

HVO North spoil groundwater contours

DATE: 07/03/2016

FIGURE No: **E-2**

Appendix F Groundwater calculations assumptions

In order to apply Darcy's Law, several assumptions were made to calculate the hydraulic conductivity (K), hydraulic gradient (i) and area (A). These assumptions are detailed below.

Hydraulic Conductivity (K)

The steady state calculations utilised the hydraulic properties detailed in MER (2010b). In order to be conservative in the calculations, the highest hydraulic conductivity values for the coal measures (Bayswater Seam) were used to calculate the amount of seepage from the coal measures into the pit. A horizontal hydraulic conductivity (K_{xy}) value of 6 x 10^{-3} m/day and a vertical hydraulic conductivity (K_z) value of 2.60 x 10^{-4} m/day was used. The amount of alluvial groundwater seeping through the barrier wall was calculated using a K_{xy} value of 5.8 x 10^{-4} m/day. The results are summarised in Table F 1.

Notes: K_z *Hydraulic conductivity derived from MER (2011) for PCM Layer 2*
I_z *Vertical hydraulic gradient*
Q_z *Is the amount of water discharged*

Table F 1 Hydraulic properties_ MER (2010 Carrington Model

Strata	K_{xy} (m/day)	K_z (m/day)
Regolith	1 to 95	1
Alluvium	10	10
Shallow PCM (Layer 2-5)†	7.78 x 10^{-4}	7.00 x 10^{-5}
Bayswater Seam	6.00 x 10^{-3}	2.60 x 10^{-4}
Underlying PCM	3.70 x 1 0^{-3}	2.10 x 10^{-6}
Barrier Wall	5.8 x 10^{-4}	

Notes: *† Average of Permian Coal Measure (PCM) Layers 2 to 5 (MER, 2010)*
K_{xy}: Horizontal permeability
K_z: Vertical hydraulic conductivity

Hydraulic Gradient (i)

The hydraulic gradient values have been calculated using groundwater levels taken around September 2015. Equation 2 was used to calculate the horizontal hydraulic gradient (i_{xy}). The gradient of the Permian aquifer was estimated by calculating the difference in groundwater elevations for coal seam bore CGW52 and the Carrington Pit, divided by the distance of the bore from the pit. The groundwater elevation for the Carrington Pit was estimated to be around -20 mRL.

The gradient of the alluvial aquifer through the barrier wall was estimated by calculating the difference in groundwater levels for alluvial bore CGW55A, and the estimated basal elevation of the barrier wall. The results are summarised in Table F 2.

Horizontal Hydraulic Gradient Equation:

$$i_{xy} = \frac{\Delta h}{\Delta L} = \frac{h_2 - h_1}{length} \qquad \text{(Equation 2)}$$

where:

i_{xy} is the horizontal hydraulic gradient (dimensionless)

Δh is the difference between the hydraulic heads (m)

ΔL is the flow path length between the piezometer and edge of the pit (m)

Table F 2 Horizontal hydraulic gradients

Carrington Pit Location	Bore	Discharge Point	Distance from Bore to Discharge Point (m)	Bore Groundwater Level (mRL)	Discharge Point Elevation (mRL)	Horizontal Hydraulic Gradient (i_{XY})
Palaeochannel east limb	CGW52 (Broonie 2)	Carrington Pit	150	34.85	-20	0.37
Carrington Barrier Wall	CGW55A (Alluvium)	Base of Barrier Wall	5	57.71	50	1.54

Notes: † *extrapolated width of barrier wall – through alluvium*
‡ *extrapolated base of alluvium north of barrier wall*

Equation 3 was used to calculate the vertical hydraulic gradient (i_z) between the alluvium and the coal seam aquifers in three locations. In order to calculate i_z, bore construction details and September 2015 groundwater levels were used for nested bores CGW52 and CGW53, which are screened within the alluvium and Permian coal seams at each site. The depth to the base of the alluvium was estimated to be around 50mRL, based on lithological log for bore CFW59 and extrapolation of the HVO geological model. The results are summarised in Table F 3.

Vertical Hydraulic Gradient Equation:

$$i_z = \frac{\Delta h}{\Delta L} \qquad \textit{(Equation 3)}$$

where:

- i_z is the vertical hydraulic gradient (dimensionless);
- Δh hydraulic head in the alluvial bore (mRL) minus the hydraulic head in the coal seam bore (mRL); and
- ΔL thickness of interburden calculated from the depth of the alluvial bore (assumed as the base of the alluvium (mRL) minus the estimated depth to the base of the Permian overburden (mRL).

Table F 3 Vertical hydraulic gradients

Alluvium bore	Coal seam bore	Elevation of base Alluvium (mRL)	Depth to base of Permian overburden (mRL)	ΔL (m)	SWL in Alluvium Bore (mRL)	SWL in Coal bore (mRL)	Δh (m)	Vertical Hydraulic Gradient (iz)	Average vertical Hydraulic Gradient (iz)
CGW52A	CGW52 (Broonie 2)	52.8	35	17.8	58.79	34.85	23.94	1.34	1.34
CGW53A	CGW53 (Broonie 1)	55.8	35	20.8	58.81	38.03	20.78	1.00	

Note: *SWL Standing Water Level*

Area (A)

The area (A) used to calculate leakage of alluvial groundwater into coal seam aquifers (Q_z) was based on the length of the pit wall and the width of the alluvium. The width of the alluvium was estimated from aerial photography measurements of the distance between the Hunter River and the edge of the pit wall.

The area (A) used to calculate leakage of coal seam groundwater into the pits (Q_{xy}) was calculated based on the length of the pit wall and the thickness of exposed Permian coal measures within the Carrington Pit highwall. The estimated thickness of exposed coal measures was extrapolated from the HVO geological model data.

Appendix G Groundwater flow calculations

Vertical Hydraulic Gradient Calculation (Iz)

Carrington Pit Location	Alluvium bore	Broonie coal seam bore	Depth of alluvium Bore (mRL)	Depth to base of Permian overburden (mRL)*	Depth of alluvium bore minus overburden depth ΔL (m)	Groundwater level in alluvium bore (mRL)	Groundwater level in coal bore (mRL)	Head difference between alluvium and coal seam bore Δh (m)	Vertical hydraulic gradient (i_z)	Adopted vertical hydraulic gradient (i_z)	Hydraulic gradient
Palaeochannel east limb	CGW52A	CGW52 (Broonie 2)	52.8	35.00	17.8	58.79	34.85	23.94	1.34	1.34	Downward
Palaeochannel east limb	CGW53A	CGW53 (Broonie 1)	55.8	35.00	20.8	58.81	38.03	20.78	1.00		Downward

Horizontal Hydraulic Gradient Calculation (Ixy)

Carrington Pit Location	Bore	Discharge Point	Distance from Bore to Discharge Point (m)	Bore Groundwater Level (mRL)	Discharge Point Elevation (mRL)	Horizontal Hydraulic Gradient (i_{XY})	Adopted horizontal hydraulic gradient (i_{xy})
Palaeochannel east limb	CGW52 (Broonie 2)	Carrington Pit	150	34.85	-20	0.37	0.37
Carrington Barrier Wall - South	CGW55A (Alluvium)	Base of Barrier Wall	5	57.71	50	1.54	1.54

Horizontal Leakage from target Coal Seam to Pit

Location	Horizontal Hydraulic Conductivity (MER, 2010) K_{XY} (m/d)	Horizontal Hydraulic Gradient (i_{XY})	Pit Wall Length (m)	Exposed Face (m)	Horizontal Discharge to Pit Q_{XY} (L/s)	Horizontal Discharge from Coal Seams to Pit Q_{XY} (ML/d)
Carrington Pit	6.00E-03	0.37	1,100	60.00	1.68	0.14
Carrington Barrier Wall - South	5.80E-04	1.54	1,100	10.00	0.11	0.01

Vertical Leakage from Alluvium to target Coal Seam

Vertical Leakage from Alluvium to Broonie Coal Seam at..	Vertical Hydraulic of PCM Layer 2 in MER (March 2010) K_Z (m/d)	Vertical Hydraulic Gradient (i_z)	Pit Wall Length (m)	Width of Alluvium (m)	Vertical Discharge from Alluvium to Broonie Coal Seams Q_Z (L/s)	Vertical Discharge from Alluvium to Broonie Coal Seams Q_Z (ML/d)	Percentage of Pit Inflow from Alluvium Q_z/Q_{XY} (%)
Palaeochannel east limb	2.60E-04	1.34	1,100	300	1.34	0.12	80%

Notes

i_{XY}	Horizontal hydraulic gradient
i_Z	Vertical hydraulic gradient. Head difference between nested bores.
K_{XY}	Horizontal hydraulic conductivity (m/d)
K_Z	Vertical hydraulic conductivity (m/d)
Q_{XY}	Estimated leakage of groundwater from target coal seams into pits (ML/d)
Q_Z	Estimated leakage groundwater from alluvium, through the interburden and into target coal seams (ML/d)
Q_z/Q_{xy}	Pit inflow sourced from alluvium groundwater (%)
*	Estimated depth to base of Permian overburden from CFW59 lithological log & geological cross-sections in MER (2005)

Groundwater Flow

Q=KiA

Q	Discharge (m^3/d)
K	Hydraulic Conductivity (m/d)
i	Hydraulic Gradient
A	Area Intersected (m^2)

Australasian
Groundwater
and Environmental
Consultants Pty Ltd
(AGE)

Report on

HVO South and Lemington

2015 Annual Groundwater Impacts Report

Prepared for
Coal and Allied Operations Pty Ltd

Project No. G1810   March 2016
www.ageconsultants.com.au   ABN 64 080 238 642

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Report on

HVO South and Lemington
2015 Annual Groundwater Impacts Report

1 Introduction

The Hunter Valley Operations (HVO) mining complex is located approximately 20 km north-west of Singleton, NSW. The complex is divided into its HVO North and HVO South components by the Hunter River (refer Figure 1). This report focuses on HVO South (the Project area), located south of the Hunter River. The mine is owned by Rio Tinto Coal Australia (RTCA) and operated by Coal and Allied Operations Pty Ltd (Coal & Allied).

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) have been engaged by Coal and Allied to address the Special Environmental Conditions in Schedule 3 of the Project Approval, issued by the Minister for Planning (March, 2009). This report supports the Annual Environmental Management Report (AEMR) for 2015, and addresses Condition No. 28 of the Project Approval. Condition No. 28 requires the report to include:

- "*alluvial and hard rock buffer groundwater levels;*
- *interpreted drawdown levels resulting from existing and/or ongoing mining operations of the project;* and
- *accounting for any drawdown loss of alluvial groundwater or river flows*."

Furthermore, this report presents the assessment of existing consent comittments for Lemington Underground (LUG) Bore 20BL17392, specifically conditions 13 and 14. The majority of the requirements are assessed as part of the annual Groundwater Impact Report; however, there are several additionnal assessment criteria for the LUG Bore, including:

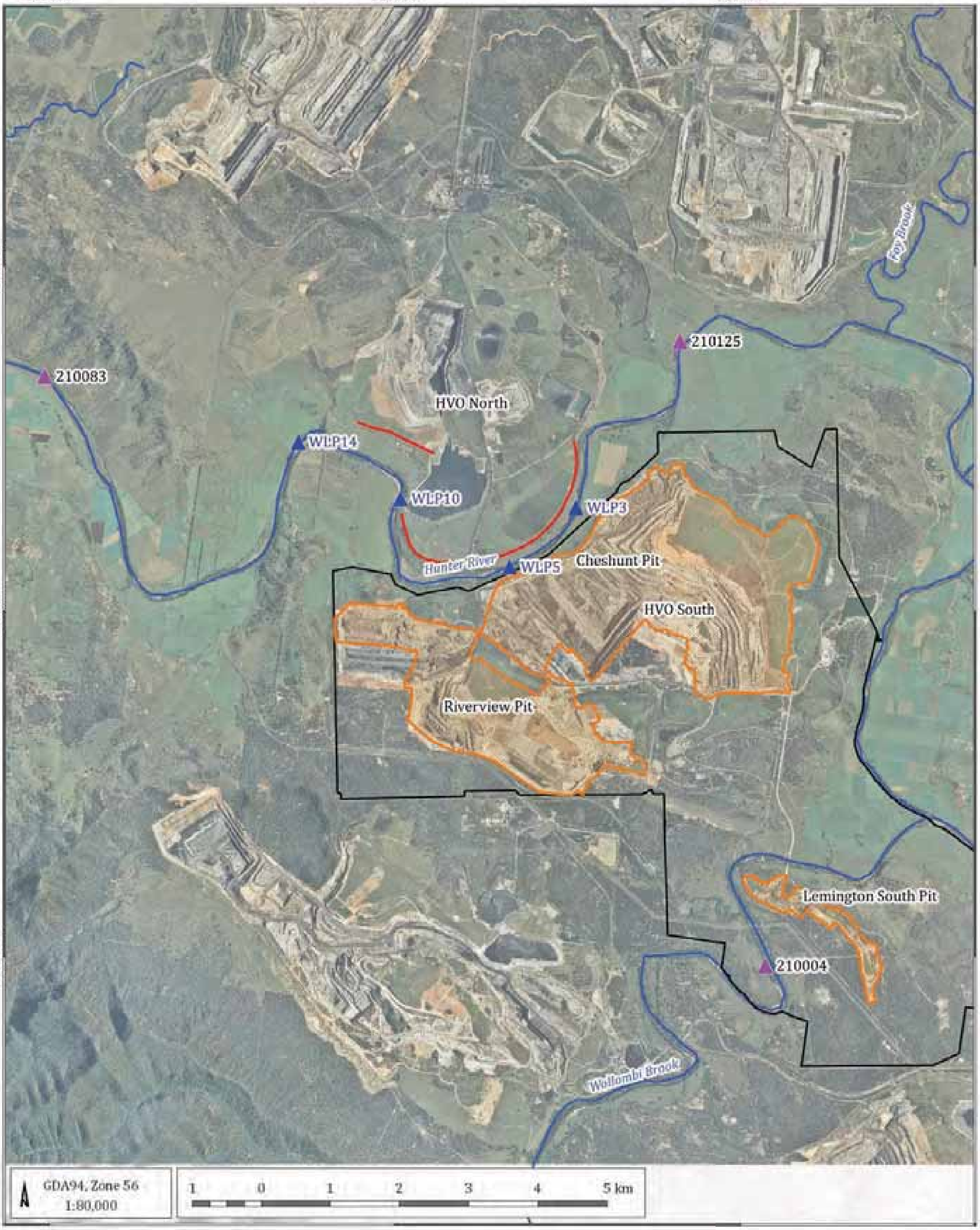
- *"review actual impacts of the extractions on any aquifers, groundwater dependant ecosystems and streams in the area";*
- *"make comparisons between actual and predicted impacts (modelled results)";*
- *"provide statistics for the monitoring data collated for each bore for the previous year"; and*
- *"assess compliance with the licence terms and conditions".*

The New South Wales Office of Water (NOW) has identified alluvial and hard rock buffer zones for mines located along surface water systems, such as rivers and streams. The HVO South buffer zones are located between the Hunter River and the open cut coal mine pits in the Cheshunt area (Cheshunt Pit), as well as between Wollombi Brook alluvial system and Lemington South Pit 1. Active mining occurred in the Cheshunt Pit and Riverview Pit during 2015.

2 Project setting

2.1 Location

This report focuses on HVO South, which is located to the south of the Hunter River and comprises of the Cheshunt and Lemington South Pit areas. HVO South is bound by the Golden Highway to the west, and the New England Highway to the east. Several mines are located around HVO South, including Warkworth Mine and Wambo Mine, which are located within 2 km of Lemington South Pit 1. Refer to Figure 1.



LEGEND

- Disturbance area
- Mine lease
- HVO gauge station
- WHO gauge station
- Barrier wall
- Major drainage

HVO South - 2015 Annual Groundwater Impacts Review (G1810)

Project area

DATE 22/02/2016

FIGURE No. **1**

2.2 Climate

The climate of the HVO area is mostly temperate, and characterised by hot, wet summers and mild, dry winters. Climate monitoring data collected by Coal and Allied at the HVO Corp Meteorological Weather Station during 2015 is summarised in Table 1.

Table 1 Climate averages: HVO Corp. Meteorological Data 2015

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean max temp (°C)	30.7	30.3	30.1	23.7	19.9	17.9	16.7	19.0	22.0	30.9	31.2	29.8	n/a
Mean min temp (°C)	18.3	17.6	16.1	13.1	10.2	7.2	5.7	7.4	9.5	8.7	17.8	15.4	n/a
Mean monthly rainfall since 2007(mm)	67.5	82.4	72.1	52.4	33.8	70.4	29.0	39.5	33.1	34.0	99.4	77.5	696.8*
Total monthly rainfall 2015 (mm)	176.8	37.6	19.2	169.0	50.2	25.8	23.8	48.6	19.4	30.8	101.0	111.4	813.6

Note: **Mean Annual average (2007-2015)*

The total annual rainfall for 2015 was 813.6 mm with the wettest month in January (176.8 mm). On average, 2015 was wetter than the previous eight years with 116.8 mm cumulative rainfall above the average.

Monthly Cumulative Rainfall Departure (CRD) using available rainfall data has been calculated for the period 2007 to December 2015 using rainfall data from the HVO Corp. Meteorological data. The CRD method is a summation of the monthly departure of rainfall from the long-term average monthly rainfall. A rising trend in the CRD plot indicates periods of above average rainfall, whilst a falling slope indicates periods when rainfall is below average.

The CRD graph for the period 2007 to 2015 is shown in Figure 2. The CRD indicates that the site experienced intermittent periods of above average rainfalls between November 2014 to January 2015 and April 2015 to May 2015. Between June and November 2015 the period of rainfall is similar to the average.

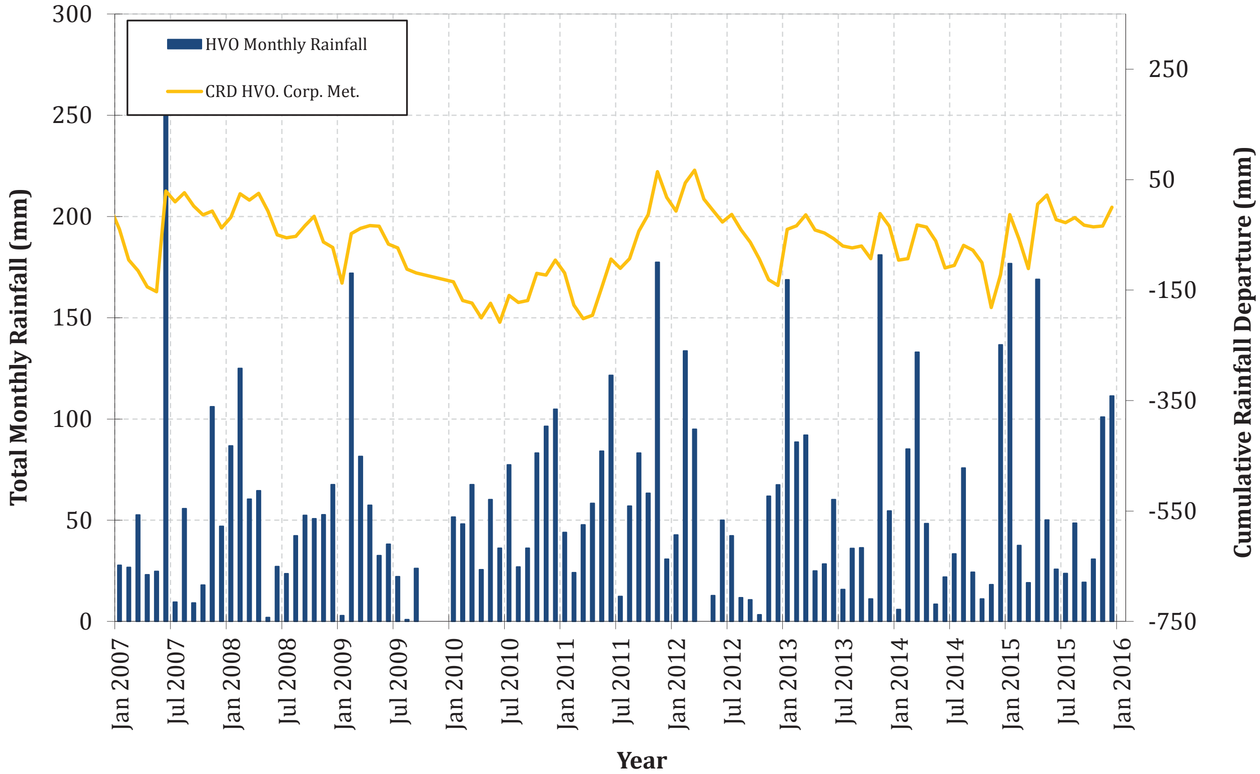


Figure 2 Cumulative rainfall departure comparison - HVO

2.3 Surface water

Cheshunt and Riverview pits are bounded on the north and east by the Hunter River. Lemington Pit is separated from the other pits by Wollombi Brook

The New South Wales Office of Water (NOW) collects real time river flow data via the Hunter Integrated Telemetry System (HITS), which is installed at gauges along the Hunter River and the Wollombi Brook, both upstream and downstream of the mine pits (Figure 1), the stream gauge stations used include:

- Hunter River Station 210083 – Hunter River stream gauge located approximately 12 km upstream of the Cheshunt Pit area (60.96 mRL at zero gauge);
- Hunter River Station 210125 – Hunter River stream gauge located approximately 3 km downstream of Cheshunt Pit North (50.33 mRL at zero gauge); and
- Wollombi Brook Station 210004 – Wollombi Brook stream gauge located approximately 1 km upstream of the Lemington South Pit 1 – North Void (47.76 mRL at zero gauge).

HVO also collects monthly river elevation data from four stations along the Hunter River as shown in Figure 1. The two closest HVO monitoring stations to HVO South are:

- Hunter River HVO Station WLP3 – Hunter River survey point located approximately 800 m north of Cheshunt Pit North; and
- Hunter River HVO Station WLP5 – Hunter River survey point located approximately 200 m north of Cheshunt Pit South.

Long term stream level data for the four mentioned HVO survey points and NOW stream gauge stations are shown in Appendix A. Table 2 summarises the surface elevation in the Hunter River during 2015 in the vicinity of Cheshunt pit.

Table 2 Water elevation monitoring data (mAHD) - Hunter River at HVO

Station ID	Easting	Northing	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WLP3	312613	6401505	54.8	54.9	54.9	54.9	55.0	55.1	55.0	55.1	55.1	54.8	54.9	54.8
WLP5	311655	6400647	55.8	55.8	55.8	55.9	56.0	56.0	56.0	56.2	56.1	55.8	55.9	55.8

There were four main peak flow events recorded during 2015:

- the main peak flow was recorded on 23 April after a major rainfall event on 21 April (68.4 mm). The water level returned to the average elevation in ten days;
- 26 August after a rainfall event between 23 and 24 August;
- 17 November after a rainfall event between 12 and 13 November; and
- 27 December after a major rainfall event between the 21 and 22 December.

The Hunter River is a stream that is regulated by release from Glenbawn Dam; however, the Hunter River water level rises generally very quickly after a main rainfall event and reaches the peak level(s) after two to three days. The water level generally falls within the ten days following peak flow.

2.4 Geology

The stratigraphic sequence of the Permian coal measures is shown in Figure 3, regional geology map was sourced from the 1:100,000 scale geological map, published by the Department of Mineral Resources (Glen & Beckett, 1993) and reproduced in Figure 4.

The Quaternary alluvium in Figure 4 has been digitised based on the 1:25,000 Geology Maps of Singleton (McIlveen, 1984), Muswellbrook (Summerhayes, 1983), Jerrys Plains (Sniffin & Summerhayes, 1987) and Doyles Creek (Sniffin et al, 1988). It is important to note that the mapping does not accurately define the extent of alluvium, as large-scale mapping often incorporates desktop assessment with limited ground truthing. AGE (2011) show mapping over-estimates the extent of the alluvium, which compares resistivity investigation results from Groundsearch Australia (2006) to the mapped extent from the 1:25,000 Singleton Geological Map (McIlveen, 1984).

2.4.1 Stratigraphy

The stratigraphic sequence in the region comprises two distinct units, Quaternary alluvium and Permian sediments. The Quaternary alluvium consists of silt, sand and gravel in the alluvial floodplains of the Hunter River and Wollombi Brook. The alluvium unconformably overlies the Permian sediments, which comprise of coal seam sequences with overburden and interburden consisting of sandstone, siltstone, tuffaceous mudstone, and conglomerate.

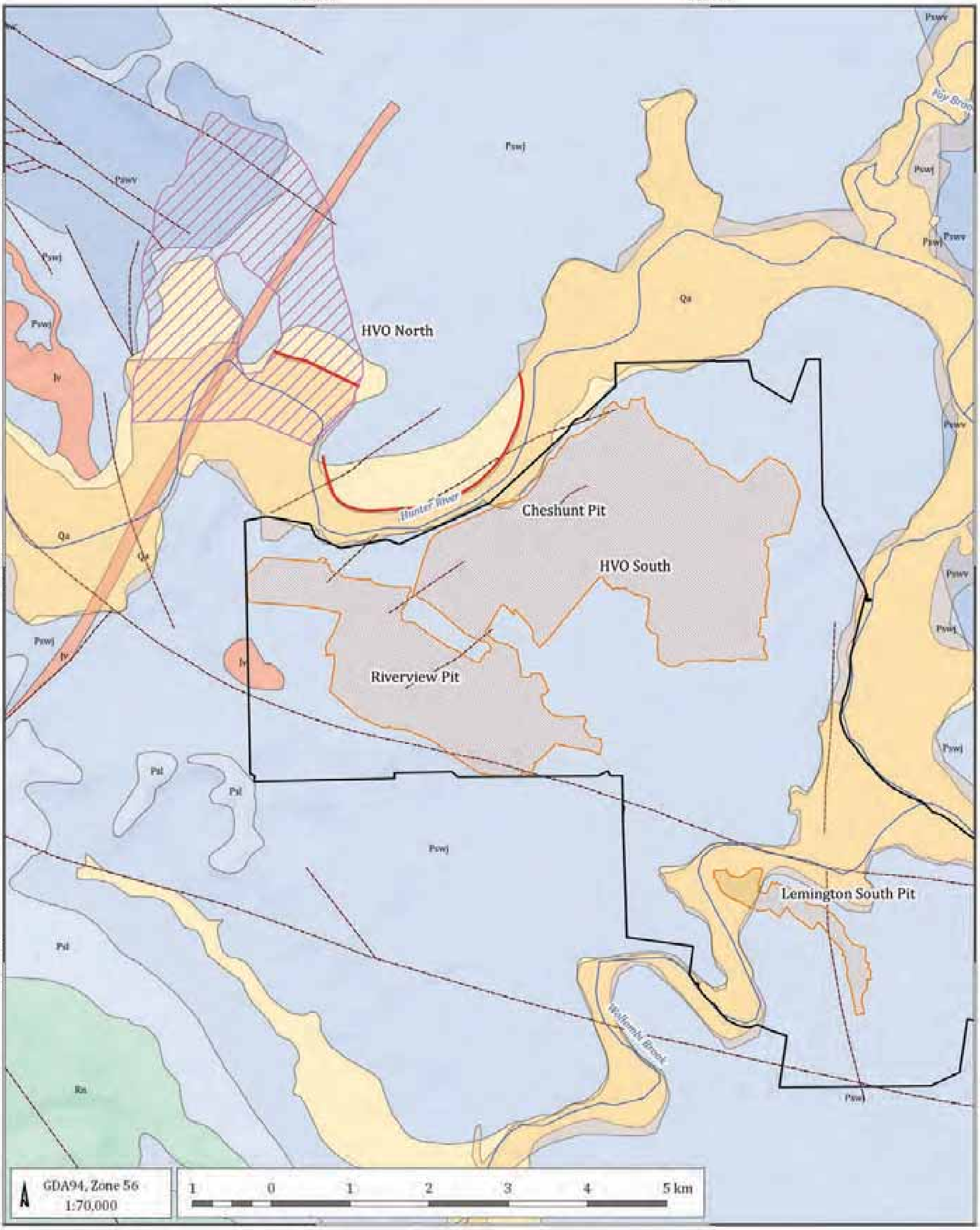
The Middle Permian rocks form a regular layered sedimentary sequence dipping in a general south-westerly direction, with the Whittingham Coal Measures containing the main economic coal seams. The Whittingham Coal Measures include the Jerrys Plains Subgroup, which is the sequence being mined at HVO South (Figure 4). Coal seams mined in the Lemington South Pit 1 include the Glen Munro Seam (GM), Woodlands Hill Seam (WDH), Arrowfield Seam (AFS) and Bowfield Seam (BFS). , and. Coal seams mined in the Cheshunt Pit include the Mt Arthur Coal Seam (MTA), Piercefield Coal Seam, Vaux Coal Seam and Broonie Coal Seam. The Archerfield Sandstone and the Vane Subgroup underlie the Jerrys Plains Subgroup.

Super Group	Coal Measures	Subgroup	Formation	Seam
SINGLETON SUPER GROUP	WHITTINGHAM COAL MEASURES	**DENMAN FORMATION**		
		JERRYS PLAINS SUBGROUP	MOUNT LEONARD FORMATION	WHYBROW SEAM
			ALTHORPE FORMATION	
			MALABAR FORMATION	REDBANK CREEK SEAM
				WAMBO SEAM
				WHYNOT SEAM
				BLAKEFIELD SEAM
			SAXONVALE MBR	
			MOUNT OGILVIE FORMATION	GLEN MUNRO SEAM
				WOODLANDS HILL SEAM
			MILBRODALE FORMATION	
			MOUNT THORLEY FORMATION	ARROWFIELD SEAM
				BOWFIELD SEAM
				WARKWORTH SEAM
			FAIRFORD FORMATION	
			BURNAMWOOD FORMATION	MOUNT ARTHUR SEAM
				PIERCEFIELD SEAM
				VAUX SEAM
				BROONIE SEAM
				BAYSWATER SEAM inc. RAVENSWORTH
		ARCHERFIELD SANDSTONE		

Figure 3 Whittingham Coal Measures Stratigraphic Table

Note: Lemington South Pit – target coal seams

Cheshunt Pit – target coal seams



LEGEND

- Mine lease
- Disturbance area
- Paleochannel (MER, 2005)
- Quaternary alluvium (1:25k AGE)
- Barrier wall
- Regional Fault
- Major drainage

Geology

- Qa - Quaternary alluvium
- Jv - Jurassic volcanics
- Rn - Narrabeen Group
- Psl - Newcastle Coal Measures
- Pswj - Jerrys Plains Subgroup
- Pswv - Archerfield Ss., Vane Subgroup
- Pswc - Saltwater Creek Formation

HVO South - 2015 Annual Groundwater Impacts Review (G1810)

Geology

DATE: 22/02/2016

FIGURE No: **4**

2.4.2 Structural geology

The major structural feature at HVO South is the Bayswater Syncline that strikes north-south. The Bayswater Syncline is located to the east of Cheshunt Pit and west of Lemington South Pit 1. On the western limb of the Bayswater Syncline is the "*Western Graben*", which trends in a north-south direction (NTEC, 2010). Figure 4 shows several faults trending south-west to north-east in the Cheshunt area, and trending north to south near Lemington South Pit 1.

Resistivity studies by Groundsearch Australia (2008) have also identified two possible faults across Barry's Flat, which is located north-east of Cheshunt Pit. AGE (2010a) indicated that these two faults may have caused stratigraphic discontinuities and over-thrusting of seams.

An anticlinal structure is also present within the northern highwall of Cheshunt Pit. Figure 5 highlights the anticline (in red), and shows minor displacement of the coal measures along minor faults (in yellow). Along the crest of the anticline, the Mount Arthur Coal Seam appears to sub-crop beneath the alluvium (MER 2005).

Figure 5 Cheshunt Pit anticline

2.5 Hydrogeology

The hydrogeological setting at HVO South is comprised of shallow Quaternary alluvial aquifers, and deeper Permian coal measures. Sections 2.5.1 and 2.5.2 below detail the hydrogeological characteristics of the alluvium and Permian coal measures.

2.5.1 Alluvial aquifer

Figure 4 shows the mapped extent of Quaternary alluvium. AGE (2010b) assessed that the alluvium along the Wollombi Brook and Hunter River are generally 10 m to 15 m thick, with the alluvium thinning to 0 m to 5 m towards the edges of the alluvial plain. This is consistent with the Groundsearch Australia (2006) report findings of alluvium to 6.4 m depth, approximately 100 m from Wollombi Brook.

Recharge to the alluvium occurs via direct rainfall infiltration and localised recharge via lateral seepage from the Hunter River and Wollombi Brook during periods of high flows. Resistivity studies by Groundsearch Australia (2006 and 2008) suggest a moderate to high hydraulic conductivity for the alluvium. Falling head tests on bores within the Wollombi Brook alluvium indicate a hydraulic conductivity of 0.2 m/day to 1.6 m/day (AGE, 2010b).

2.5.2 Permian coal measures

The Permian coal measures can be categorised into the following hydrogeological units:

- the majority of the Permian comprises interburden / overburden, consisting of very low to low permeability and very low yielding sandstone, siltstone and conglomerate units; and
- low to moderately permeable coal seams, each typically ranging in thickness from 2.5 m to 10 m, which are the prime water bearing strata within the Permian sequence.

The Permian coal measures occur as a regular layered south westerly dipping sedimentary sequence. In most areas around HVO South, low permeability interburden separates the alluvium and coal measures; however, MER (2005) and Groundsearch Australia (2006) reported that the coal seams may subcrop below the alluvium intermittently near Cheshunt Pit and Barry's Void.

The low to moderately permeable coal seams have recorded horizontal hydraulic conductivity (Kxy) values of between 4.0 x 10^{-3} m/day and 0.6 m/day (Rust PPK, 1997 and MER, 2005). The hydraulic conductivity of the low yielding interburden/overburden has been recorded between 1.0 x 10^{-4} m/day and 1.0 x 10^{-5} m/day (Rust PPK, 1997, MER, 2005 and AGE, 2010b).

3 Monitoring programme

Groundwater monitoring is undertaken at the site as per the Project Approval - Schedule 3 Condition 27. This water management plan (WMP) was updated in July 2015. It defines the groundwater monitoring programme for the Hunter Valley Operations (HVO), North and South. The summary of the monitoring bore construction and details is provided in Appendix B.

3.1 Monitoring bore network

The groundwater monitoring network at HVO South consists of 67 monitoring bores (both single screened bores and multiple piezometer installations). The 67 bores / piezometers are located in the following areas:

- Cheshunt Pit area – 28 bores; and
- Lemington South Pit – 39 bores.

A summary of the bore target formations is included in Table 3 below. Monitoring bore locations for Cheshunt Pit and Lemington South Pit are shown in Figure 6 to Figure 8, respectively.

Table 3 Monitoring bore screened lithology

Location	Lithology	No. of bores
Cheshunt	Regolith	1
	Regolith, alluvium	1
	Alluvium	11
	Interburden	4
	Mt Arthur Seam	11
Lemington	Alluvium	4
	Interburden	1
	Glen Munro Seam	1
	Woodlands Hill Seam	7
	Arrowfield Seam	4
	Bowfield Seam	17
	Piercefield Seam	4
	Vaux Seam	1

The groundwater monitoring programme records the following parameters monthly, quarterly, biannually or annually:

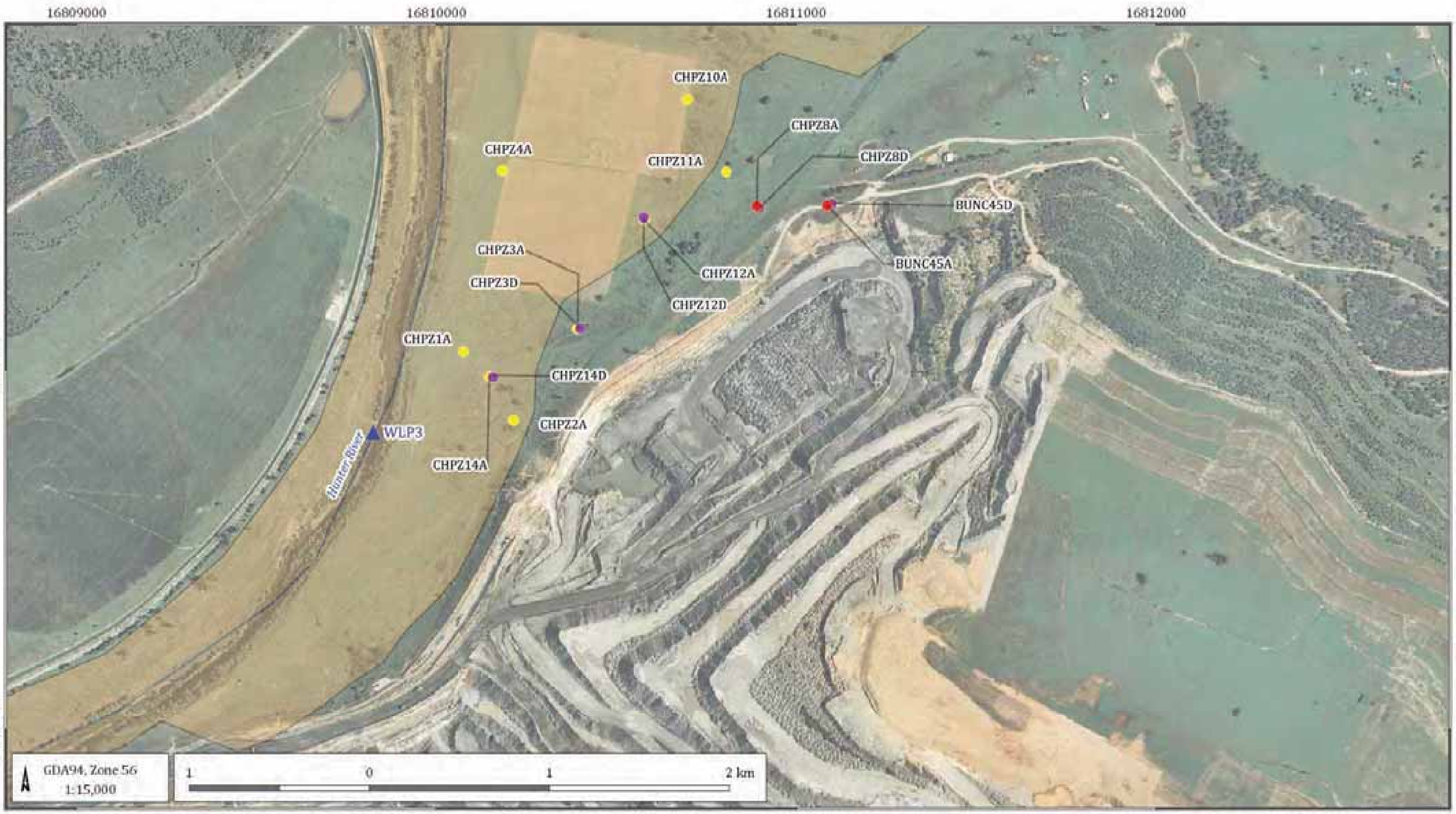
- groundwater level (manual reading and some bores are equipped with data loggers);
- field water quality - electrical conductivity (EC) and pH; and
- comprehensive analysis.

3.2 Trigger levels

Trigger levels from 95th percentile were assigned for maximum value to a list of relevant borehole for EC and pH. Additionally, 5th percentile minimum value was assigned to the pH.

Site specific investigation is initiated when:

- three consecutive measurements of EC or pH exceed trigger values; and
- professional judgement determines that a single deviation or a developing trend could result in environmental harm.



LEGEND

Monitoring bore type

- Alluvium
- Mt Arthur Seam
- Regolith
- HVO gauge station

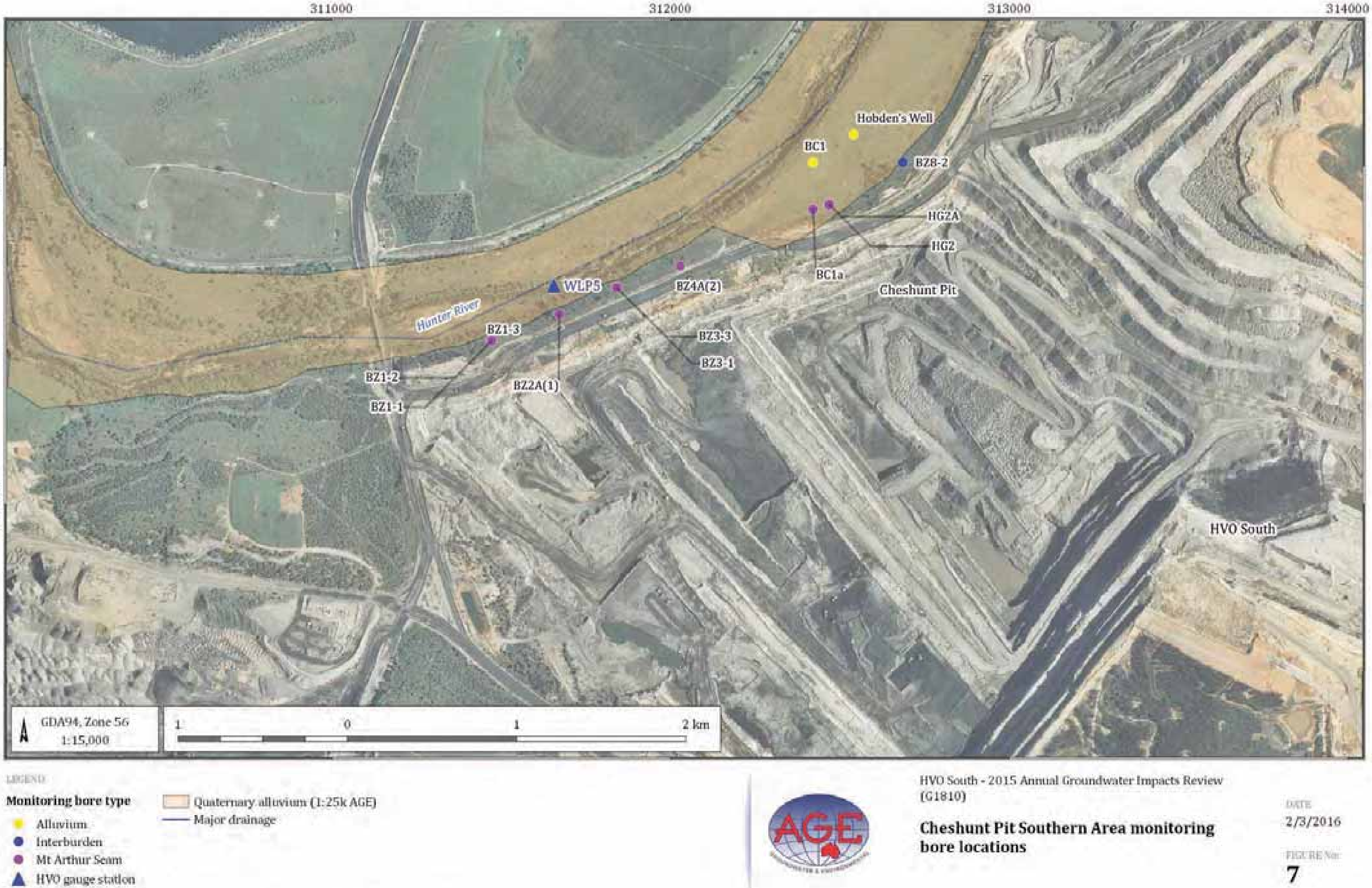
- Quaternary alluvium (1:25k AGE)
- Major drainage

HVO South - 2015 Annual Groundwater Impacts Review
(G1810)

Cheshunt Pit Northern Area monitoring bore locations

DATE
22/02/2016

FIGURE No:
6

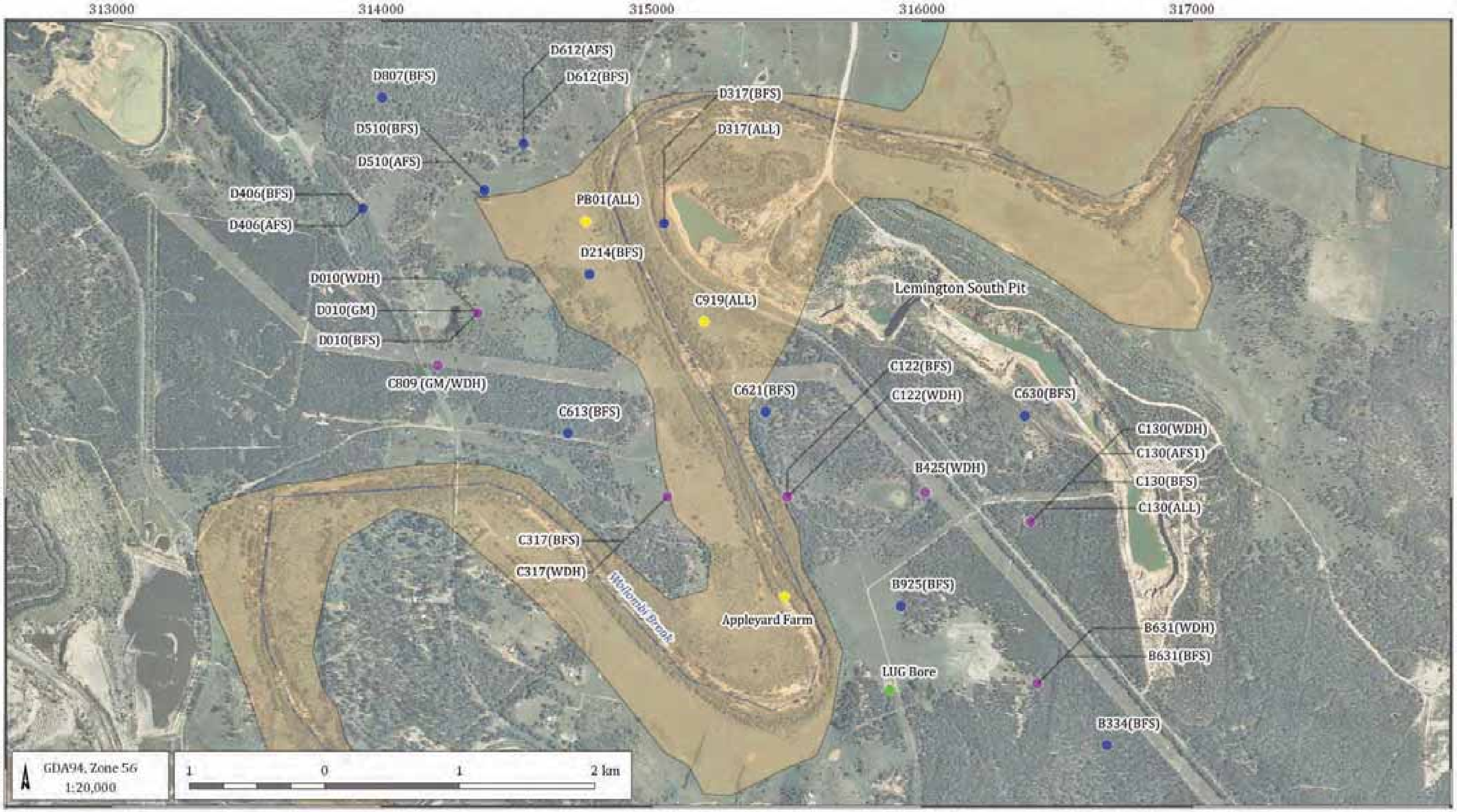


HVO South - 2015 Annual Groundwater Impacts Review (G1810)

Cheshunt Pit Southern Area monitoring bore locations

DATE 2/3/2016

FIGURE No: 7



LEGEND

Monitoring bore type

- Alluvium
- Bowfield Seam
- Dewatering bore
- Woodlands Hill Seam

Quaternary alluvium (1:25k AGE)
Major drainage

HVO South - 2015 Annual Groundwater Impacts Review
(G1810)

Lemington monitoring bore locations

DATE
2/3/2016

FIGURE No:
8

4 Groundwater quality

Electrical conductivity (EC) and pH were measured in 60 bores in 2015 with 173 individual measurements of pH and EC. These measurements were undertaken quarterly or six-monthly.

In addition, 19 bores were sampled for laboratory analysis of major ions and selected metals. Two sampling rounds were undertaken in February and August on Cheshunt Pit and Lemington South bores.

4.1 Field Chemistry

Available 2015 EC and pH field values are graphed and tabulated in Appendix C. These graphs and tables are used to help identify trends throughout the year and assess the compliance with the WMP. Table 4 below summarises the field EC and pH measurements for 2015.

Table 4 Electrical conductivity (EC) and pH data summary

Location	Lithology	Total bores sampled	Number of measure-ments	Mean EC (µS/cm)	Min EC (µS/cm)	Max EC (µS/cm)	Mean pH	Min pH	Max pH
Cheshunt	Alluvium	8	35	773	417	1334	7.1	6.5	7.5
	Regolith	1	4	1998	1950	2030	6.7	6.6	6.8
	Regolith, alluvium	1	3	1649	1587	1686	6.8	6.8	6.9
	Interburden	4	16	3907	1253	7470	7.1	6.5	7.6
	Mt Arthur Seam	9	35	1641	747	6900	6.9	6.3	7.3
Lemington	Alluvium	3	12	1144	213	3890	7.0	6.2	7.7
	Glen Munro Seam	1	2	10865	10140	11590	7.0	6.9	7.1
	Woodlands Hill Seam	7	16	11396	7540	20900	7.1	6.8	7.5
	Arrowfield Seam	4	8	13284	10790	15890	7.1	6.	7.4
	Bowfield Seam	16	32	7443	2790	13330	7.4	6.7	9.3
	Interburden	1	4	21600	20800	22300	6.9	6.8	7.0
	Piercefield Seam	4	7	8316	6370	13320	7.1	6.8	7.4
	Vaux Seam	1	1	3750	3750	3750	6.7	6.7	6.7

Groundwater on site is brackish to saline with the lowest EC measured within the Hunter River alluvium in the Lemington area. pH ranges from 6.2 to 7.7, with the exception of the Lemington Underground (LUG) dewatering bore with an average pH of 8.8.

No consecutive value excedeed trigger levels in 2015.

The graphs of field EC (appendix C) identify that EC concentrations are:

- generally stable troughout the year within the alluvium and of similar quality to bores across the different mine areas;
- increasing within Arrowfield Seam in Lemington Pit (bores CF130, D406, D510 and D612) and increasing slightly within Woodlands Hill and Bowfield Seams in the later part of 2015; and
- variable within the Cheshunt area ranging between 1,200 and 8,000 µS/cm; and
- in the order of 22,000 µS/cm in bores in the Lemington area.

4.2 Laboratory analysis

Schoeller plots have been created in order to compare major ion chemistry of groundwater samples. Groundwater type comparison is possible even if some of the major ions were not analysed. Schoeller plots compare the normalised concentration of ions (in milliequivalents / litre) on a vertical logarithmic axis with the analytes identified on the horizontal axis. Points for each ion are then connected to form a line. Similar shaped lines from multiple samples indicate a similarity in origin and vertical displacement of similar lines indicates dilution with fresh water (resulting in downward shift in the line) or concentration / evaporation (resulting in an upward shift).

Schoeller plots have been prepared forthe Lemington South and Cheshunt Pits for alluvium, regolith, interburden and Mount Arthur Seam. Figure 9 and Figure 10 show representative Schoeller plots for each of these lithological units for 2015 for both Lemington South and Cheshunt Pits, respectively. The detailed plots for all the bores with sufficient water quality data are included in Appendix C and regrouped both analyses from early and late 2015 for the same bore.

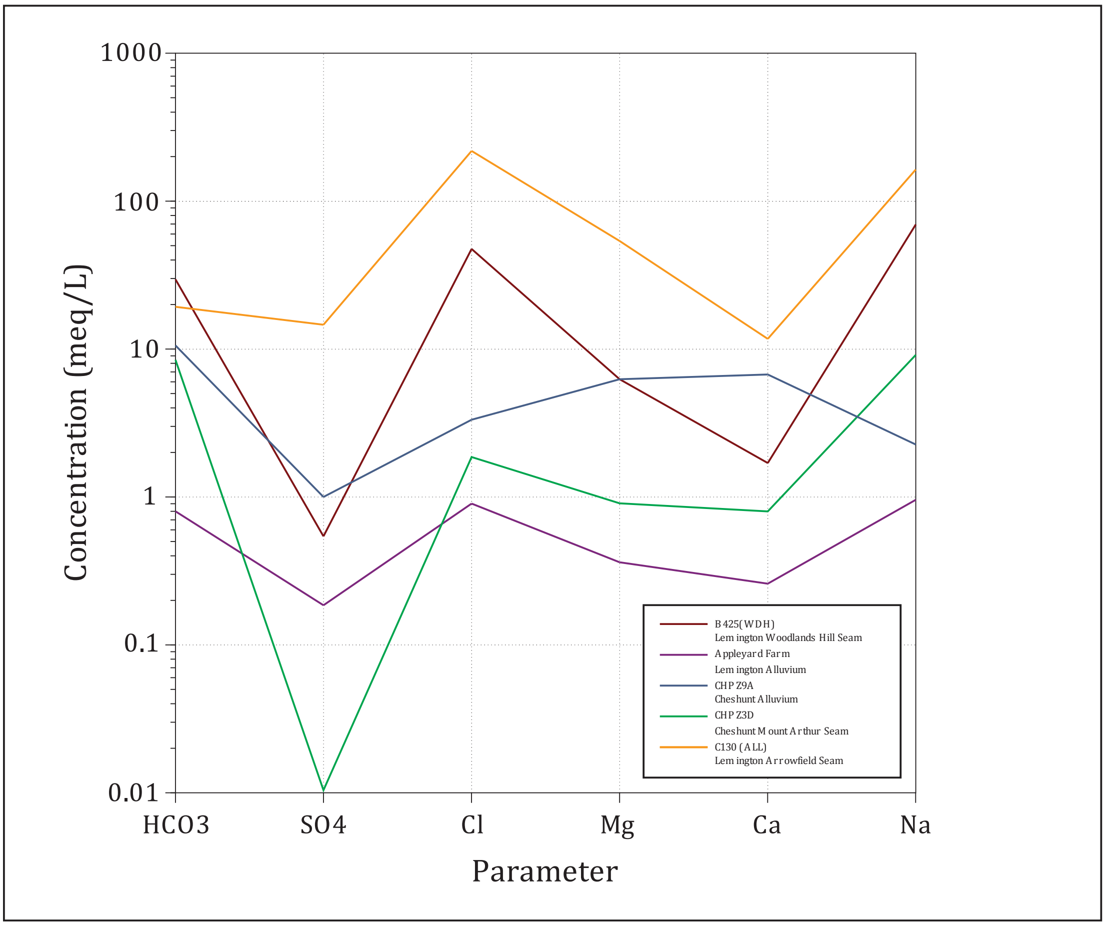
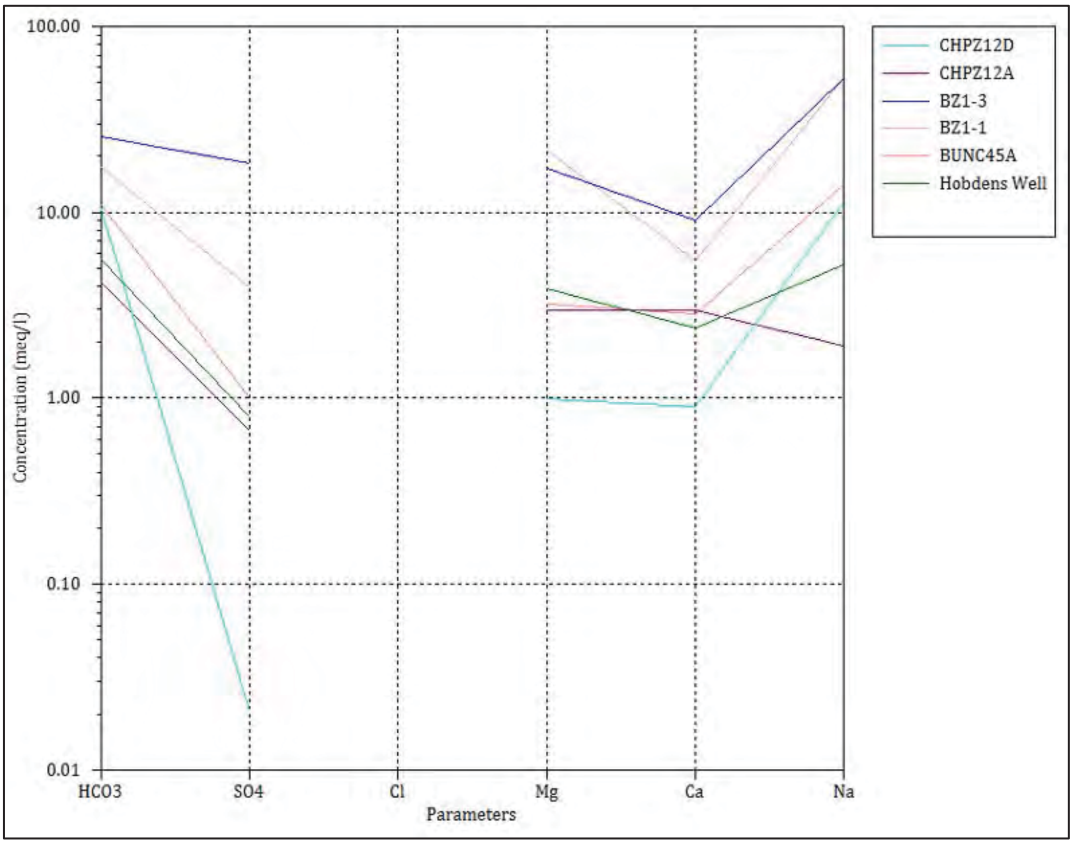


Figure 9 **Schoeller plot of typical alluvium or seam chemistry**



Note : CHPZ12D (Cheshunt Pit_Mt Arthur Seam); CHPZ12A (CheshuntPit_alluvium), BZ1-3 (Cheshunt_Mt Arthur Seam); BZ1-1 (Cheshunt_interburden); BUNC45A (Cheshunt Pit_regolith), Hobden's Well (Cheshunt_alluvium)

Figure 10 Schoeller plot of typical alluvium or seam chemistry – Cheshunt Pit

The results of the above Schoeller plot analysis are similar to the previous reporting period.. Sodium (Na) is the most dominant ion in most samples

The main groundwater quality observations for 2015 are as follows:

- Groundwater within the alluvium has similar chemistry to groundwater from Cheshunt Pit, with low concentrations of Sulphate (SO_4) and comparable concentrations of Magnesium (Mg) and Calcium (Ca).
- Groundwater within the interburden and coal seam show comparable trends. Minor ions are sulphate and calcium; with the exception of monitoring bore CHPZ8D, which has a low concentration of sodium, similar to some monitoring bores within the alluvium.

5 Groundwater levels

Manual measurements of groundwater levels have been collected at HVO South since 2007 and data-loggers were installed in 16 bores from 2009. This report specifically assesses groundwater trends over the 2015 calendar year; however, available data from 2014 has been used to assess potential changes from the previous reporting year. Long-term hydrographs are shown in Appendix D.

The groundwater levels were measured within 61 bores for the 2015 reporting period. Four bores were dry or with small amount of water during the entire year:

- BC1, BZ1-2 and BZ4A(2) in Cheshunt Pit area, and
- C122(BFS) in Lemington South Pit was moist and there was not sufficient water for sampling.

Groundwater level trends in each pit area are discussed below. The hydrographs are contrasted with the CRD curve, as well as river levels recorded at the aforementioned NOW and HVO river level measuring stations.

The comparison of groundwater levels against rainfall and river levels assists in assessing the degree of connectivity between surface water and groundwater and fluctuations due to infiltration of rainfall through the unsaturated zone. Note that the available recorded water level from data loggers were not corrected with the water level measured during the monitoring programme and were graphed to observe the groundwater trend over a short period. Manual measured groundwater level was graphed by plot to assess long term groundwater trend.

The most complete groundwater data sets were from the August and September monitoring events and were used for the groundwater flow interpretation and the contoured data (the alluvium [Hunter River and Wollombi Brook], Mt Arthur Seam and Bowfield Seam). Groundwater flow contours are presented in Appendix E.

5.1 Cheshunt Pit – Northern Area

5.1.1 Alluvium

Groundwater contours (m AHD) for August 2015 (Appendix E) show general groundwater flow direction is towards the Hunter River.

Groundwater hydrographs for the alluvial bores show groundwater levels in 2015 responding to changes in rainfall and river level (refer Figure 11 and Appendix D). The overall groundwater level trend correlates well with variation of surface water elevation with a peak river and groundwater level observed in late April and a recession for the rest of the year after the second main river peak in August. A very similar response was observed in 2014. This provides a good indication of connection between the alluvial aquifer and the Hunter River.

The groundwater levels were below river levels (recorded at WLP3) during the year 2015 which indicates recharge from the surface water to the alluvium; which is as per the previous reporting year.

Groundwater levels for the alluvium indicate no impact from mining for the year.

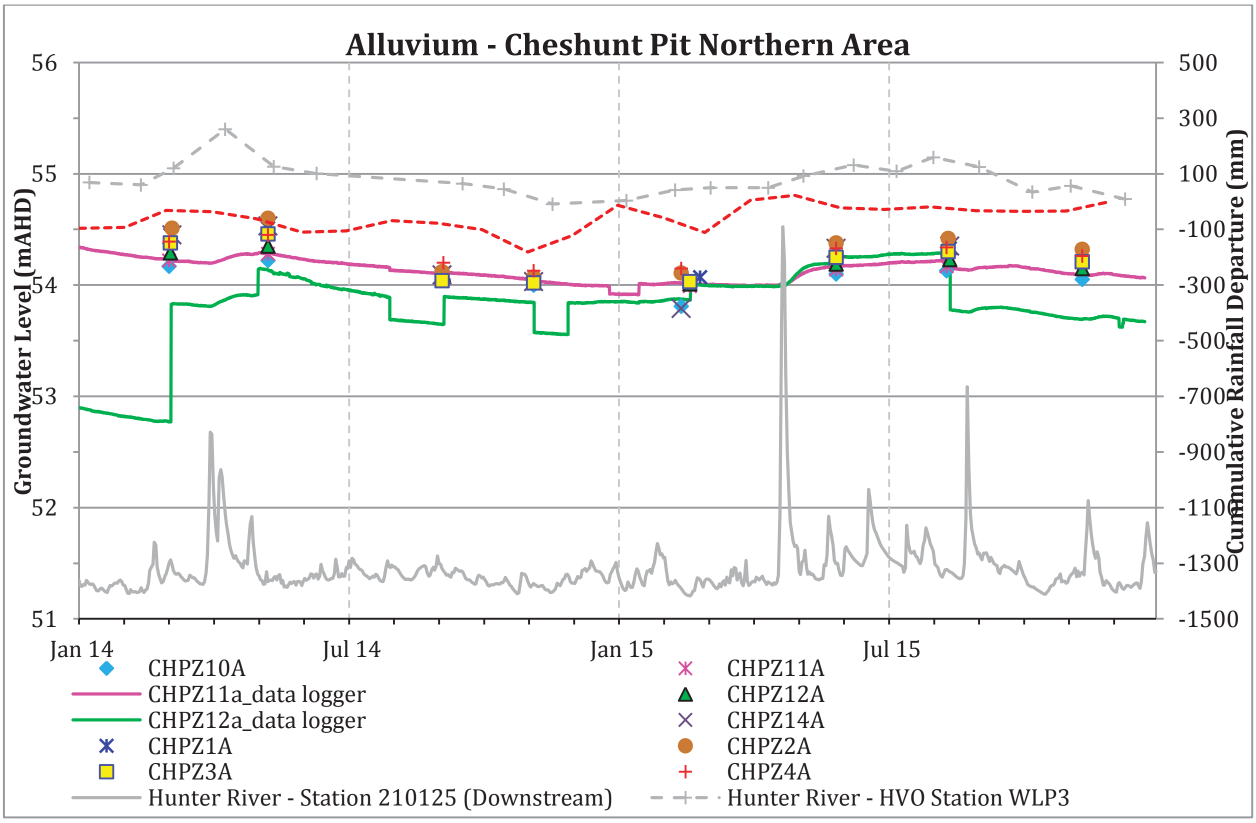


Figure 11 Cheshunt Pit Northern Area Alluvium - Hydrograph

5.1.2 Mount Arthur Seam (MTA)

Groundwater contours for August 2015 (Appendix E) indicates groundwater within the Mt Arthur seam to flows to the north.

Groundwater hydrographs for the MTA bores are presented in Figure 12 and Appendix D. Data loggers installed in the monitoring bores CHPZ3D and CHPZ12D recorded small water level fluctuations which are likely related to the main river peaks. This indicates a possible hydraulic connection between the coal seam and the river. This is likely to occur where the Mt Arthur Seam subcrops beneath both the River and the alluvium to the north–west of Barry's Pit.

The groundwater levels within the monitoring bores trend to increase during the year 2015, except for the bore BUNC45D which decreases since 2014. This last bore is located at adjacent the historic Barry's Void and has lower groundwater level than the other monitoring bores in the area.

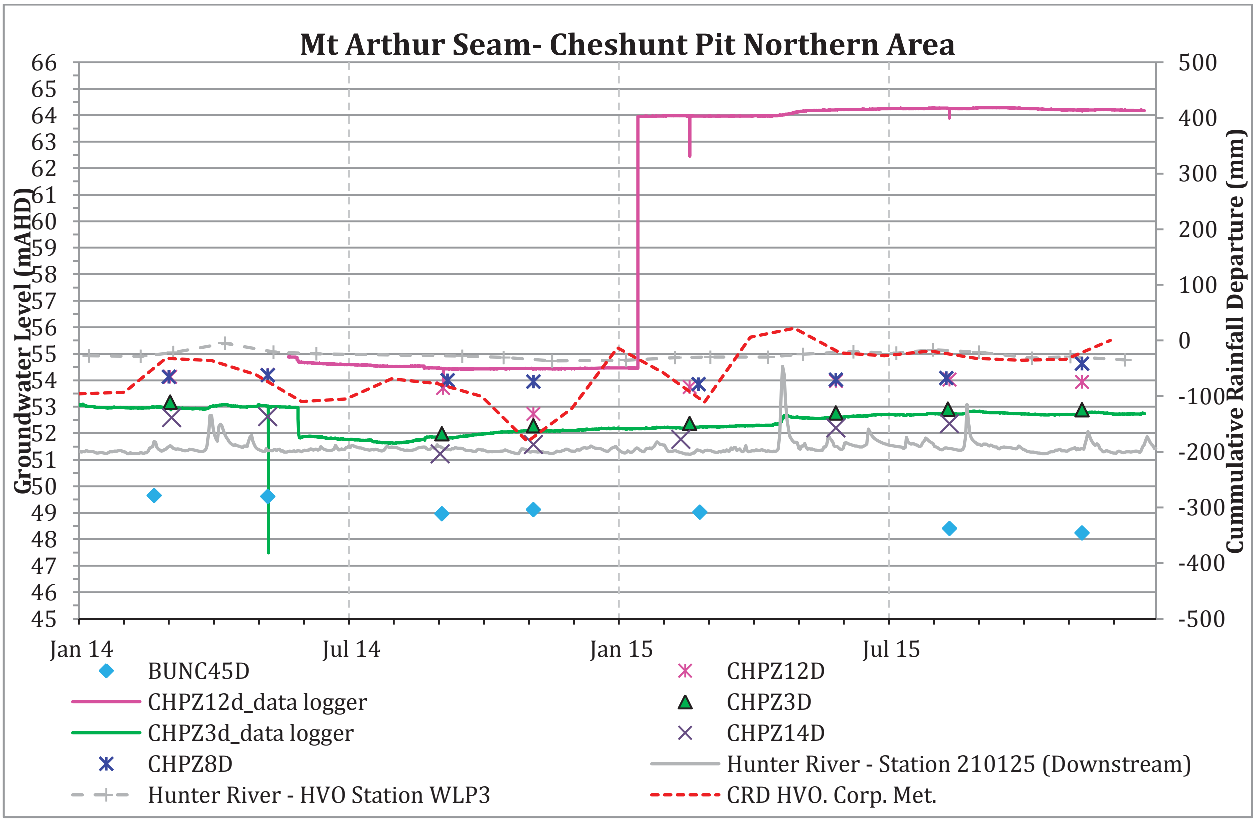


Figure 12 Cheshunt Pit North- Mt Arthur Seam - Hydrograph

5.1.3 Regolith

Groundwater hydrographs for the regolith bores are presented in Figure 13 and Appendix D)Groundwater levels within the regolith show similar variation to the variation in the CRD and the Hunter River level. This indicates possible connection between the surface water and the groundwater.

Groundwater level recorded within the bore BUNC45A, located in the north of Cheshunt Pit, dropped up to one metre between February and August 2015.

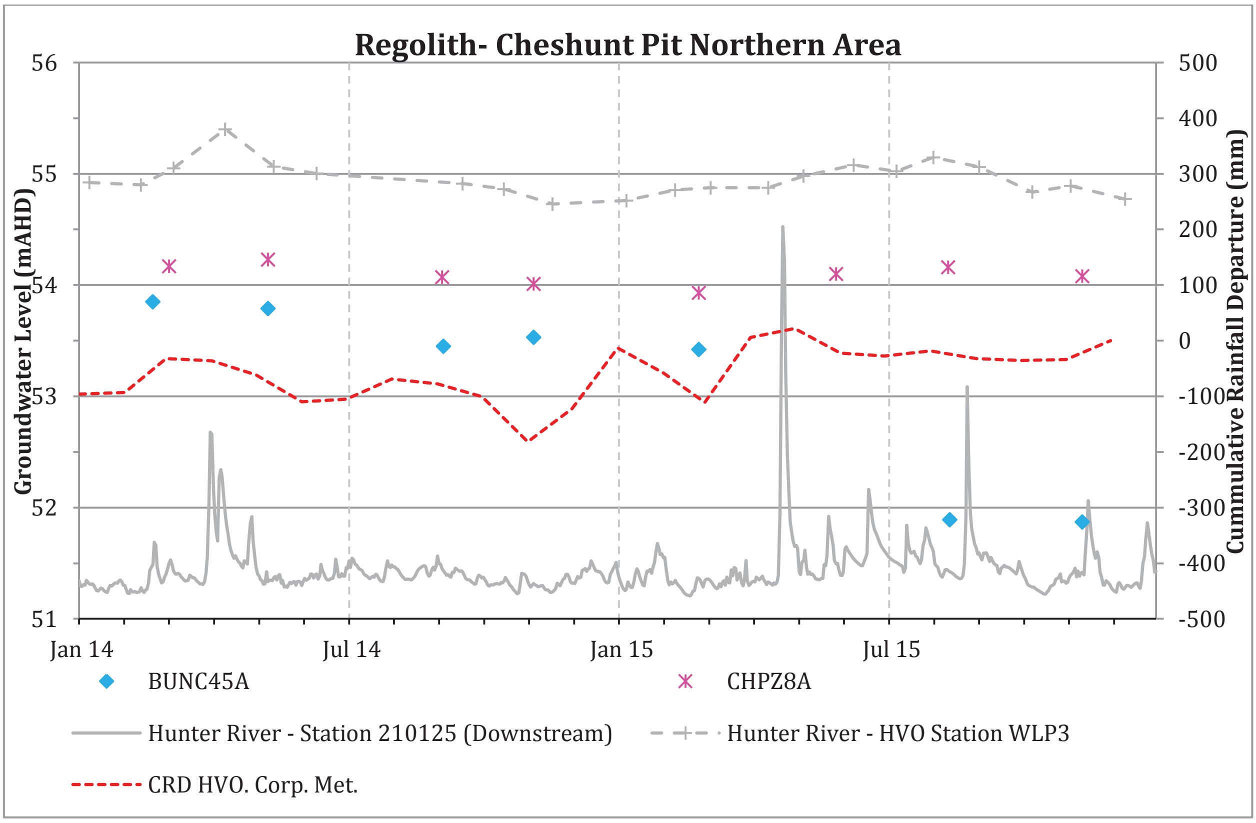


Figure 13 Cheshunt Pit Northern Area - Regolith - Hydrograph

5.2 Cheshunt Pit – Southern Area

5.2.1 Alluvium and interburden

Three alluvium aquifer monitoring bores are present in the Cheshunt Pit – Southern Area, including BC1, BZ1-2 and Hobden's Well. These bores are 8.5 m, 10 m and 13.9 m deep, respectively. Of the three bores, BC1 and BZ1-2 were dry throughout 2015.

The groundwater trends are presented graphically in Figure 14. The groundwater level within Hobden's Well has comparable fluctuation and elevation to the water level recorded in Hunter River gauge station WLP3. This indicates a connection between the Hunter River and the alluvium.

Additionally, the groundwater level measured within the interburden has similar fluctuation and elevation to the alluvium.

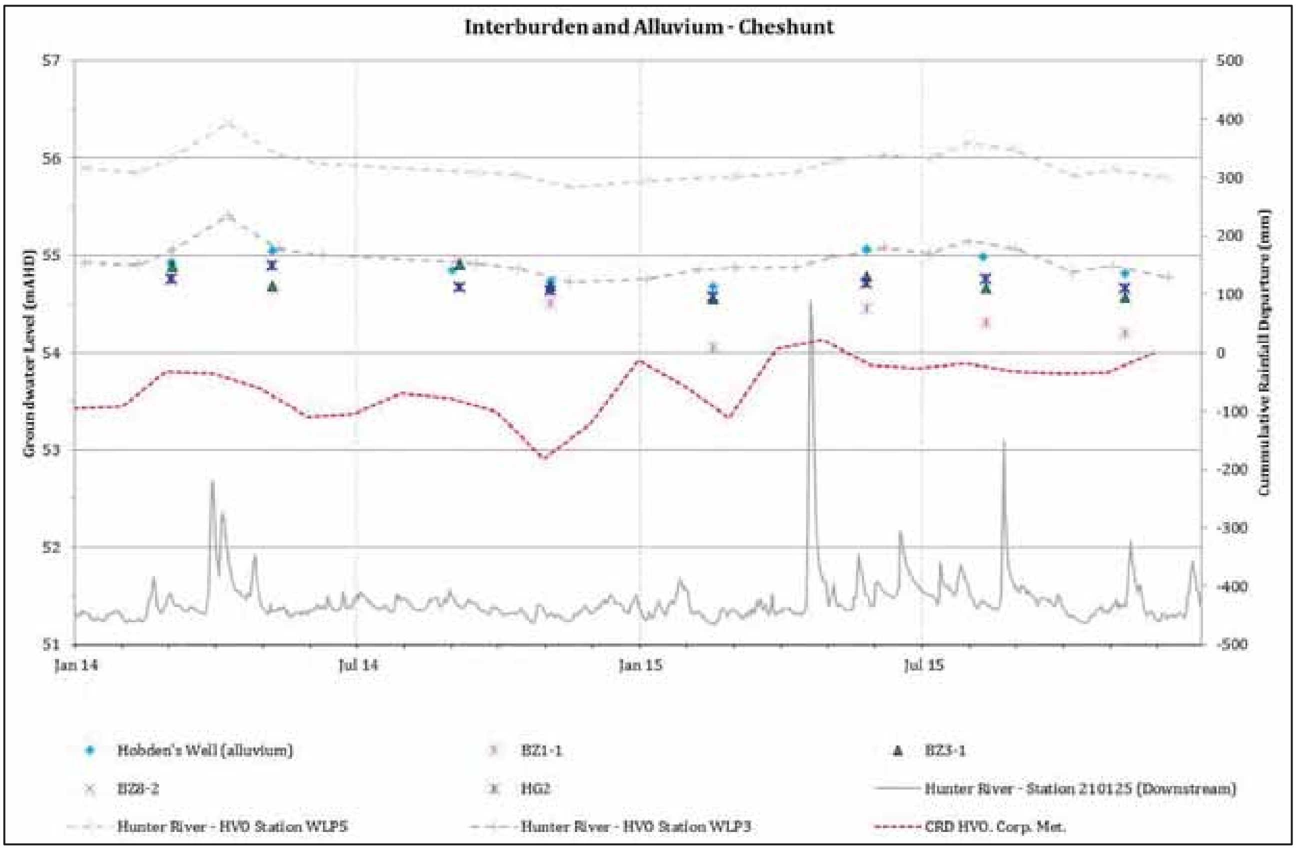


Figure 14 Cheshunt Pit – Interburden and Alluvium - Hydrograph

5.2.2 Mount Arthur Seam (MTA)

Groundwater contours for the MTA water levels of August 2015 (Appendix E) indicate that groundwater within the Mount Arthur Seam generally flows towards the south and toward the actively mined Cheshunt Pit (where the Mt Arthur seam is mined). This is the result of localised depressurisation due to active mining. The direction of groundwater flow remains the same as in 2014.

The MTA hydrograph in Figure 15 indicate that:

- There is no obvious correlation between CRD and groundwater levels recorded in the Mount Arthur Seam.
- Groundwater level within the bores BZ1-3, BZ2A(1) and BZ3-3, north of the advancing Cheshunt Pit highwall, have declined by approximately one metre since 2014. They show a clear response to mining in the active Cheshunt Pit.
- Bores BC1A and HG2A, located further east, had relatively stable groundwater levels across 2014 and 2015, showing little response to pit depressurisation.

This is likely due to :

- Distance between the bores and the active mining areas at Cheshunt Pit.
- The presence of a fault or faults may cause an isolating effect between the bores and the effects of depressurisation.
- Recharge occurring from the north-east is masking the effects of depressurisation. This can also be noted via the groundwater EC in the bores that do not show a response to mining. These bores have EC measurements that are significantly lower than those that are impacted by mining (refer to Appendix CC). This may be indicative of recharge or interconnection from the overlying alluvium.

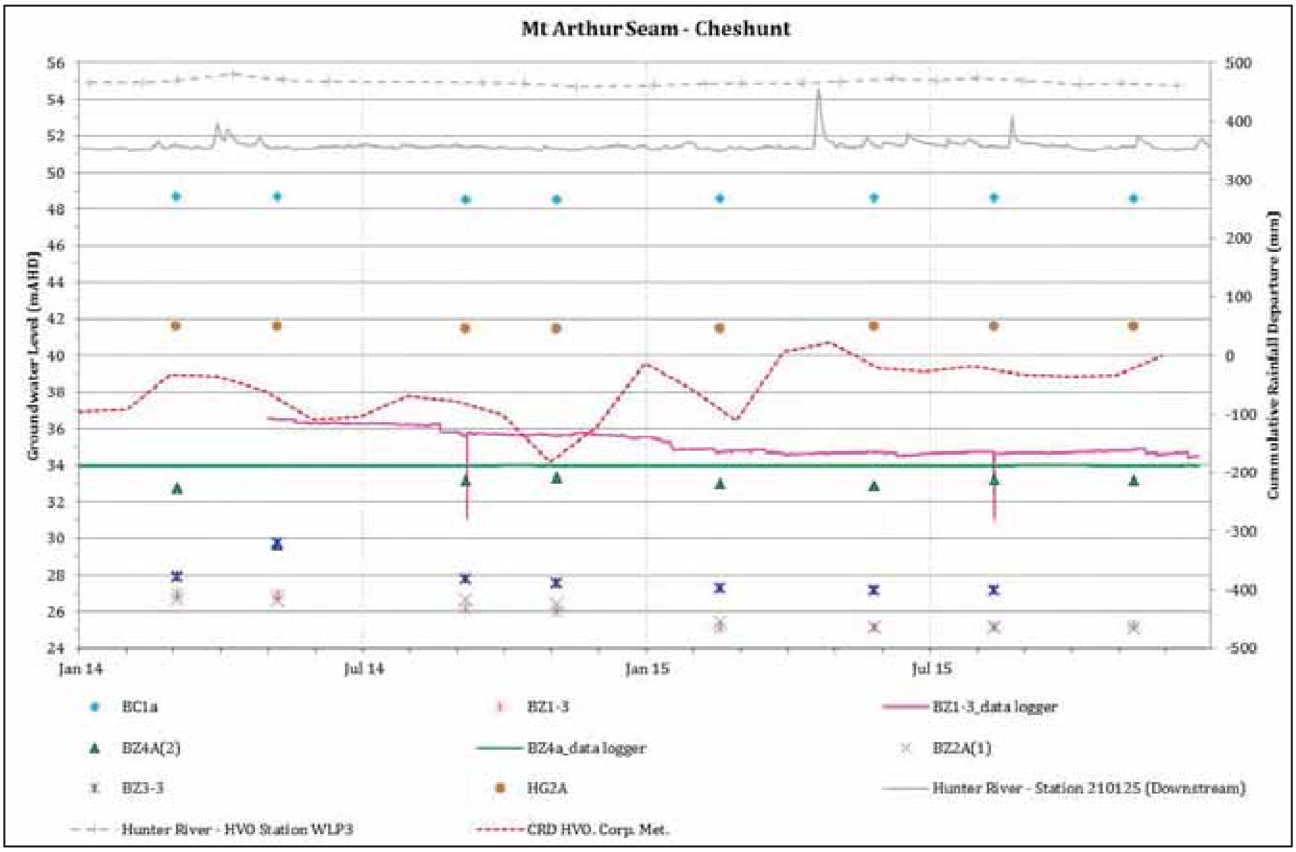


Figure 15 Cheshunt Pit – MTA seam – Hydrograph

5.3 Lemington South Pit 1

5.3.1 Alluvium

The frequency of monitoring in Bores C130(ALL), C919(ALL), D317(ALL) and PB01(ALL) was increased from 6-monthly to monthly in 2014. A review of the monitoring program was undertaken in late 2013, following the receipt of a licence to abstract water from the disused Lemington Underground mine workings, namely via the LUG Bore. A bore at Appleyard Farm, has been monitored monthly since 2012. Hydrographs from these bores are included in Figure 16 and Appendix D.

Key obesrvations include:

- Groundwater levels in bore C919(ALL) is relatively stable across 2014 and 2015. The water level rose slightly in May 2015, coinciding with high rainfall and river peak. This rise was not seen in the adjacent bore - D317.
- The groundwater level recorded in bore PB01(all), on the left bank of the creek, appears to vary more often than the bores on the right bank and is likely a function of the river level and hydraulic connection with the alluvium.
- The hydrograph of the bore at Appleyard Farm, located close to the Wollombi Brook, shows a very close correlation with the water level in Wollombi Brook Station 210004. The hydrograph shows that the elevation, timing and magnitude of the groundwater response in Appleyard Farm bore almost exactly matches the river level, which in turn indicates an connection between the alluvium and the river at this location.

These observations indicate that the hydraulic connection between Wollombi Brook and the alluvium is greater on the left bank of Wollombi Brook than the alluvium on the right bank

Also, there is a noticable step in the data logger data D317 and C919. The most likely cause of this step is a logger correction error at the time of download.

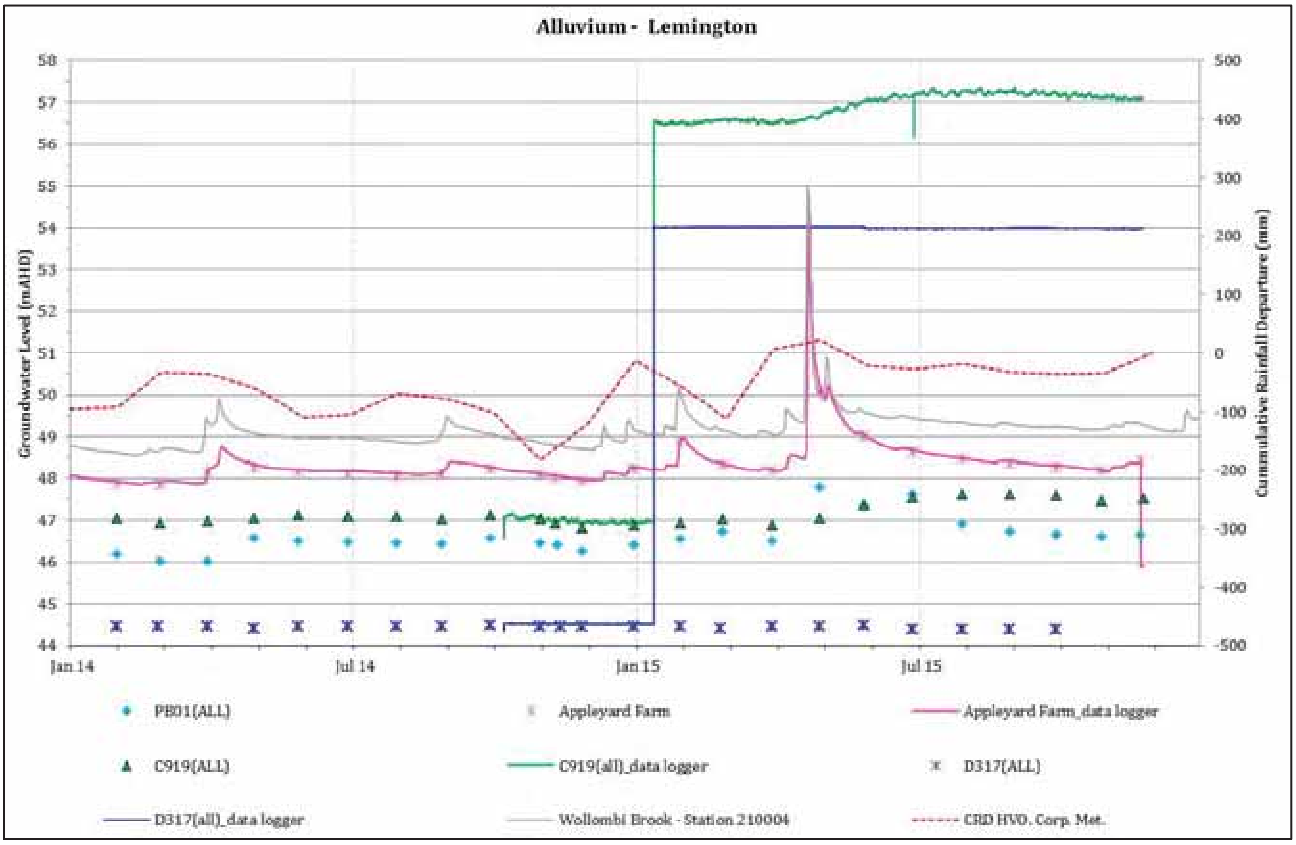


Figure 16 Lemington Pit – Alluvium - Hydrograph

5.3.2 Woodland Hill Seam (WDH) and Glen Munro Seam (GM)

Groundwater levels measured within the Woodland Hill Seam show very little observed change over 2014 and 2015 (refer Figure 17). Bore B425 (WDH) shows a declining groundwater level in 2014 and a rising level in 2015 similar to the CRD. This groundwater level variation is also observed in the bore C809 (GM/WDH) and D010(GM).

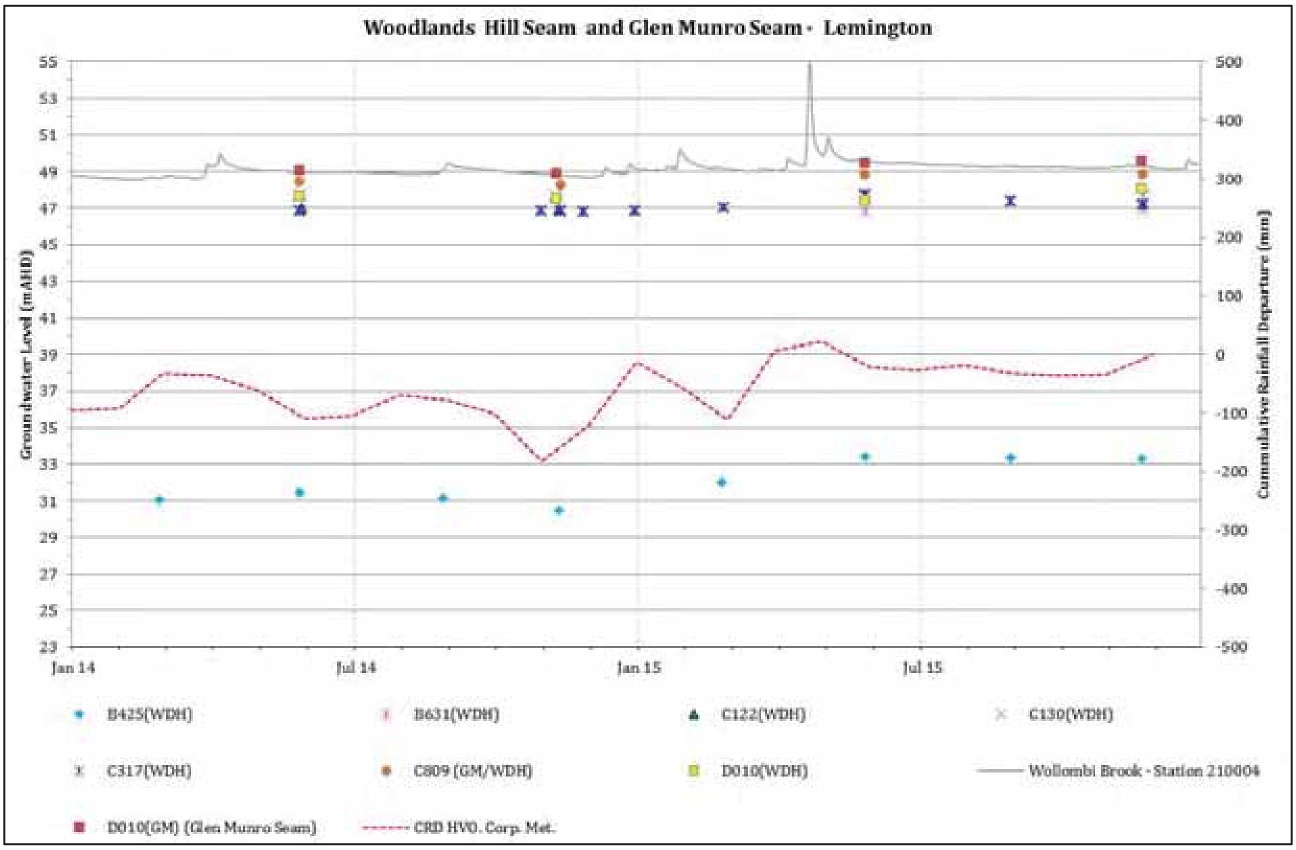


Figure 17 Lemington Pit – Woodlands Hill and Glen Munro seams - Hydrograph

5.3.3 Arrowfield Seam (AFS)

The groundwater levels in four bores constructed to the Arrowfield Seam were recorded in May 2014 to November 2015. The hydrographs for the Arrowfield Seam bores including the 2014 to 2015 data are shown in Figure 18 and Appendix D.

Groundwater level in the bores D510(AFS) and D406(AFS) show very slight variation, with rising levels in November 2015. The bores C130(AFS1) and D612(AFS) recorded continuous rising groundwater levels since 2014.

The recovery of groundwater levels in all four Arrowfield bores is likely related to the returning to natural state post-mining of underground mines adjacent to this area.

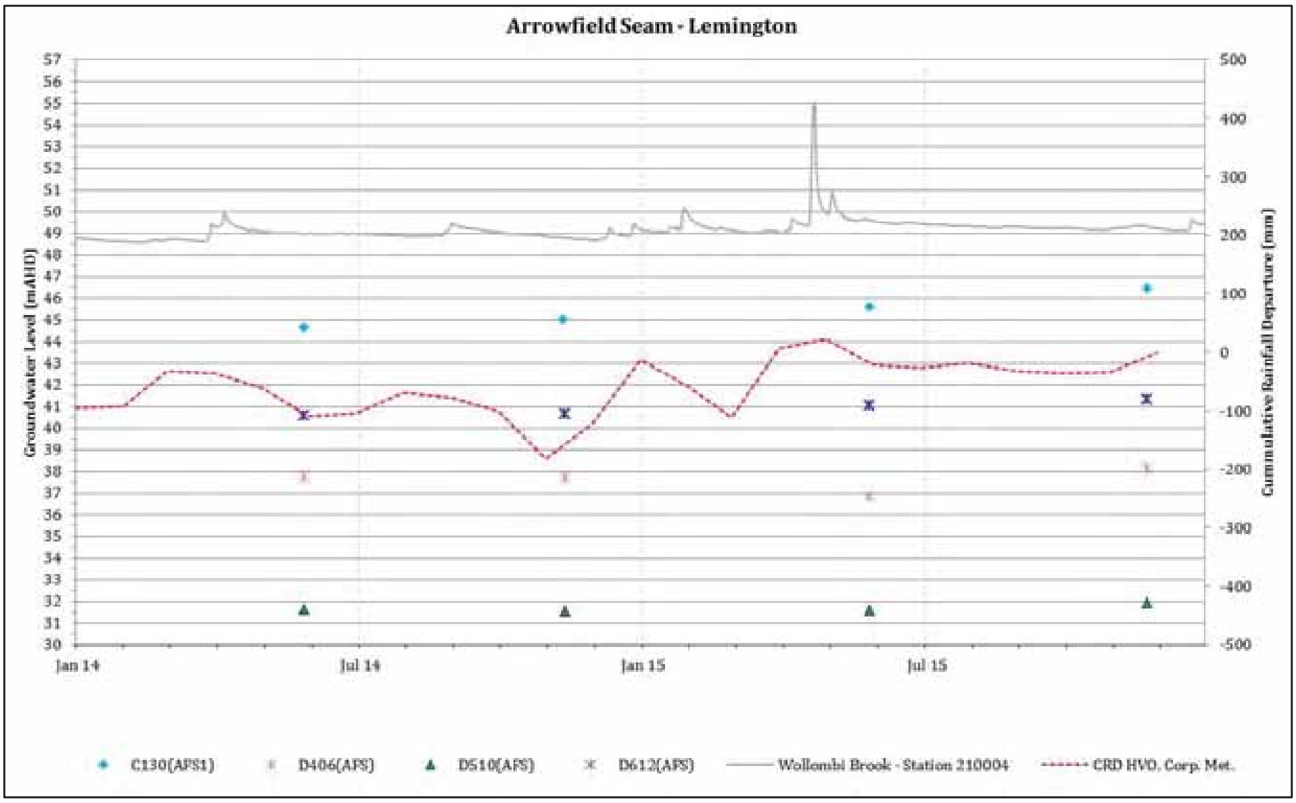


Figure 18 Lemington Pit – Arrowfield seam - Hydrograph

5.3.4 Bowfield Seam (BFS)

The groundwater levels in 16 bores screened in the Bowfield Seam, with eight located north of Wollombi Brook and eight to the south, were recorded in quarterly or six-monthly during the review period. The hydrographs for the Bowfield Seam bores including the 2014-2015 data are shown in Figure 19, Figure 20 and Appendix D.

Groundwater level contours for November 2015 (Appendix E) indicate that groundwater in the vicinity of Lemington South Pit 1 within the Bowfield Seam flows away from the pit, in a general south-westerly direction. West of Wollombi Brook, groundwater within the Bowfield Seam flows mostly toward the north-west.

South of the Pit Void, groundwater levels in the Bowfield Seam record similar fluctuation for all monitoring bores, which coincides with rainfall (CRD). The groundwater level variation recorded in bore B631(BFS) is slightly less than the other bores.

A slight groundwater rise and subsequent fall were observed in north of the pit void which coincides with rainfall (CRD). Groundwater elevation was stable in 2014 and rose in early 2015. Water levels in the void were generally high compared to previous years. The groundwater rise in 2015 is most probably related to the rainfall recharge due to higher than average rainfall, which concided with a higher CRD curve in 2015. Discussion of the impacts (if any) of water abstraction from the LUG Bore are given in Section 7.

Also, there is a noticable step in the data logger data B925. The most likely cause of this step is a logger correction error at the time of download.

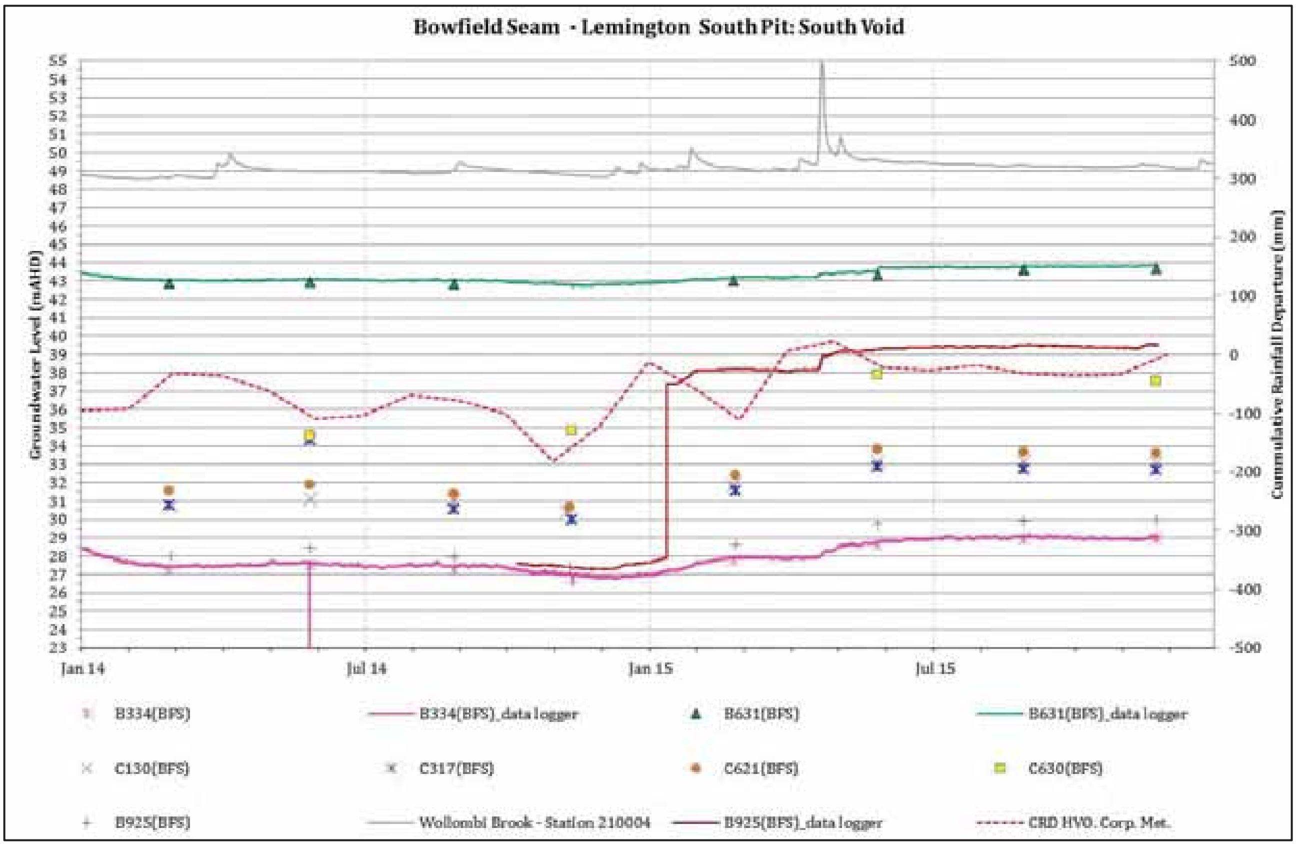


Figure 19 Lemington Pit – Bowfield seam (South) - Hydrograph

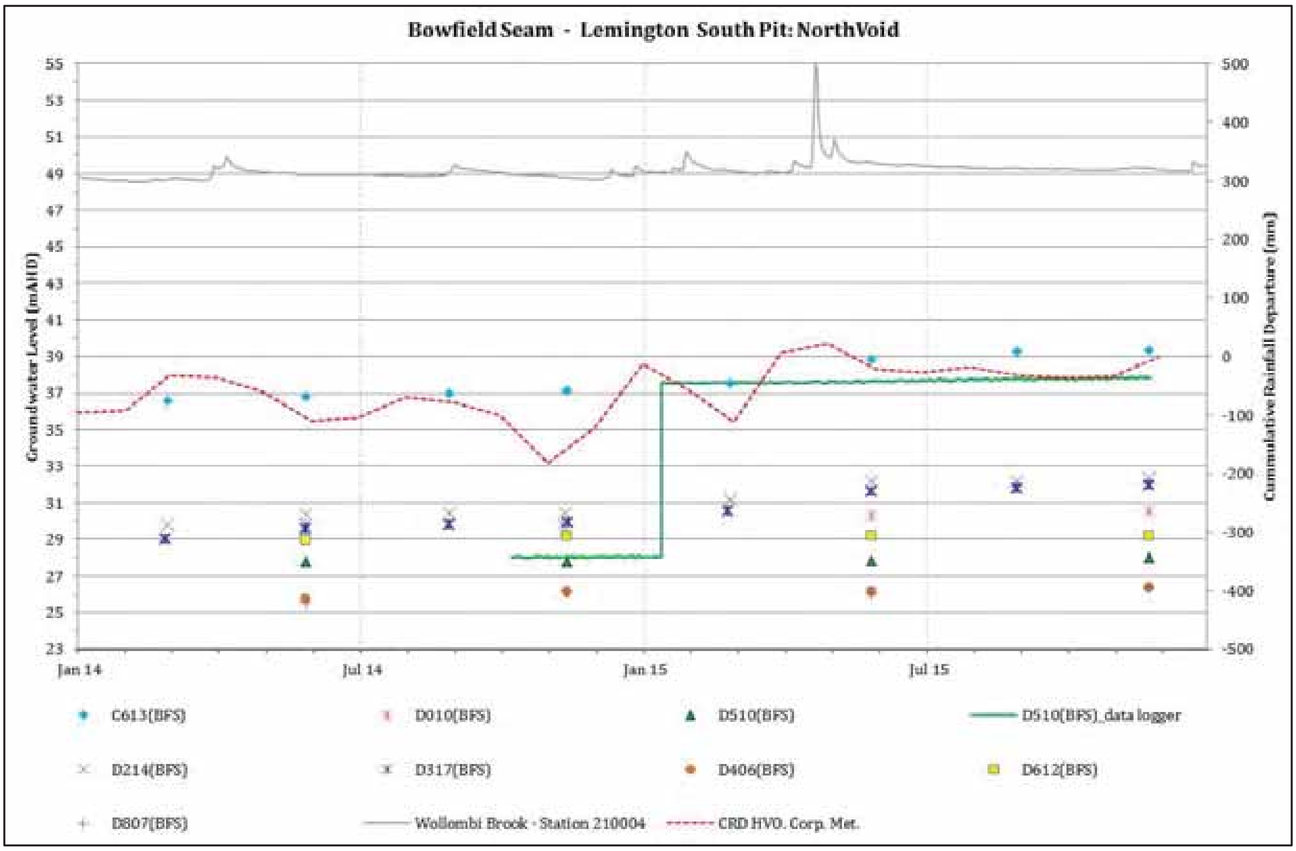


Figure 20 Lemington Pit – Bowfield seam (North) - Hydrograph

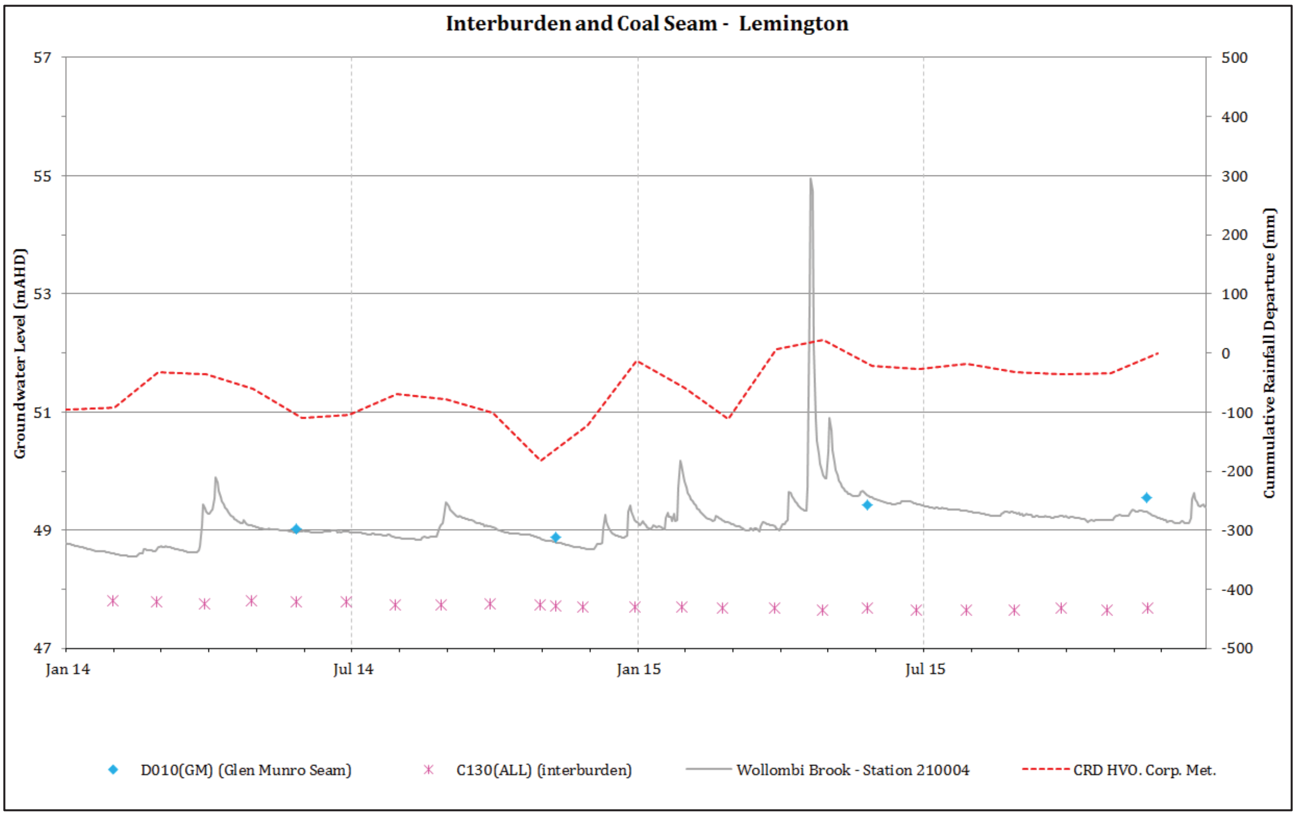


Figure 21 Lemington Pit – Interburden and Coal seam - Hydrograph

6 Analytical modelling of flow loss from alluvial groundwater

The following section details the estimated loss of alluvial groundwater due to mining operations at HVO South. Groundwater leakage from coal seams into the mine pits (Q_{XY}), and vertical leakage of alluvial groundwater into the underlying Permian coal measures (Q_Z), were calculated by applying Darcy's Law (*Equation 1*). Several assumptions were made in order to calculate flow loss, which are detailed in Appendix F. Flow loss calculation results are shown and discussed in further calculation details presented in Appendix G.

Darcy's Law

$$Q = KiA \qquad (Equation\ 1)$$

where:

Q	is the amount of water discharged (m^3/day)
K	is the hydraulic conductivity (m/day)
i	is the hydraulic gradient (dimensionless)
A	is the area (e.g. exposed coal seam) (m^2)

6.1 Horizontal discharge (Q_{xy})

Leakage of groundwater from the target coal seams, namely Mt Arthur (MTA) and Bowfield Seams (BFS) into the pits (Q_{xy}) has been calculated using Darcy's Law (see Appendix F for the assumptions applied and Appendix G for the calculations) with the results shown in Table 5. The results indicate that approximately 0.13 ML/day of groundwater from the BFS enters the Lemington South Pit 1. The results also indicate that groundwater inflow from the MTA enters the pits at a rate of between 0.9 ML/day to 2.1 ML/day for the whole Cheshunt Pit area (including Cheshunt anticline). The highest inflows are predicted to occur at the anticline structure observed on the northern highwall of Cheshunt Pit, with predicted seepage rates of between 0.41 ML/day to 1.63 ML/day. These estimates are based on field observations of structural features on the highwall (JP Environmental 2013), and pump rate estimates by JP Environmental in 2011. Further testing and investigation of the hydraulic properties at the anticline structure and observations of pit water inflows and pumping rates are recommended to improve data confidence.

Detailed groundwater models have been undertaken at HVO South by MER (2005), ERM (2008) and NTEC (2009). Modelled leakage estimates for Cheshunt Pit range between 0.22 ML/day/km (MER, 2005 and NTEC, 2010) and 2.2 ML/day (ERM, 2008). Leakage into Lemington South Pit 1 (North Void) is modelled to reach between 0.08 ML/day (NTEC, 2009) and 0.8 ML/day (ERM, 2008). The calculated estimates of groundwater leakage show a good agreement with previously modelled leakage estimates reported by MER (2005), ERM (2008) and NTEC (2009).

6.2 Vertical discharge (Qz)

The vertical leakage of water from the alluvium into the underlying coal measures (Q_Z) was calculated and the results are summarised in Table 6. The results indicate a combined alluvial groundwater loss of approximately 2.36 ML/day for the Cheshunt Pit area (Money Box Pit, Cheshunt Pit and Cheshunt Pit anticline) and an estimated groundwater loss of approximately 0.01 ML/day for Lemington South Pit. The largest loss of alluvial groundwater relates to the Cheshunt Pit anticline, with a predicted loss of around 1.96 ML/day. Estimates for Cheshunt Pit are considered conservative, with the Kz value used based on coal seam parameters in Rust PPK (1997), in order to account for potential sub-cropping of the Mount Arthur Seam beneath the alluvium.

The vertical leakage rates (Q_Z) defining the downward flow of groundwater from the alluvium to the coal seams were divided by the rate of groundwater leakage from target coal seams into the pits (Q_{XY}). The results (% Q_Z/Q_{XY}) indicate that:

- approximately 8% of groundwater seepage is likely to be sourced from the alluvium at Cheshunt North;
- approximately 99% of groundwater seepage is likely to be sourced from the alluvium at Cheshunt Pit;
- approximately 99% of water discharging from the anticline structure at Cheshunt Pit is likely to be sourced from alluvial groundwater; and
- approximately 7% of groundwater seepage is likely to be sourced from the alluvium at Lemington South Pit.

Real time river flow data and Hunter Integrated Telemetry System (HITS) data collected by NOW indicates that baseflow for the Hunter River is 151 ML/day at Station 210083 (approximately 12 km upstream of Cheshunt Pit). The time weighted discharge rate duration curve, which is based on historical streamflow data since 1970, shows that the Hunter River flows at a rate of around 150 ML/day, approximately 75 % of the time, and flows at a rate of around 60 ML/day, approximately 95% of the time. The total leakage of alluvial groundwater (Q_Z) into the coal seams for Money Box Pit and Cheshunt Pit is estimated at approximately 2.36 ML/day and would equate to an approximate flow loss of 1.6% to 3.9% from the Hunter River adjacent to these pits.

NOW data from Wollombi Brook at Station 210004 (approximately 1 km upstream of Lemington South Pit 1) shows that the flow rate is approximately 4 ML/day, 75 % of the time, no flow occurs at the 95^{th} percentile. The total leakage of alluvial groundwater (Q_Z) from the Lemington South Pit 1 – North Void is estimated at 0.01 ML/day, and indicates an approximate stream flow loss of 0.3% from Wollombi Brook.

It is anticipated that the 1.6% and 0.3% flow loss, based on the 75th percentile, is a more realistic estimate, as the reduction in flow will correspondingly reduce the hydraulic gradient and rate of recharge into the surrounding aquifers. These flow loss estimates are considered conservative due to the assumptions made in the calculations (i.e. high K_Z for Cheshunt and Money Box Pits).

In addition, the loss from the Hunter River is potentially lower than calculated. Seepage into the Money Box Pit anticline structure is still a possibility, with recharge being primarily from spoil in mined-out pits located north of the Hunter River. In addition, the river flow loss calculations assume that all alluvial groundwater is sourced from the Hunter River or Wollombi Brook; however, groundwater level hydrographs suggest some recharge to the alluvial aquifers is sourced from rainfall.

The leakage values calculatd above are well beneath those as documented in the Hunter Valley Operations South Coal Project Environmental Assessment Report (ERM, 2008), suggesting a maximum predicted seepage volume of 7.3 ML/day.

Table 5 Estimated leakage of groundwater from coal seams into pits

Lithology	Location	Flow Direction	Horizontal Hydraulic Conductivity (MER,2010) K_{XY}-(m/d)	Horizontal Hydraulic Gradient (i_{XY})	Pit Wall Length (m)	Coal Seam Thickness (m)	Horizontal Discharge from Coal Seams to Pit Q_{XY} (L/s)	Horizontal Discharge from Coal Seams to Pit Q_{XY} (ML/d)	Percentage of Pit Inflow from Alluvium Q_Z/Q_{XY} (%)
Mt Arthur	Cheshunt - Money Box Pit	Horizontal	0.05	0.43	650	10	1.6	0.14	94%
Mt Arthur	Cheshunt Pit Anticline	Horizontal	2.3 - 9.1	0.45	10	40	4.8 - 18.9	0.41 - 1.63	~99%
Mt Arthur	Cheshunt Pit	Horizontal	0.05	0.31	1010	10	1.8	0.16	~99%
Mt Arthur	Cheshunt - Northern Area	Horizontal	0.05	0.27	1100	10	1.7	0.15	8%
						Cheshunt Area Total	**9.9-24.0**	**0.9-2.1**	-
Bowfield	Lemington South Pit 1	Horizontal	0.05	1.03	350	7	1.5	0.13	7%

Notes:
K_{xy} *Derived from NTEC (2010) and Rust PPK (1997) (m/day)*
i_{xy} *Horizontal hydraulic gradient*
Q_{xy} *Volume of groundwater discharging into mine pit*

Table 6 Estimated leakage of alluvial groundwater into coal seams

Lithology	Location	Flow Direction	Vertical Hydraulic Conductivity of PCM Layer 2 in MER (March 2010) K_Z (m/d)	Vertical Hydraulic Gradient (i_z)	Pit Wall Length (m)	Width of Alluvium (m)	Vertical Discharge from alluvium to coal seams Q_Z (L/s)	Vertical discharge from alluvium to coal seams Q_Z (ML/d)
Mt Arthur	Cheshunt - Money Box Pit	Vertical	0.001	0.81	650	250	1.5	0.1
Mt Arthur	Cheshunt Pit Anticline	Vertical	1	0.79	10	250	22.7	2.0
Mt Arthur	Cheshunt Pit – Southern Area	Vertical	0.001	0.98	1010	250	2.9	0.2
Mt Arthur	Cheshunt Pit – Northern Area	Vertical	0.0001	0.44	1100	250	0.1	0.0
						Cheshunt Area Total	**27.3**	**2.4**
Bowfield	Lemington South Pit 1	Vertical	0.0001	0.67	350	360	0.1	0.0

Notes: *Kz* *Derived from Rust PPK Pty Ltd (1997) Groundwater and Mine Water Management Study, South Lemington Mine (m/day)*

iz *Vertical hydraulic gradient*

Qz *Is the amount of water discharged (L/s)*

7 Lemington Underground (LUG) bore compliance

Lemington Underground (LUG) bore licence (20BL173392) was granted on 23rd September 2013 and is intended to regulate the abstraction of up to 1,800 ML/annum between 1 July and 30 June. The LUG bore abstracts water from the abandoned LUG mine void to supply water to both Hunter Valley Operations (HVO) and Mount Thorley Warkworth (MTW) mine sites (Rio Tinto, 2014). The following sections address the key criteria / licence conditions for LUG Bore licence 20BL173392, not covered in the other report sections.

7.1 Abstraction data

Table 7 shows the groundwater abstraction data for the licence reporting period (July 2014 to June 2015). There has been no abstraction from the bore since the 9 October 2014. The total abstraction for the previous licence reporting period (14/15) was 122.7 ML, which is less than 7% of the annual allocation.

Table 7 Summary Groundwater Abstraction Data

Month / Year	Groundwater Extracted (ML)
July 2014	7.6
August 2014	46.6
September 2014	42.7
October 2014	25.8
November 2014	0
December 2014	0
January 2015	0
February 2015	0
March 2015	0
April 2015	0
May 2015	0
June 2015	0
Total	**122.7**

7.2 LUG Bore monitoring data

Table H 1 (Appendix H) summarises details of the LUG bore monitoring network. This network monitors LUG bore abstraction impacts (if any) upon alluvium and coal seam aquifers. Groundwater level data from the monitoring network was used to create groundwater hydrographs in Appendix F, and to assess potential abstraction induced drawdown in the alluvium and coal seam aquifers near the LUG bore.

7.2.1 Alluvial Groundwater level near LUG Bore

Over 2014 and 2015, the LUG bore licence reporting period, groundwater levels in alluvial bores PB01(ALL), C919(ALL) and Appleyard Farm have similar fluctuation than the Wollombi Brook water level. After ceasing extraction from the LUG bore on 9 October, the groundwater level does not appear to rise or show a sign of recovery.

As previously mentioned, alluvial groundwater levels appear to be correlated with changes in stream level and rainfall. There are no impacts observed from the extraction of LUG bore.

7.2.2 Coal Seam groundwater levels near LUG Bore

The following findings can be observed from the data collected over the 2014/2015 LUG bore licence reporting period:

- Groundwater levels within the Woodlands Hill Seam and Glen Munro Seam bores seem relatively stable during 2014 and are seen to rise after January 2015. This variation observed in the groundwater level appears to correlate with the CRD (rainfall) rather the water extraction from LUG bore. In addition, it is likely that there is recharge to these shallow seams from rainfall. There is no observation of groundwater level rising after cessation of pumping from the LUG bore on 9 October 2014. This data suggests that the groundwater level within these shallow seams is not impacted by groundwater abstraction from the LUG Bore.
- Groundwater levels within D510 (AFS) and D406 (AFS) in the Arrowfield Seam were stable during 2014 and rose slightly in 2015. Water level within C130 (AFS1) and D612 (AFS) have increased constantly since 2014. During 2015, groundwater level rose in all monitoring bores; however, there is no visible recovery observed within the groundwater level after cessation of pumping from the LUG bore due to the resolution of the monitoring data. The groundwater level increase may be a combination of above average rainfall as shown by the CRD curve and recovery of the water level in the Arrowfield seam.
- On both sides of the Wollombi Brook, groundwater levels within Bowfield seam rose in early 2015. Groundwater level seems correlated with the CRD curve and the higher elevation in early 2015 may also be affected by changes in water level in the void, which is used for the storage of excess mine water.

7.3 Summary and recommendations

Based on available data, LUG Bore (20BL173392) complies with licence conditions and there may be a slight recovery of water levels in the Arrowfield and Bowfield seams, post interruption of pumping from the LUG bore. Rainfall recharge and use of the void for water storage likely also have an impact on LUG bore water levels.

Given the above, ongoing monitoring of the LUG Bore monitoring network bores is recommended to assess long term impacts (if any) of decommissioning of the LUG Bore. Furthermore, the use of additional dataloggers should be considered to provide better resolution of the groundwater level trends.

8 Conclusions

The following conclusions for the HVO South area are drawn from the data presented in the previous sections. No exceedence outside the triggers values were observed for EC and pH.

Hunter River Alluvium

- Flow and gradient: groundwater in the Hunter River alluvium flows toward the river. The hydraulic gradient beneath Barry's Flat is low, which is likely related to a high hydraulic conductivity of the alluvium and topography of the land surface.
- The groundwater levels around the northern portion of the Cheshunt area and Lemington South Pit appear to respond to peak flow events at Hunter River and Wollombi Brook gauging stations. Furthermore, groundwater elevation within the alluvium is lower than the Hunter River (WLP3) and Wollombi Brook Station (21004). This indicates that the alluvium may be an area where the river is the predominant source of recharge.

Mt Arthur Seam- Cheshunt / Barry's Pits

- Groundwater within Mount Arthur Seam generally flows toward the south and the actively mined Cheshunt Pit, which is consistent with the 2014 reporting period
- Groundwater levels adjacent to the Cheshunt Pit on the west side and the northern portion of the Cheshunt area (BUNC45D) declined during the 2014 and 2015 monitoring period. This decrease is likely due to depressurisation of the Mount Arthur Seam from mining.
- Few Mount Arthur Seam bores between Cheshunt Pit, overlain by alluvium, exhibited stable groundwater levels over 2015.
- The majority of Mount Arthur Seam bores in the northern portion of the Cheshunt area overlain by the alluvium showed a response to peak flow events at Hunter River stream gauging stations. Faulting and displacement of stratigraphy or the subcrop of the coal seams within this region may have resulted in hydraulic connection between the coal measures and the alluvium.
- Higher groundwater elevations in the alluvium compared to the underlying coal seams indicate the potential for downward seepage from the alluvium to the Permian coal seams at each of the pits.

Arrowfield and Bowfield Seam- Lemington

- Groundwater level in Arrowfield Seam adjacent to Lemington South Pit 1 rose between 2014 and 2015.
- Groundwater levels variations within Bowfield Seam are similar to the CRD curve.
- The increased water levels in this area may be due to a combination of above average rainfall as shown by the CRD curve and recovery of the water level in the Arrowfield seam.

Alluvial Groundwater Loss

- Calculation of potential inflows involved several assumptions, as detailed in Appendix F. Darcy's Law calculations indicate that approximately 0.9 ML/day to 2.1 ML/day of groundwater from the Mount Arthur Seam enters Cheshunt Pit area. This volume includes inflows into Cheshunt Pit and the Cheshunt Pit anticline.
- The results from the calculations also indicate that approximately 0.13 ML/day of groundwater from the BFS enters Lemington South Pit 1 - North Void. This volume is similar to that estimated in 2014.

- The inflow calculations suggest the alluvium is the likely groundwater source for approximately 8%, 7% and 99% of groundwater inflows for Cheshunt Pit northern area, Lemington South Pit 1 and Cheshunt Pit (excluding the anticline structure), respectively. The results also show that up to approximately 99% of groundwater inflow at the Cheshunt Pit anticline structure could be alluvium sourced.
- The total leakage of alluvial groundwater into the coal seams for the Cheshunt area is in the order of 2.36 ML/day and would equate to an approximate flow loss of 1.6% from the Hunter River in areas adjacent to the pits (based on assumptions and August 2015 groundwater data). The total leakage of alluvial groundwater to the Lemington South Pit 1 – North Void is 0.01 ML/day and indicates an approximate stream flow loss of 0.3% from Wollombi Brook.
- The source of water inflows into the Cheshunt Pit may be a combination of the Permian coal measures, Hunter River, rainfall and potentially the backfilled North Void (located north of the Hunter River). The identified anticline structure along with other structural features may act as conduits for groundwater flow between HVO North and HVO South mine areas.

LUG Bore monitoring bore data

- LUG bore (20BL173392) complies with the licence condition. The increased water levels in the LUG monitoring network may be due to a combination of above average rainfall as shown by the CRD curve and the storage of excess mine water in the void.

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Appendix A Surface water

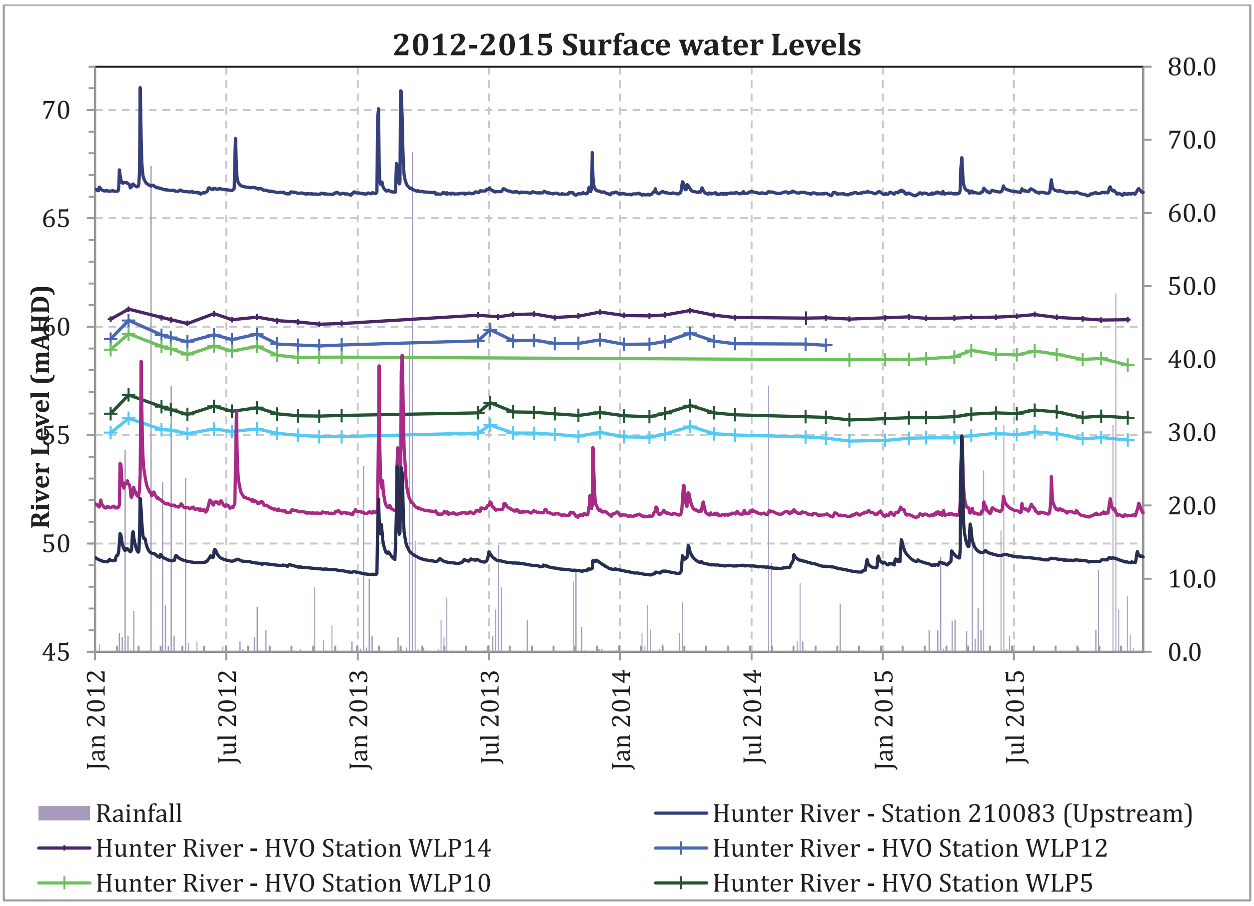


Figure A 1 Hunter River and Wollombi Brook creek levels

Table A 1 2015 HVO Hunter River stream level (mRL) data

Station ID	Easting	Northing	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WLP3	312613	6401505	54.8	54.9	54.9	54.9	55.0	55.1	55.0	55.1	55.1	54.8	54.9	54.8
WLP5	311655	6400647	55.8	55.8	55.8	55.9	56.0	56.0	56.0	56.2	56.1	55.8	55.9	55.8
WLP10	310080	6401634	58.5	58.5	58.5	58.6	58.9	58.7	58.7	58.9	58.7	58.5	58.5	58.2
WLP12	309346	6402294	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
WLP14	308598	6402453	60.4	60.5	60.4	60.4	60.4	60.4	60.5	60.6	60.4	60.4	60.3	60.3

Appendix B Monitoring bore construction details

Bore ID	Type	Status	Easting	Northing	Ground elevation (mAHD)	Collar height (maGL)	Bore depth (mbGL)	Tof of screen (mbGL)	Base of screen (mbGL)	VWP sensor (mAHD)	VWP sensor (mbGL)	Bore diameter (mm)	Lithological description	Location
CHPZ10A	MB	EX	313334	6402297	63.4	0.8	12.6	9.5	12.6	-	-	50	Alluvium	Cheshunt
CHPZ11A	MB	EX	313429	6402129	61.9	1.0	10.6	7.2	10.6	-	-	50	Alluvium	Cheshunt
CHPZ12A	MB	EX	313238	6402013	63.5	0.3	11.5	9.5	11.5	-	-	50	Alluvium	Cheshunt
CHPZ14A	MB	EX	312883	6401639	66.0	0.4	16.0	12.8	16.0	-	-	50	Alluvium	Cheshunt
CHPZ1A	MB	EX	312820	6401697	65.9	1.0	18.7	15.0	18.7	-	-	50	Alluvium	Cheshunt
CHPZ2A	MB	EX	312941	6401539	65.8	0.6	16.9	13.7	16.9	-	-	50	Alluvium	Cheshunt
CHPZ3A	MB	EX	313086	6401756	63.9	0.7	14.5	14.5	11.5	-	-	50	Alluvium	Cheshunt
CHPZ4A	MB	EX	312904	6402123	66.3	0.8	14.2	10.9	14.2	-	-	50	Alluvium	Cheshunt
BUNC45D	MB	EX	313677	6402060	73.8	0.4	30.7	25.9	28.9	-	-	50	Mt Arthur Seam	Cheshunt
CHPZ12D	MB	EX	313236	6402019	63.6	0.3	14.3	12.0	15.0	-	-	50	Mt Arthur Seam	Cheshunt
CHPZ14D	MB	EX	312891	6401639	65.9	0.3	18.8	28.8	25.6	-	-	50	Mt Arthur Seam	Cheshunt
CHPZ3D	MB	EX	313094	6401756	63.7	0.6	16.0	20.5	23.6	-	-	50	Mt Arthur Seam	Cheshunt
CHPZ8D	MB	EX	313508	6402047	61.2	1.1	9.5	6.0	9.5	-	-	50	Mt Arthur Seam	Cheshunt
BUNC45A	MB	EX	313667	6402055	73.3	0.3	21.2	17.3	20.3	-	-	50	Regolith	Cheshunt
CHPZ8A	MB	EX	313503	6402051	60.9	0.8	6.3	4.0	6.0	-	-	50	Regolith, alluvium	Cheshunt
BC1	MB	AU	312421	6401010	66.4	0.3	8.5	-	-	-	-	-	Alluvium	Cheshunt
BZ1-2	MB	AU	311472	6400483	71.8	0.4	-	7.0	10.0	-	-	-	Alluvium	Cheshunt
Hobden's Well	MB	EX	312540	6401093	71.0	0.7	13.9	-	-	-	-	-	Alluvium	Cheshunt
BZ1-1	MB	EX	311472	6400483	71.8	0.4	-	21.0	24.0	-	-	-	Interburden	Cheshunt
BZ3-1	MB	EX	311840	6400640	70.3	0.3	26.2	-	-	-	-	-	Interburden	Cheshunt
BZ8-2	MB	EX	312685	6401010	67.8	-	-	-	-	-	-	-	Interburden	Cheshunt

Bore ID	Type	Status	Easting	Northing	Ground elevation (mAHD)	Collar height (maGL)	Bore depth (mbGL)	Tof of screen (mbGL)	Base of screen (mbGL)	VWP sensor (mAHD)	VWP sensor (mbGL)	Bore diameter (mm)	Lithological description	Location
HG2	MB	EX	312469	6400886	67.5	0.6	15.5	-	-	-	-	-	Interburden	Cheshunt
BC1a	MB	EX	312421	6400872	66.4	0.3	21.1	-	-	-	-	-	Mt Arthur Seam	Cheshunt
BZ1-3	MB	EX	311472	6400483	71.8	0.4	35.0	-	-	-	-	-	Mt Arthur Seam	Cheshunt
BZ2A(1)	MB	EX	311671	6400561	71.7	0.4	39.0	-	-	-	-	-	Mt Arthur Seam	Cheshunt
BZ3-3	MB	EX	311840	6400640	70.3	0.4	38.0	-	-	-	-	-	Mt Arthur Seam	Cheshunt
BZ4A(2)	MB	EX	312029	6400705	74.4	0.6	41.4	-	-	-	-	-	Mt Arthur Seam	Cheshunt
HG2A	MB	EX	312469	6400886	67.5	0.6	27.8	-	-	-	-	-	Mt Arthur Seam	Cheshunt
Appleyard Farm	MB	EX	315491	6394639	43.4	0.8	10.0	7.0	10.0	-	-	-	Alluvium	Lemington
C919(ALL)	MB	EX	315192	6395655	58.0	0.3	11.5	-	-	-	-	-	Alluvium	Lemington
D317(ALL)	MB	EX	315044	6396018	59.5	0.3	14.7	9.2	12.2	-	-	-	Alluvium	Lemington
PB01(ALL)	MB	EX	314754	6396026	55.0	-	-	-	-	-	-	-	Alluvium	Lemington
C130(AFS1)	MB	EX	316400	6394916	63.0	0.3	42.2	-	-	-	-	-	Arrowfield Seam	Lemington
D406(AFS)	MB	EX	313931	6396074	57.0	0.3	-	-	-	-	-	-	Arrowfield Seam	Lemington
D510(AFS)	MB	EX	314380	6396141	54.8	0.3	30.5	25.5	30.5	-	-	-	Arrowfield Seam	Lemington
D612(AFS)	MB	EX	314524	6396314	62.0	0.4	0.0	-	-	-	-	-	Arrowfield Seam	Lemington
B334(BFS)	MB	EX	316684	6394088	73.0	0.3	51.8	58.5	-	-	-	-	Bowfield Seam	Lemington
B631(BFS)	MB	EX	316425	6394319	72.0	0.3	36.1	78.0	-	-	-	-	Bowfield Seam	Lemington
B925(BFS)	MB	EX	315921	6394604	65.0	0.4	41.2	81.0	-	-	-	-	Bowfield Seam	Lemington
C122(BFS)	MB	EX	315501	6395007	58.0	-	-	-	-	-	-	-	Bowfield Seam	Lemington

Bore ID	Type	Status	Easting	Northing	Ground elevation (mAHD)	Collar height (maGL)	Bore depth (mbGL)	Tof of screen (mbGL)	Base of screen (mbGL)	VWP sensor (mAHD)	VWP sensor (mbGL)	Bore diameter (mm)	Lithological description	Location
C130(BFS)	MB	EX	316400	6394916	63.0	0.0	64.5	55.0	61.0	-	-	-	Bowfield Seam	Lemington
C317(BFS)	MB	EX	315054	6395007	60.0	0.4	76.2	-	-	-	-	-	Bowfield Seam	Lemington
C613(BFS)	MB	EX	314688	6395243	63.0	0.3	85.5	-	-	-	-	-	Bowfield Seam	Lemington
C621(BFS)	MB	EX	315421	6395321	58.0	0.3	57.5	-	-	-	-	-	Bowfield Seam	Lemington
C630(BFS)	MB	EX	316378	6395306	69.0	0.3	49.1	-	-	-	-	-	Bowfield Seam	Lemington
D010(BFS)	MB	EX	314355	6395687	56.0	0.4	68.1	-	-	-	-	-	Bowfield Seam	Lemington
D214(BFS)	MB	EX	314768	6395831	56.5	0.3	53.5	43.0	52.5	-	-	-	Bowfield Seam	Lemington
D317(BFS)	MB	EX	315043	6396019	59.5	0.3	44.0	39.0	44.2	-	-	-	Bowfield Seam	Lemington
D406(BFS)	MB	EX	313931	6396074	57.0	0.3	61.3	-	-	-	-	-	Bowfield Seam	Lemington
D510(BFS)	MB	EX	314380	6396141	54.8	0.3	38.0	34.0	38.0	-	-	-	Bowfield Seam	Lemington
D612(BFS)	MB	EX	314524	6396314	62.0	0.3	35.1	-	-	-	-	-	Bowfield Seam	Lemington
D807(BFS)	MB	EX	314002	6396484	59.7	0.4	41.0	36.0	41.0	-	-	-	Bowfield Seam	Lemington
D010(GM)	MB	EX	314355	6395687	56.0	-	-	-	-	-	-	-	Glen Munro Seam	Lemington
C130(ALL)	MB	EX	316400	6394916	63.0	0.3	17.0	-	-	-	-	-	Interburden?	Lemington
C1(WJ039)	MB	EX	317142	6400707	71.2	-	-	-	-	-	-	-	Piercefield Seam	Lemington
GW9701	MB	EX	315901	6401798	93.6	-	-	-	-	-	-	-	Piercefield Seam	Lemington
GW9702	MB	EX	316436	6401479	98.6	-	-	-	-	-	-	-	Piercefield Seam	Lemington
GW9710	MB	EX	316700	6400486	82.6	-	-	-	-	-	-	-	Piercefield Seam	Lemington
F1.5(WF533)	MB	EX	316607	6398247	54.9	-	-	-	-	-	-	-	Vaux Seam	Lemington

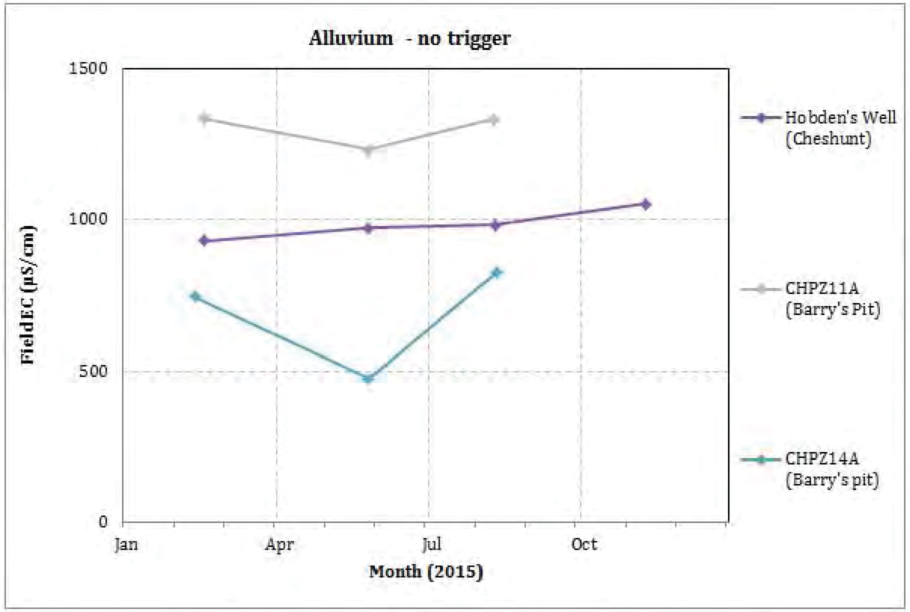
Bore ID	Type	Status	Easting	Northing	Ground elevation (mAHD)	Collar height (maGL)	Bore depth (mbGL)	Tof of screen (mbGL)	Base of screen (mbGL)	VWP sensor (mAHD)	VWP sensor (mbGL)	Bore diameter (mm)	Lithological description	Location
B425(WDH)	MB	EX	316010	6395024	58.0	-	55.0	-	-	-	-	-	Woodlands Hill Seam	Lemington
B631(WDH)	MB	EX	316424	6394319	72.0	-	30.7	-	-	-	-	-	Woodlands Hill Seam	Lemington
C122(WDH)	MB	EX	315501	6395007	58.0	0.3	22.7	-	-	-	-	-	Woodlands Hill Seam	Lemington
C130(WDH)	MB	EX	316400	6394916	63.0	0.4	21.6	-	-	-	-	-	Woodlands Hill Seam	Lemington
C317(WDH)	MB	EX	315054	6395007	60.0	0.2	33.9	-	-	-	-	-	Woodlands Hill Seam	Lemington
C809 (GM/WDH)	MB	EX	314207	6395493	59.0	0.3	28.7	28.0	38.0	-	-	-	Woodlands Hill Seam	Lemington
D010(WDH)	MB	EX	314355	6395687	56.0	0.3	17.0	-	-	-	-	-	Woodlands Hill Seam	Lemington

Appendix C **Groundwater quality**

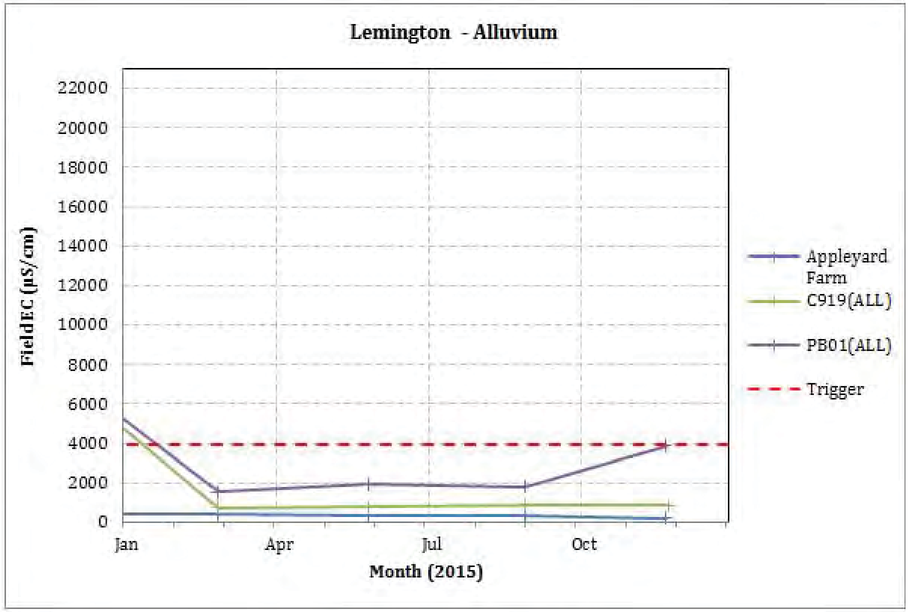
2015 Groundwater Field EC (µS/cm)															
Bore ID	Target lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trigger 95th %ile
CHPZ10A	Alluvium	Cheshunt		729			453			679			579		7440
CHPZ11A	Alluvium	Cheshunt		1334			1233			1332					n/a
CHPZ12A	Alluvium	Cheshunt		764			696			742			785		7440
CHPZ14A	Alluvium	Cheshunt		746			475			826					n/a
CHPZ1A	Alluvium	Cheshunt		793			546			813			571		7440
CHPZ2A	Alluvium	Cheshunt		807			669			831			632		7440
CHPZ3A	Alluvium	Cheshunt		671			417			657			449		7440
CHPZ4A	Alluvium	Cheshunt		798			847			779			694		7440
BUNC45D	Mt Arthur Seam	Cheshunt		2440			2520			2430			2700		2580
CHPZ12D	Mt Arthur Seam	Cheshunt		1290			1321			1300			1381		4566
CHPZ14D	Mt Arthur Seam	Cheshunt		952			939			950					n/a
CHPZ3D	Mt Arthur Seam	Cheshunt		1014			1164			1025			1031		4566
CHPZ8D	Mt Arthur Seam	Cheshunt		1302			1246			1358			747		4566
BUNC45A	Regolith	Cheshunt		1950			2020			1990			2030		7440
CHPZ8A	Regolith, alluvium	Cheshunt					1673			1587			1686		7440
Hobden's Well	Alluvium	Cheshunt		931			973			984			1053		n/a
BZ1-1	Interburden	Cheshunt		7470			6920			6670			6620		7440
BZ3-1	Interburden	Cheshunt		2220			2180			2160			2120		5180
BZ8-2	Interburden	Cheshunt		1253			1323			1420			1383		5180
HG2	Interburden	Cheshunt		5080			5350			5090			5250		5180
BC1a	Mt Arthur Seam	Cheshunt		805			888			858			878		4566
BZ1-3	Mt Arthur Seam	Cheshunt		6900			1370			1488			1418		4566
BZ2A(1)	Mt Arthur Seam	Cheshunt		2410			3280			2170			2350		4566

2015 Groundwater Field EC (µS/cm)															
Bore ID	Target lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trigger 95th %ile
HG2A	Mt Arthur Seam	Cheshunt		1428			1355			1330			1414		n/a
Appleyard Farm	Alluvium	Lemington		388			344			330			213		3965
C919(ALL)	Alluvium	Lemington		760			785			876			860		3965
PB01(ALL)	Alluvium	Lemington		1547			1910			1824			3890		3965
C130(AFS1)	Arrowfield Seam	Lemington					12460						13350		15352
D406(AFS)	Arrowfield Seam	Lemington					10790						11830		15352
D510(AFS)	Arrowfield Seam	Lemington					12900						14600		15352
D612(AFS)	Arrowfield Seam	Lemington					14450						15890		15352
B334(BFS)	Bowfield Seam	Lemington					4870						5110		12377
B631(BFS)	Bowfield Seam	Lemington					11810						13330		12377
B925(BFS)	Bowfield Seam	Lemington					4470						4840		12377
C130(BFS)	Bowfield Seam	Lemington					3600						4020		12377
C317(BFS)	Bowfield Seam	Lemington					8180						8550		12377
C613(BFS)	Bowfield Seam	Lemington					8820						9290		12377
C621(BFS)	Bowfield Seam	Lemington					3110						3310		12377
C630(BFS)	Bowfield Seam	Lemington					2830						3080		12377
D010(BFS)	Bowfield Seam	Lemington					10300						10880		12377
D214(BFS)	Bowfield Seam	Lemington					6920						7500		12377
D317(BFS)	Bowfield Seam	Lemington					2790						3000		12377
D406(BFS)	Bowfield Seam	Lemington					6700						7070		12377
D510(BFS)	Bowfield Seam	Lemington					11940						12960		12377
D612(BFS)	Bowfield Seam	Lemington					10920						11850		12377
D807(BFS)	Bowfield Seam	Lemington					9210						10340		12377

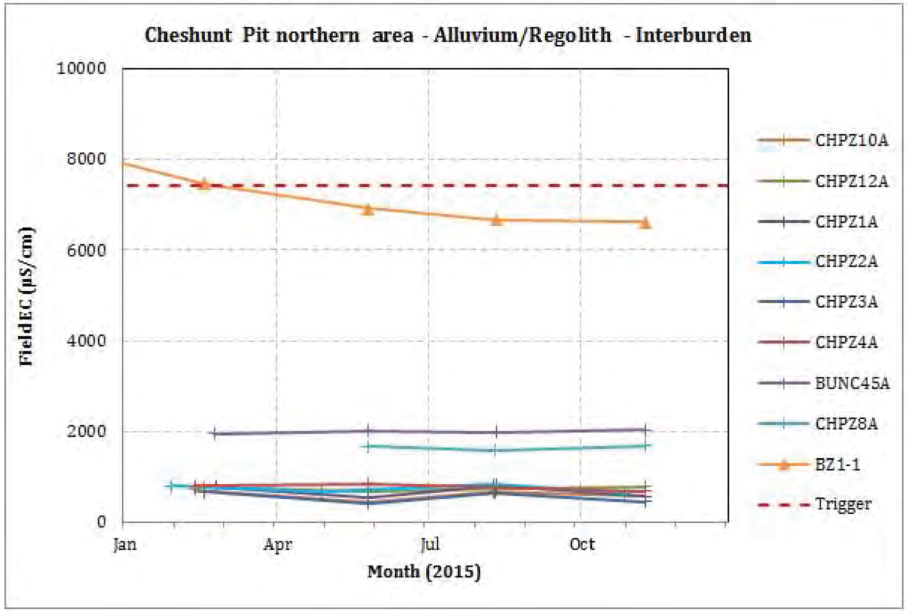
2015 Groundwater Field EC (µS/cm)															
Bore ID	Target lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trigger 95th %ile
LUG Bore	Dewatering Bore	Lemington								8210			8380		n/a
D010(GM)	Glen Munro Seam	Lemington					10140						11590		n/a
C130(ALL)	Interburden?	Lemington		22300			20800			21900			21400		22940
C1(WJ039)	Piercefield Seam	Lemington		7570			7530			7870			8120		n/a
GW9701	Piercefield Seam	Lemington					6370								n/a
GW9702	Piercefield Seam	Lemington					7430								n/a
GW9710	Piercefield Seam	Lemington					13320								n/a
F1.5(WF533)	Vaux Seam	Lemington					3750								n/a
B425(WDH)	Woodlands Hill Seam	Lemington					7660						7540		19778
B631(WDH)	Woodlands Hill Seam	Lemington					10990						12610		19778
C122(WDH)	Woodlands Hill Seam	Lemington					12930						13920		19778
C130(WDH)	Woodlands Hill Seam	Lemington					18940						20900		19778
C317(WDH)	Woodlands Hill Seam	Lemington					8490						9120		19778
C809 (GM/WDH)	Woodlands Hill Seam	Lemington					8820						9590		19778
D010(WDH)	Woodlands Hill Seam	Lemington					8660						9370		19778



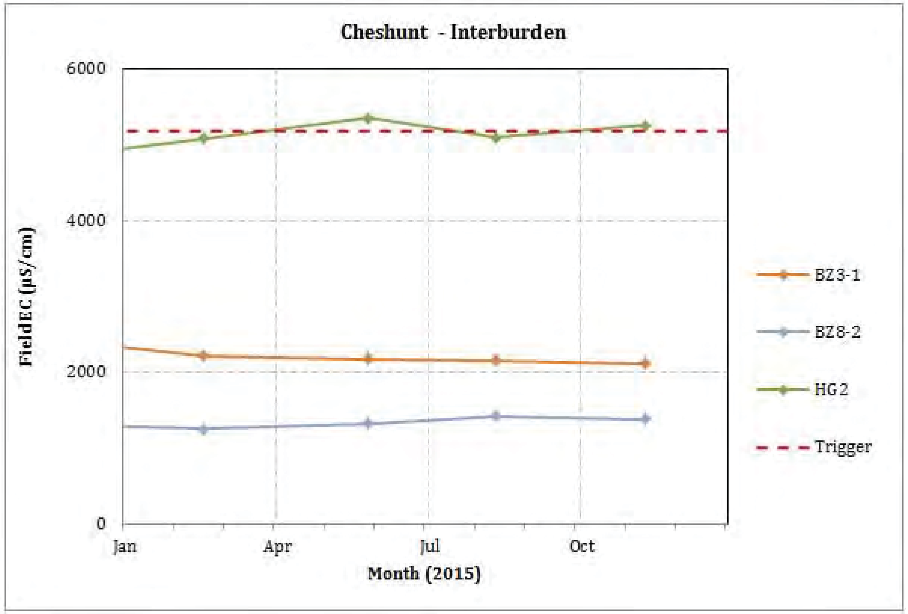
Alluvium - no trigger
1500
1000
500
0
Field EC (µS/cm)
Jan
Apr
Jul
Oct
Month (2015)
Hobden's Well (Cheshunt)
CHPZ11A (Barry's Pit)
CHPZ14A (Barry's pit)



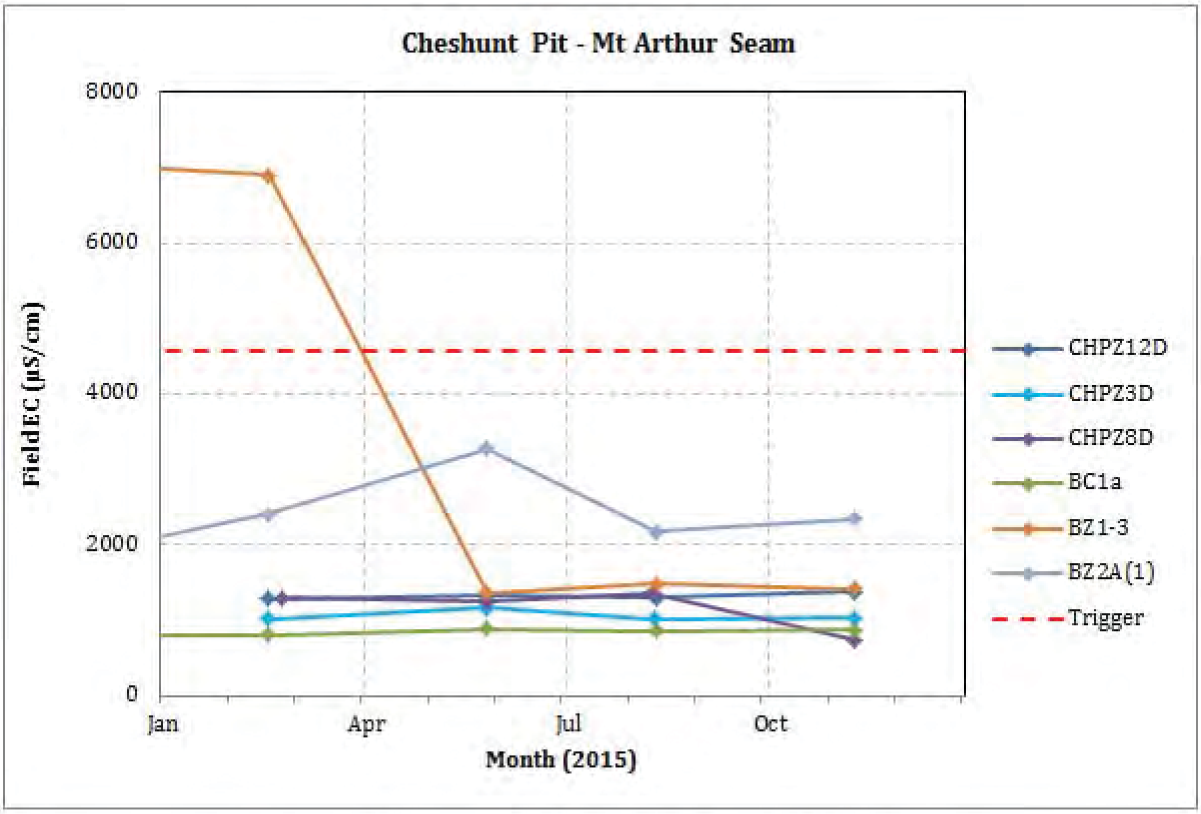
Lemington - Alluvium
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Field EC (µS/cm)
Jan
Apr
Jul
Oct
Month (2015)
Appleyard Farm
C919(ALL)
PB01(ALL)
Trigger



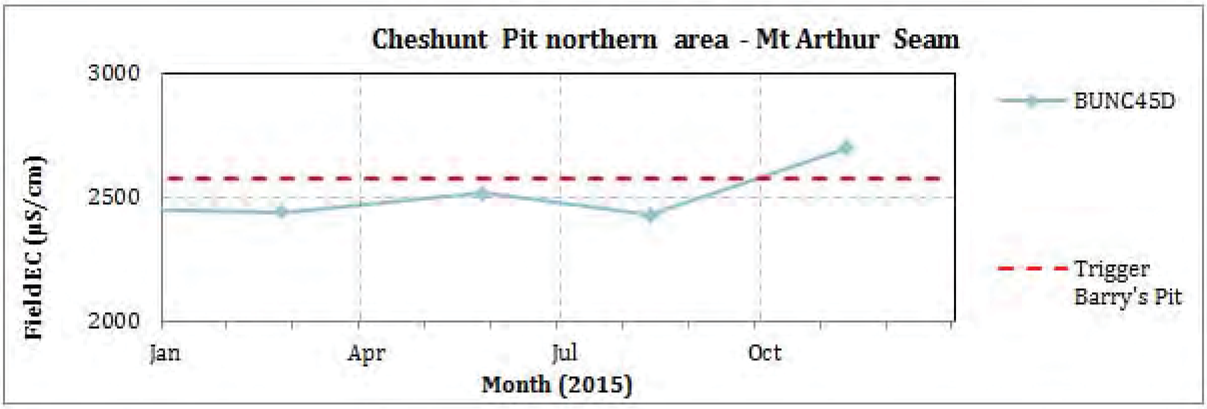
Cheshunt Pit northern area - Alluvium/Regolith - Interburden
10000
8000
6000
4000
2000
0
Field EC (µS/cm)
Jan
Apr
Jul
Oct
Month (2015)
CHPZ10A
CHPZ12A
CHPZ1A
CHPZ2A
CHPZ3A
CHPZ4A
BUNC45A
CHPZ8A
BZ1-1
Trigger



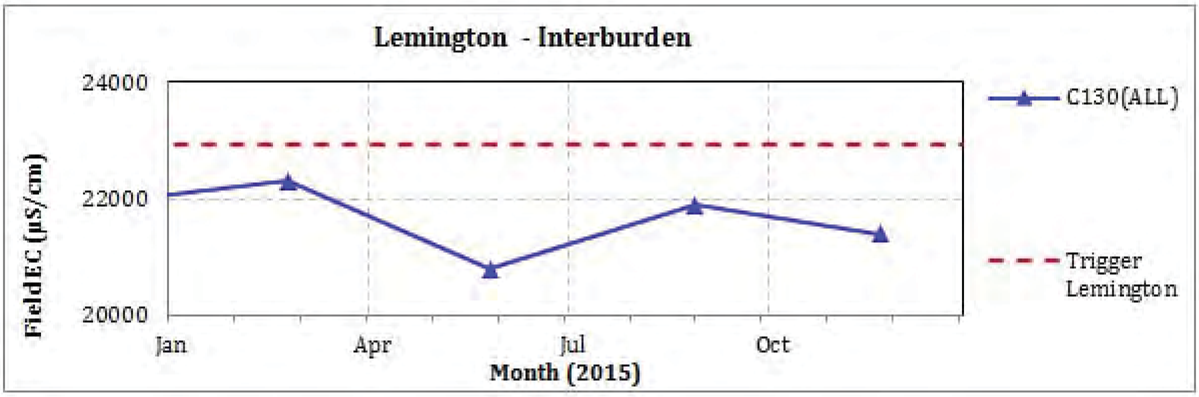
Cheshunt - Interburden
6000
4000
2000
0
Field EC (µS/cm)
Jan
Apr
Jul
Oct
Month (2015)
BZ3-1
BZ8-2
HG2
Trigger



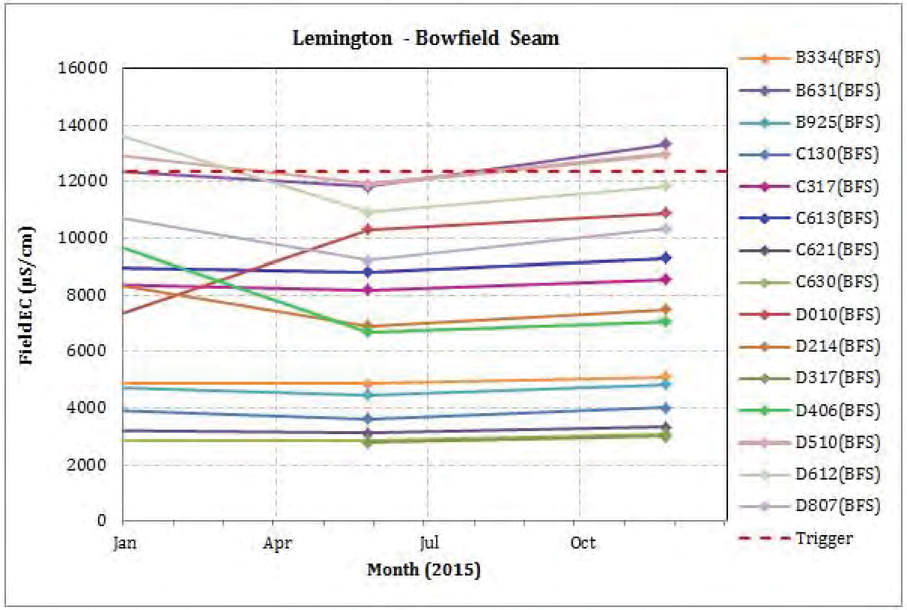
Cheshunt Pit - Mt Arthur Seam
8000
6000
4000
2000
0
Field EC (µS/cm)
Jan
Apr
Jul
Oct
Month (2015)
CHPZ12D
CHPZ3D
CHPZ8D
BC1a
BZ1-3
BZ2A(1)
Trigger



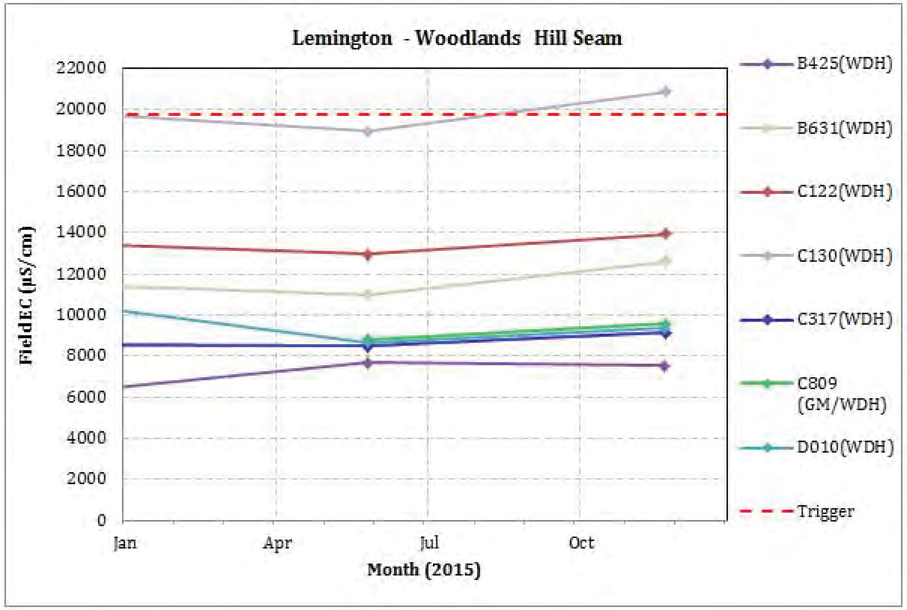
Cheshunt Pit northern area - Mt Arthur Seam
3000
2500
2000
Field EC (µS/cm)
Jan
Apr
Jul
Oct
Month (2015)
BUNC45D
Trigger
Barry's Pit



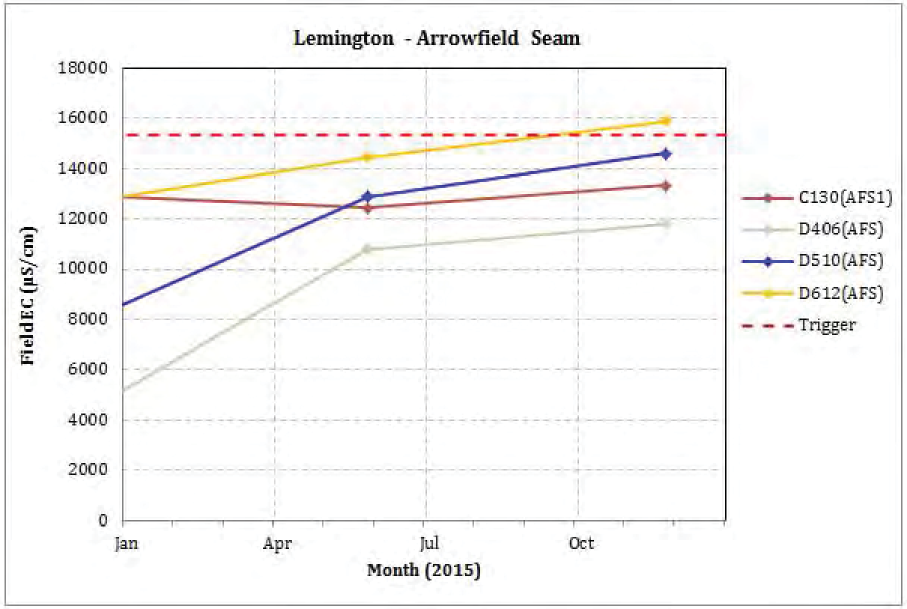
Lemington - Interburden
24000
22000
20000
Field EC (µS/cm)
Jan
Apr
Jul
Oct
Month (2015)
C130(ALL)
Trigger
Lemington



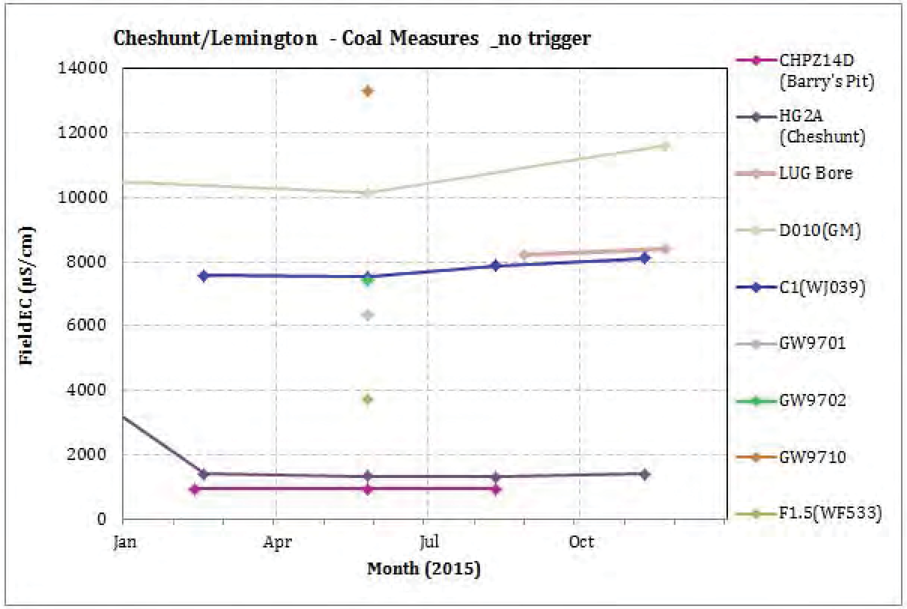
Lemington - Bowfield Seam
FieldEC (µS/cm)
16000
14000
12000
10000
8000
6000
4000
2000
0
Jan
Apr
Jul
Oct
Month (2015)
B334(BFS)
B631(BFS)
B925(BFS)
C130(BFS)
C317(BFS)
C613(BFS)
C621(BFS)
C630(BFS)
D010(BFS)
D214(BFS)
D317(BFS)
D406(BFS)
D510(BFS)
D612(BFS)
D807(BFS)
Trigger



Lemington - Woodlands Hill Seam
FieldEC (µS/cm)
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Jan
Apr
Jul
Oct
Month (2015)
B425(WDH)
B631(WDH)
C122(WDH)
C130(WDH)
C317(WDH)
C809 (GM/WDH)
D010(WDH)
Trigger



Lemington - Arrowfield Seam
FieldEC (µS/cm)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Jan
Apr
Jul
Oct
Month (2015)
C130(AFS1)
D406(AFS)
D510(AFS)
D612(AFS)
Trigger

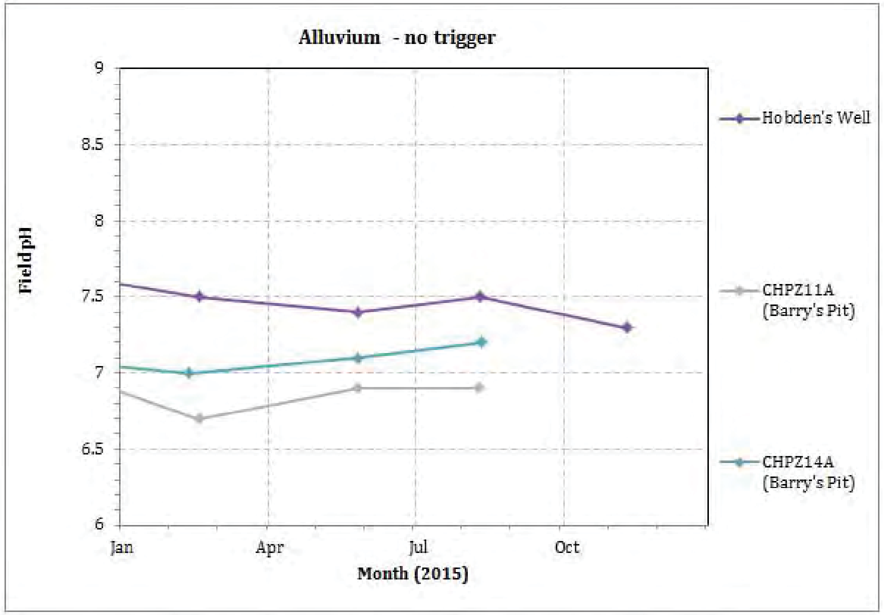


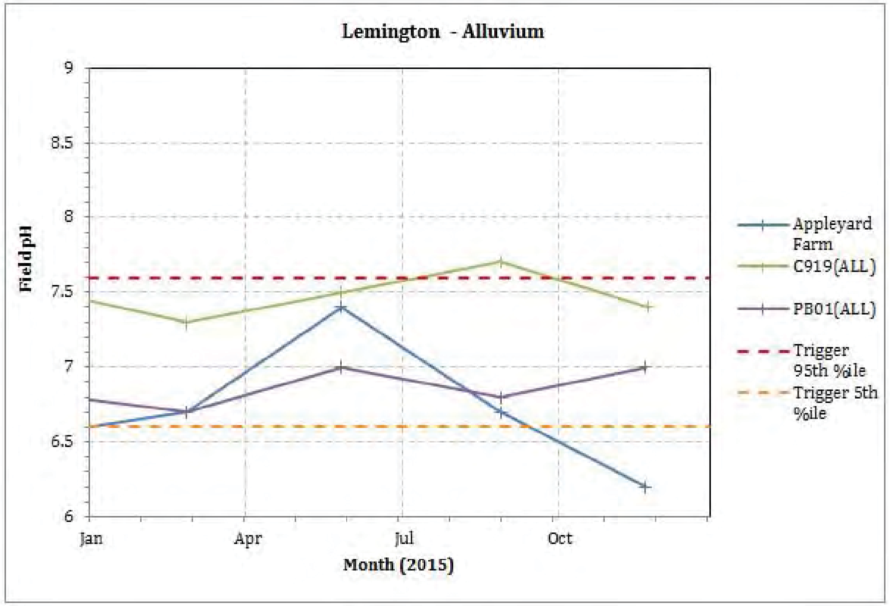
Cheshunt/Lemington - Coal Measures _no trigger
FieldEC (µS/cm)
14000
12000
10000
8000
6000
4000
2000
0
Jan
Apr
Jul
Oct
Month (2015)
CHPZ14D (Barry's Pit)
HG2A (Cheshunt)
LUG Bore
D010(GM)
C1(WJ039)
GW9701
GW9702
GW9710
F1.5(WF533)

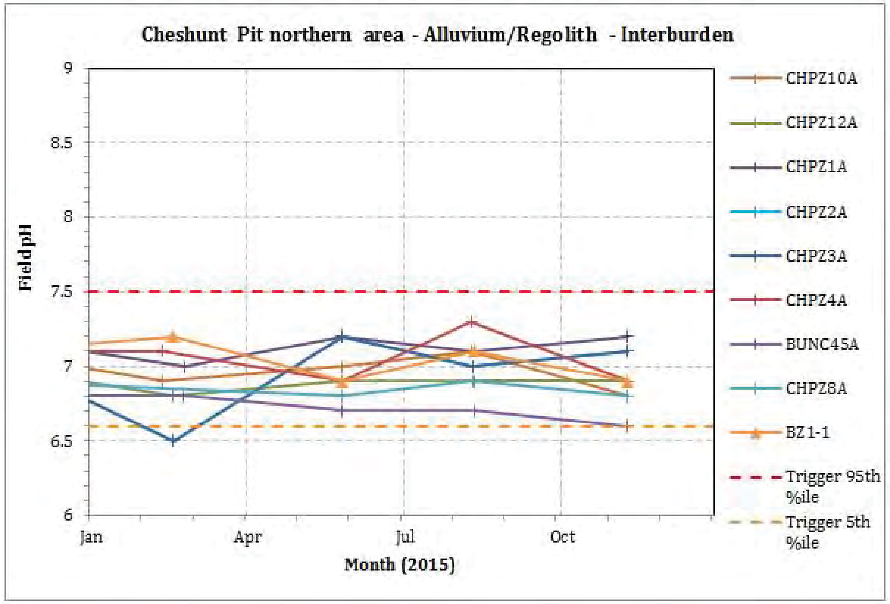
2015 Groundwater Field pH																
Bore ID	Target lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trigger 95th %ile	Trigger 5th %ile
CHPZ10A	Alluvium	Cheshunt		6.9			7			7.1			6.8		7.5	6.6
CHPZ11A	Alluvium	Cheshunt		6.7			6.9			6.9					n/a	n/a
CHPZ12A	Alluvium	Cheshunt		6.8			6.9			6.9			6.9		7.5	6.6
CHPZ14A	Alluvium	Cheshunt		7			7.1			7.2					n/a	n/a
CHPZ1A	Alluvium	Cheshunt		7			7.2			7.1			7.2		7.5	6.6
CHPZ2A	Alluvium	Cheshunt		7.1			7.3			7.2			7.2		7.5	6.6
CHPZ3A	Alluvium	Cheshunt		6.5			7.2			7			7.1		7.5	6.6
CHPZ4A	Alluvium	Cheshunt		7.1			6.9			7.3			6.9		7.5	6.6
BUNC45D	Mt Arthur Seam	Cheshunt		6.6			6.7			6.6			6.5		6.8	6.5
CHPZ12D	Mt Arthur Seam	Cheshunt		6.8			6.9			6.9			7.2		7.6	6.4
CHPZ14D	Mt Arthur Seam	Cheshunt		7.1			7.3			7.3					n/a	n/a
CHPZ3D	Mt Arthur Seam	Cheshunt		6.5			6.8			6.7			6.7		7.6	6.4
CHPZ8D	Mt Arthur Seam	Cheshunt		7.1			6.9			7.3			7.2		7.6	6.4
BUNC45A	Regolith	Cheshunt		6.8			6.7			6.7			6.6		7.5	6.6
CHPZ8A	Regolith, alluvium	Cheshunt					6.8			6.9			6.8		7.5	6.6
Hobden's Well	Alluvium	Cheshunt		7.5			7.4			7.5			7.3		n/a	n/a
BZ1-1	Interburden	Cheshunt		7.2			6.9			7.1			6.9		7.5	6.6
BZ3-1	Interburden	Cheshunt		7.3			7.6			7.6			7.4		7.5	6.9
BZ8-2	Interburden	Cheshunt		7			7			7.1			6.7		7.5	6.9
HG2	Interburden	Cheshunt		7			6.9			7			6.5		7.5	6.9
BC1a	Mt Arthur Seam	Cheshunt		7.1			6.9			7			6.8		7.6	6.4
BZ1-3	Mt Arthur Seam	Cheshunt		6.7			7.1			7.2			7.2		7.6	6.4
BZ2A(1)	Mt Arthur Seam	Cheshunt		6.6			6.6			6.4			6.3		7.6	6.4
HG2A	Mt Arthur Seam	Cheshunt		7.3			7.1			7.1			6.8		n/a	n/a

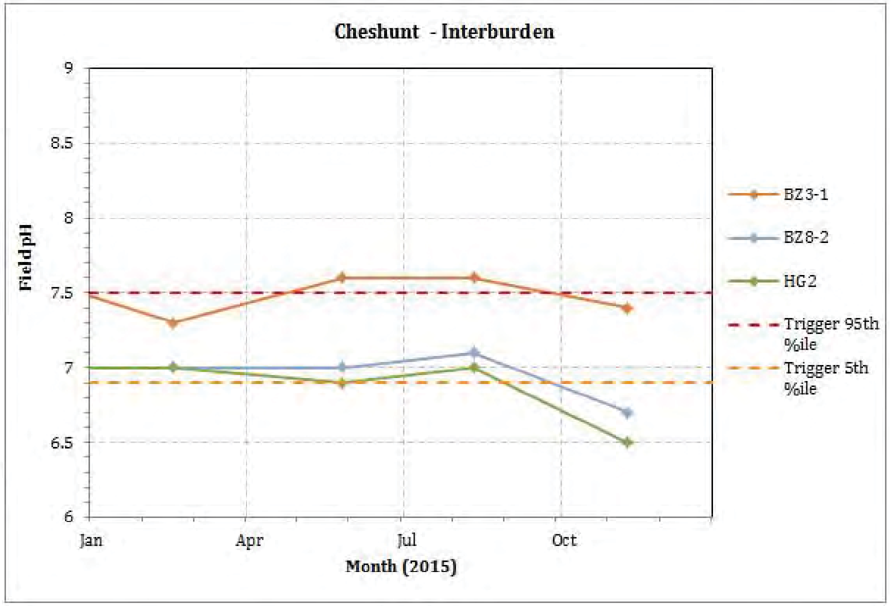
2015 Groundwater Field pH																
Bore ID	Target lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trigger 95th %ile	Trigger 5th %ile
Appleyard Farm	Alluvium	Lemington		6.7			7.4			6.7			6.2		7.6	6.6
C919(ALL)	Alluvium	Lemington		7.3			7.5			7.7					7.6	6.6
PB01(ALL)	Alluvium	Lemington		6.7			7			6.8			7		7.6	6.6
C130(AFS1)	Arrowfield Seam	Lemington					7.4						7.4		7.4	6.8
D406(AFS)	Arrowfield Seam	Lemington					7.1						7		7.4	6.8
D510(AFS)	Arrowfield Seam	Lemington					7.1						7		7.4	6.8
D612(AFS)	Arrowfield Seam	Lemington					6.9						6.8		7.4	6.8
B334(BFS)	Bowfield Seam	Lemington					7.3						7.3		7.8	6.8
B631(BFS)	Bowfield Seam	Lemington					6.7						6.7		7.8	6.8
B925(BFS)	Bowfield Seam	Lemington					7.1						6.9		7.8	6.8
C130(BFS)	Bowfield Seam	Lemington					7.5						7.6		7.8	6.8
C317(BFS)	Bowfield Seam	Lemington					7.2						7.1		7.8	6.8
C613(BFS)	Bowfield Seam	Lemington					7.2						7.1		7.8	6.8
C621(BFS)	Bowfield Seam	Lemington					7.5						7.6		7.8	6.8
C630(BFS)	Bowfield Seam	Lemington					7.6						7.8		7.8	6.8
D010(BFS)	Bowfield Seam	Lemington					7.3						7.1		7.8	6.8
D214(BFS)	Bowfield Seam	Lemington					7.6						7.7		7.8	6.8
D317(BFS)	Bowfield Seam	Lemington					7.4						7.9		7.8	6.8
D406(BFS)	Bowfield Seam	Lemington					7.4						7.3		7.8	6.8
D510(BFS)	Bowfield Seam	Lemington					7.6						7.5		7.8	6.8
D612(BFS)	Bowfield Seam	Lemington					7.1						7		7.8	6.8
D807(BFS)	Bowfield Seam	Lemington					7						7		7.8	6.8
LUG Bore	Dewatering Bore	Lemington								9.3			8.2		n/a	n/a
D010(GM)	Glen Munro Seam	Lemington					7.1						6.9		n/a	n/a

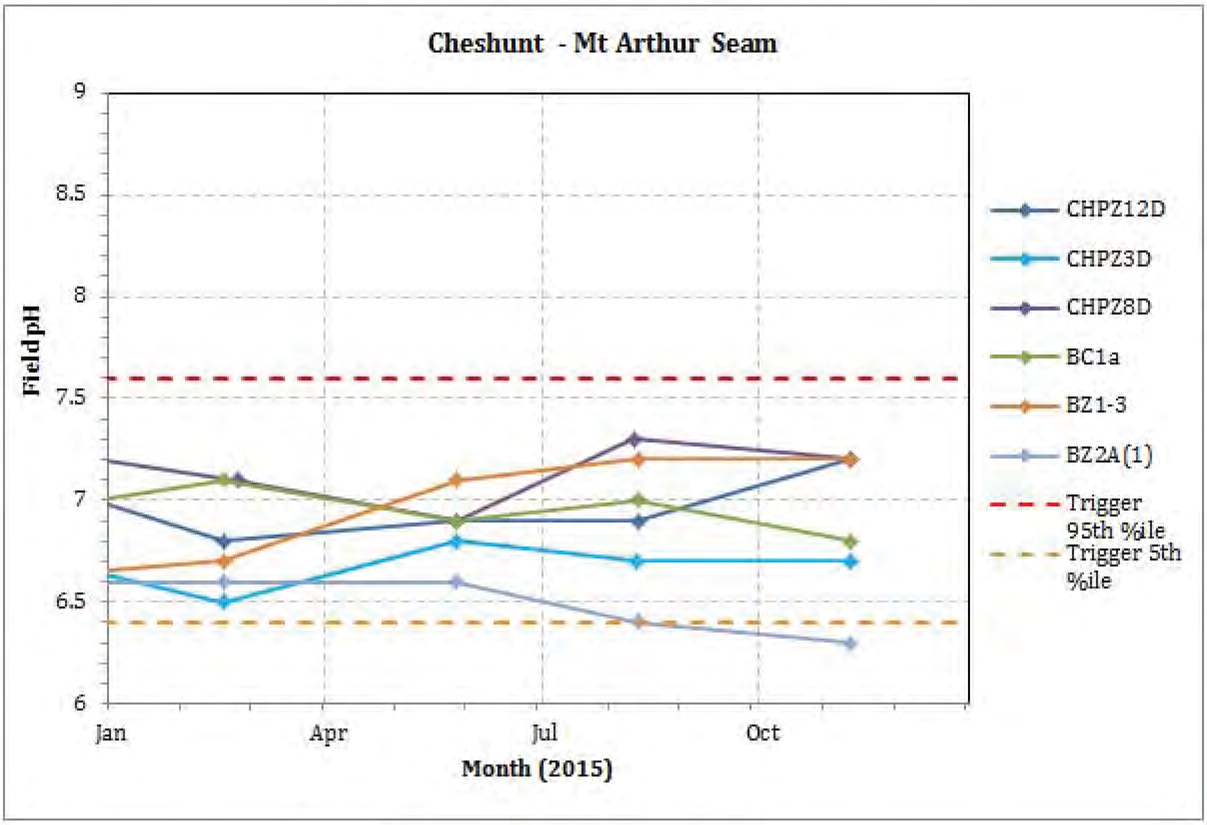
2015 Groundwater Field pH																
Bore ID	Target lithology	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trigger 95th %ile	Trigger 5th %ile
C130(ALL)	Interburden?	Lemington		6.9			7			6.8			7		7	6.7
C1(WJ039)	Piercefield Seam	Lemington		7			7			6.9			6.8		n/a	n/a
GW9701	Piercefield Seam	Lemington					7.1								n/a	n/a
GW9702	Piercefield Seam	Lemington					7.2								n/a	n/a
GW9710	Piercefield Seam	Lemington					7.4								n/a	n/a
F1.5(WF533)	Vaux Seam	Lemington					6.7								n/a	n/a
B425(WDH)	Woodlands Hill Seam	Lemington					7.5						7.4		7.7	6.7
B631(WDH)	Woodlands Hill Seam	Lemington					6.8						6.8		7.7	6.7
C122(WDH)	Woodlands Hill Seam	Lemington					7.3						7.3		7.7	6.7
C130(WDH)	Woodlands Hill Seam	Lemington					6.8						6.8		7.7	6.7
C317(WDH)	Woodlands Hill Seam	Lemington					7.3						7.4		7.7	6.7
C809 (GM/WDH)	Woodlands Hill Seam	Lemington					7.3						7.1		7.7	6.7
D010(WDH)	Woodlands Hill Seam	Lemington					7.1						7.1		7.7	6.7


Alluvium - no trigger
Field pH
9
8.5
8
7.5
7
6.5
6
Jan
Apr
Jul
Oct
Month (2015)
Hobden's Well
CHPZ11A (Barry's Pit)
CHPZ14A (Barry's Pit)

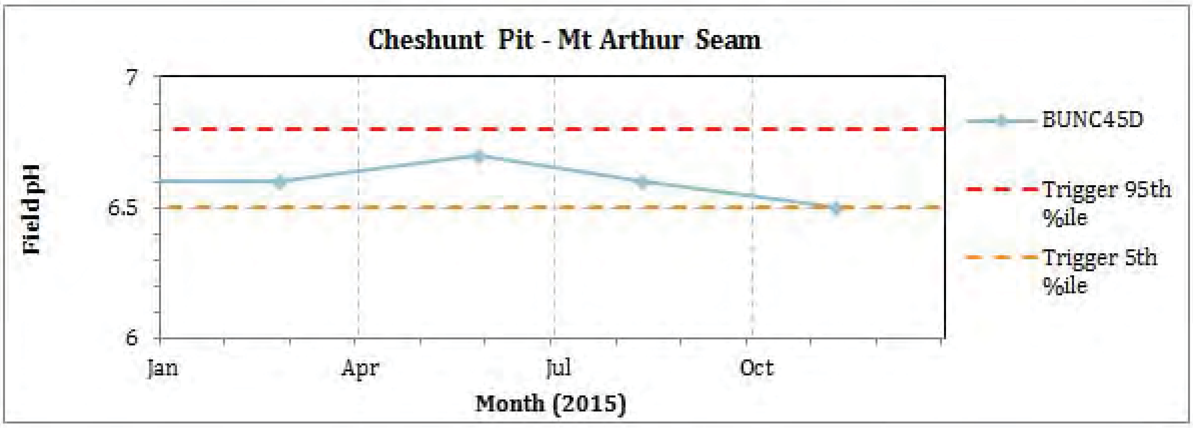

Lemington - Alluvium
Field pH
9
8.5
8
7.5
7
6.5
6
Jan
Apr
Jul
Oct
Month (2015)
Appleyard Farm
C919(ALL)
PB01(ALL)
Trigger 95th %ile
Trigger 5th %ile


Cheshunt Pit northern area - Alluvium/Regolith - Interburden
Field pH
9
8.5
8
7.5
7
6.5
6
Jan
Apr
Jul
Oct
Month (2015)
CHPZ10A
CHPZ12A
CHPZ1A
CHPZ2A
CHPZ3A
CHPZ4A
BUNC45A
CHPZ8A
BZ1-1
Trigger 95th %ile
Trigger 5th %ile

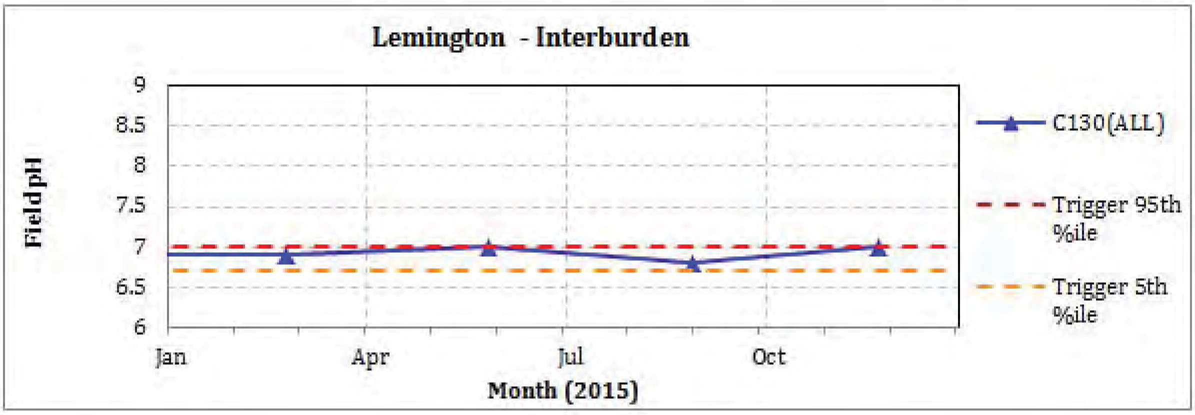

Cheshunt - Interburden
Field pH
9
8.5
8
7.5
7
6.5
6
Jan
Apr
Jul
Oct
Month (2015)
BZ3-1
BZ8-2
HG2
Trigger 95th %ile
Trigger 5th %ile



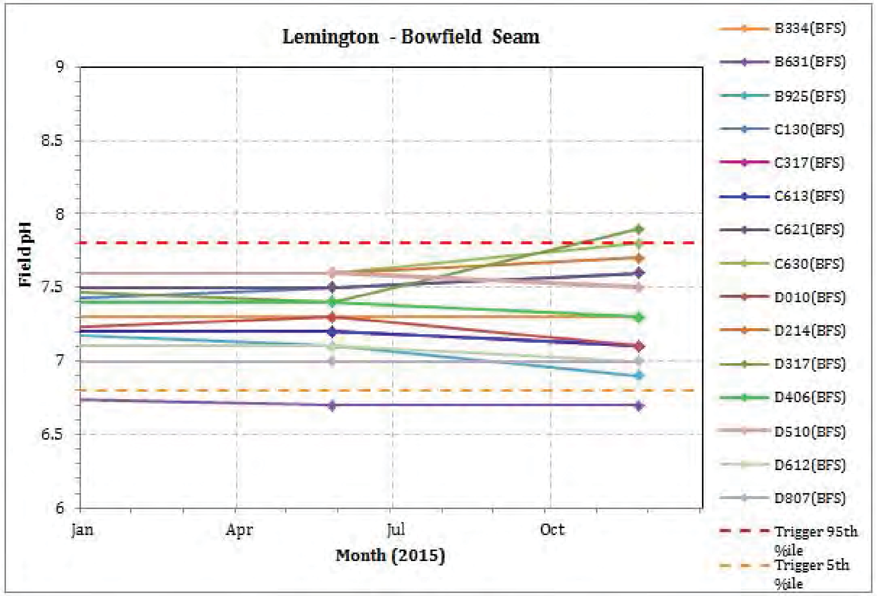
Cheshunt - Mt Arthur Seam
9
8.5
8
7.5
7
6.5
6
Field pH
Jan
Apr
Jul
Oct
Month (2015)
CHPZ12D
CHPZ3D
CHPZ8D
BC1a
BZ1-3
BZ2A(1)
Trigger 95th %ile
Trigger 5th %ile

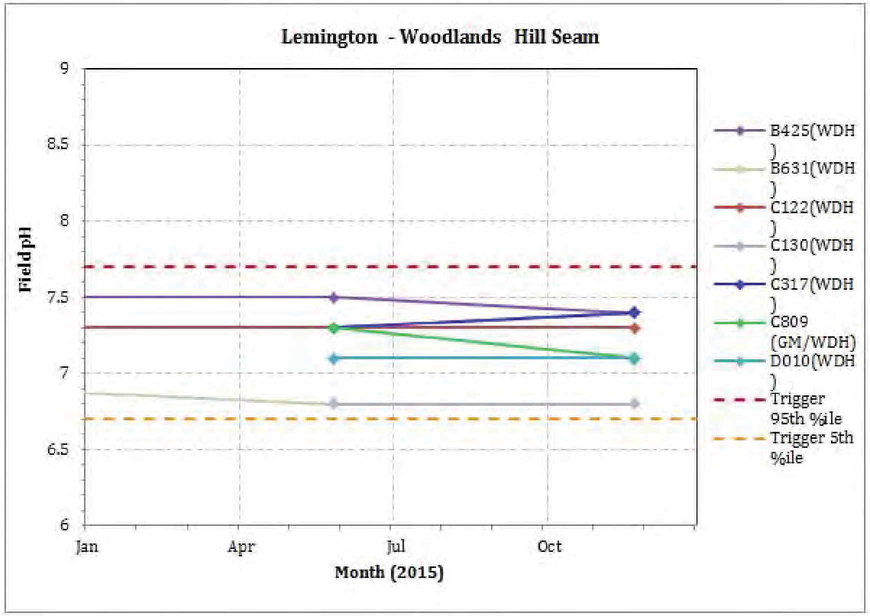


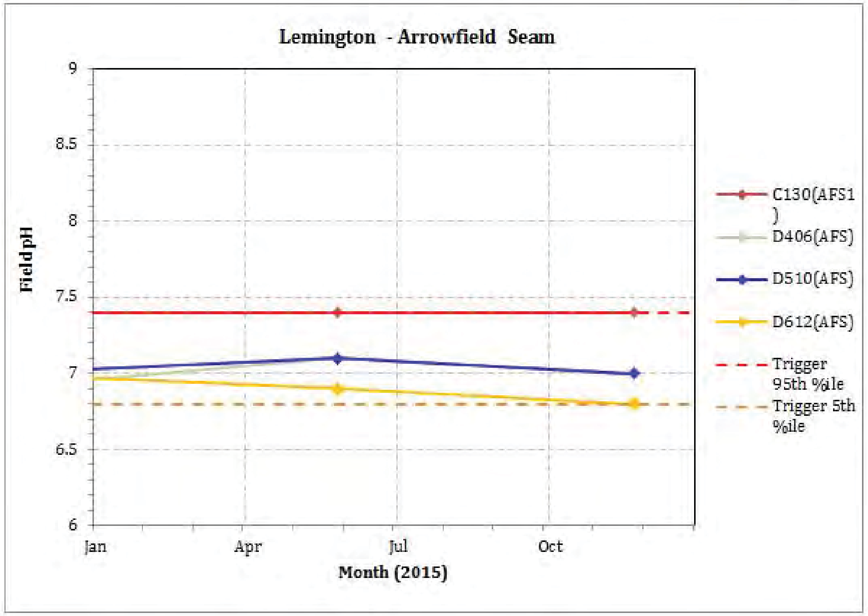
Cheshunt Pit - Mt Arthur Seam
7
6.5
6
Field pH
Jan
Apr
Jul
Oct
Month (2015)
BUNC45D
Trigger 95th %ile
Trigger 5th %ile

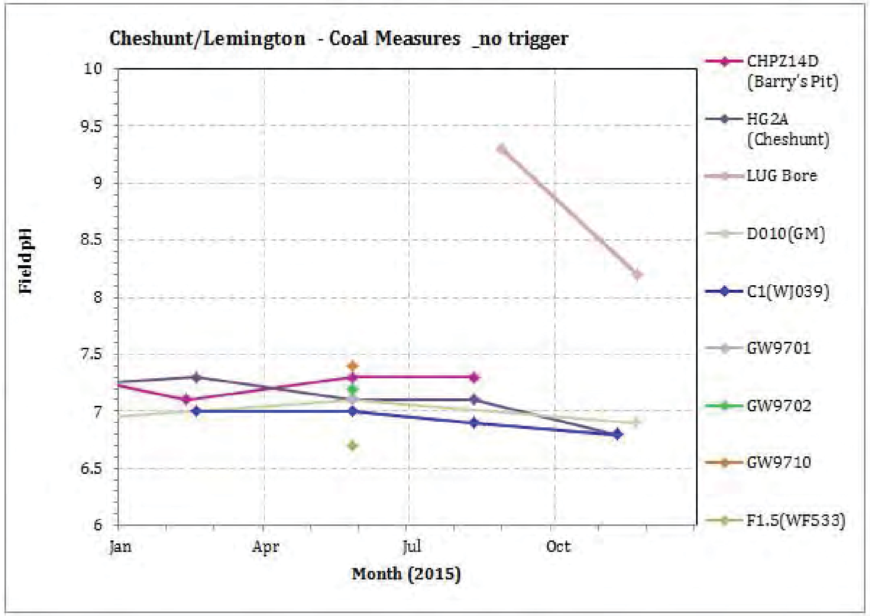


Lemington - Interburden
9
8.5
8
7.5
7
6.5
6
Field pH
Jan
Apr
Jul
Oct
Month (2015)
C130(ALL)
Trigger 95th %ile
Trigger 5th %ile


Lemington - Bowfield Seam
FieldpH
Month (2015)
Jan
Apr
Jul
Oct
B334(BFS)
B631(BFS)
B925(BFS)
C130(BFS)
C317(BFS)
C613(BFS)
C621(BFS)
C630(BFS)
D010(BFS)
D214(BFS)
D317(BFS)
D406(BFS)
D510(BFS)
D612(BFS)
D807(BFS)
Trigger 95th %ile
Trigger 5th %ile

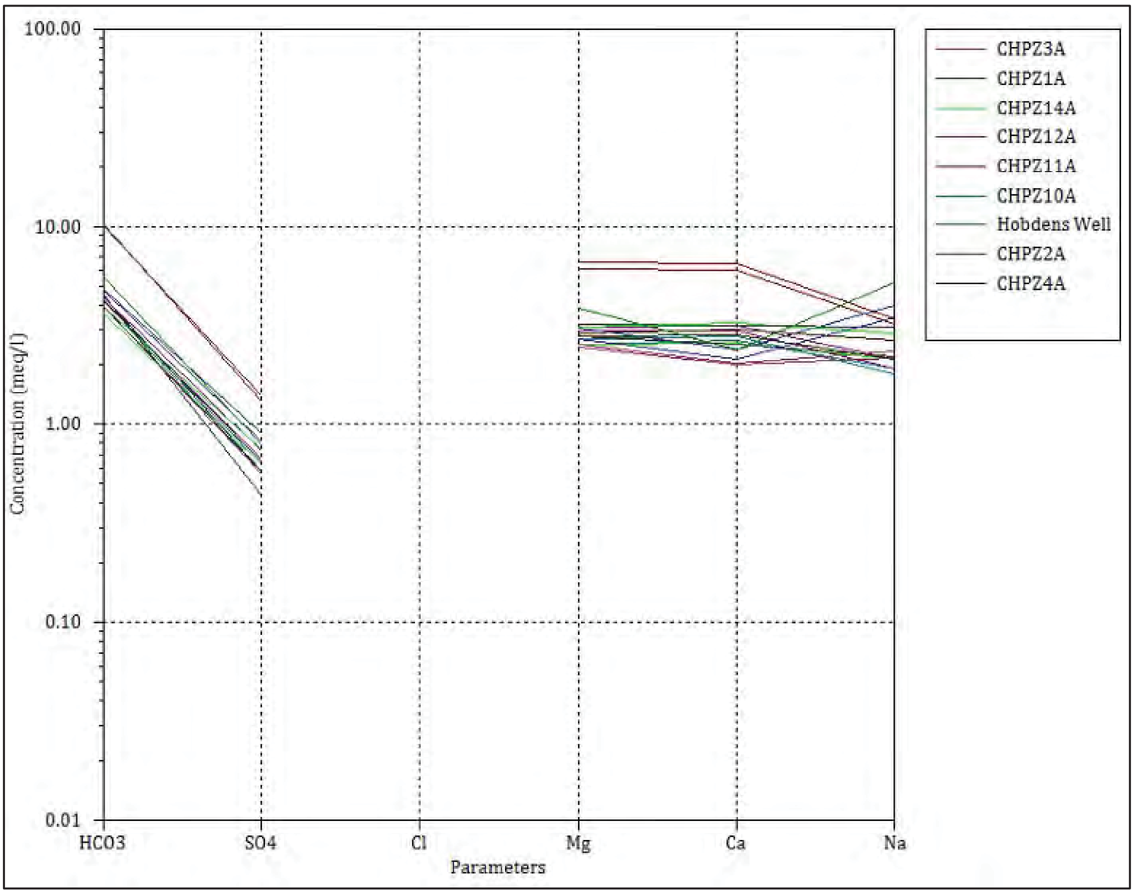

Lemington - Woodlands Hill Seam
FieldpH
Month (2015)
Jan
Apr
Jul
Oct
B425(WDH)
B631(WDH)
C122(WDH)
C130(WDH)
C317(WDH)
C809 (GM/WDH)
D010(WDH)
Trigger 95th %ile
Trigger 5th %ile


Lemington - Arrowfield Seam
FieldpH
Month (2015)
Jan
Apr
Jul
Oct
C130(AFS1)
D406(AFS)
D510(AFS)
D612(AFS)
Trigger 95th %ile
Trigger 5th %ile

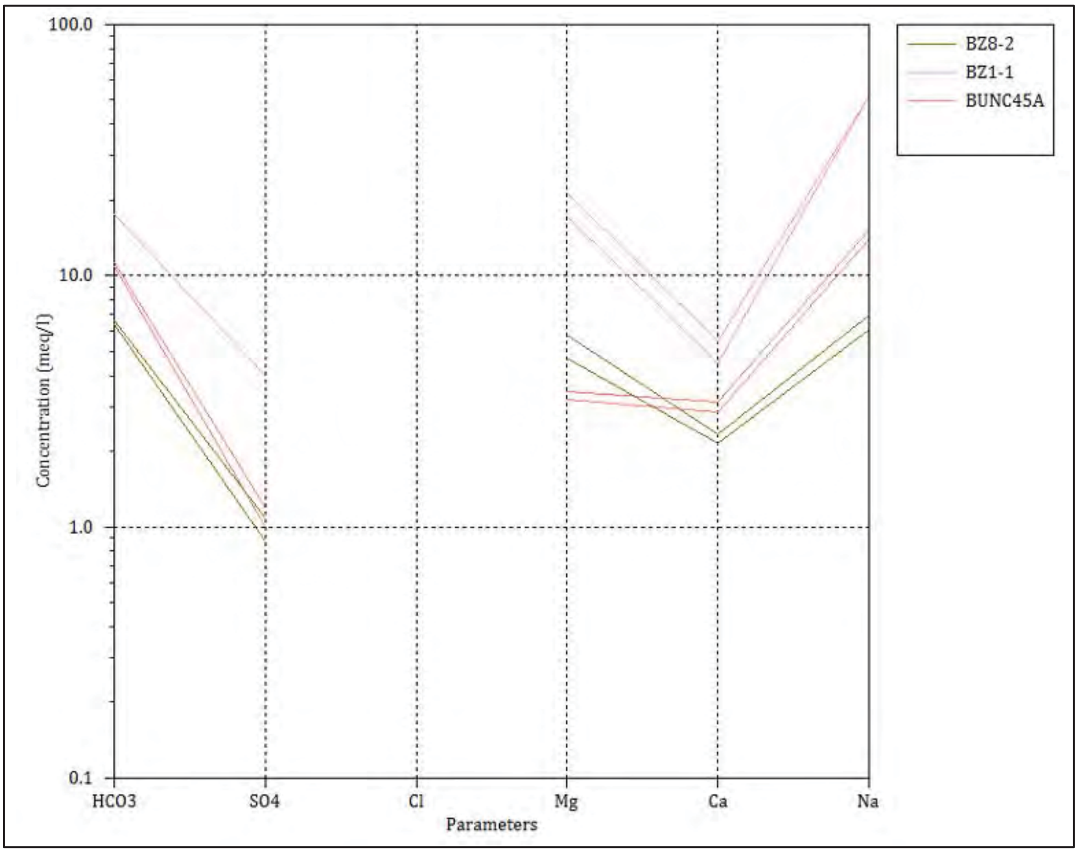

Cheshunt/Lemington - Coal Measures _no trigger
FieldpH
Month (2015)
Jan
Apr
Jul
Oct
CHPZ14D (Barry's Pit)
HG2A (Cheshunt)
LUG Bore
D010(GM)
C1(WJ039)
GW9701
GW9702
GW9710
F1.5(WF533)

Station	Lithology	Location	Date	Al - Total (mg/l)	Alk - Total (mg/l)	As - Total (mg/l)	B (mg/l)	Ba (mg/l)	Ca - Total (mg/l)	CaCO3 - Total Hard (mg/l)	Fe - Filtered (mg/L)	Hydroxide Alk (mg/l)	K - Total (mg/l)	Li (mg/l)	Mg - Total (mg/l)	Mn - Total (mg/l)	Na - Total (mg/l)	Nitrogen Ammonia (mg/l)	P - Total (mg/l)	Rb - Total (mg/l)	Se (mg/l)	Si (mg/l)	SO4 - Total (mg/l)	Sr - Total (mg/l)	TDS - Total (mg/l)	Zn - Total (mg/l)
BUNC45A	Regolith	Cheshunt	14/8/15	10	564	0.004	0.096		63				6.8		42		350				0.001		57		1060	0.16
BUNC45A	Regolith	Cheshunt	25/2/15	0.21	543	0.001	0.081		57			0	6.3		39		320				0.001		48		1090	0.01
BUNC45D	Mt Arthur Seam	Cheshunt	14/8/15	0.3	804	0.001	0.15		83				12		60		420				0.001		1		1480	0.061
BUNC45D	Mt Arthur Seam	Cheshunt	26/2/15	0.33	818	0.001	0.13		73			0	11		53		410				0.001		1		1410	0.017
BZ1-1	Interburden	Cheshunt	19/2/15	30	873	0.015	0.12		110			0	34		260		1200				0.005		190		5190	0.16
BZ1-1	Interburden	Cheshunt	14/8/15	0.35	870	0.001	0.095		90				25		210		1200				0.001		190		3680	0.057
BZ1-3	Mt Arthur Seam	Cheshunt	19/2/15	0.29	1280	0.001	0.25		180			0	52		210		1200				0.001		880		5400	0.08
BZ1-3	Mt Arthur Seam	Cheshunt	14/8/15	0.38	503	0.001	0.11		17				12		26		310				0.001		36		821	0.083
BZ8-2	Interburden	Cheshunt	19/2/15	0.99	319	0.006	0.057		43			0	5		57		140				0.001		42		741	0.016
BZ8-2	Interburden	Cheshunt	14/8/15	0.26	332	0.007	0.06		47				5.3		71		160				0.001		52		773	0.022
CHPZ10A	Alluvium	Cheshunt	13/2/15	0.008	212	0.001	0.036		56			0	0.8		33		41				0.001		27		485	0.005
CHPZ10A	Alluvium	Cheshunt	12/8/15	0.19	211	0.001	0.043		53				0.9		31		44				0.001		30		422	0.006
CHPZ11A	Alluvium	Cheshunt	19/2/15	0.079	509	0.001	0.048		120			0	3		74		74				0.001		63		829	0.005
CHPZ11A	Alluvium	Cheshunt	12/8/15	0.56	508	0.001	0.052		130				2.9		80		78				0.001		67		820	0.008
CHPZ12A	Alluvium	Cheshunt	19/2/15	0.005	208	0.001	0.044		59			0	0.8		36		44				0.003		32		470	0.005
CHPZ12A	Alluvium	Cheshunt	14/8/15	0.053	218	0.001	0.044		63				0.9		38		49				0.004		35		449	0.005
CHPZ12D	Mt Arthur Seam	Cheshunt	19/2/15	0.005	524	0.001	0.12		18			0	7.7		12		260				0.001		1		760	0.006
CHPZ12D	Mt Arthur Seam	Cheshunt	14/8/15	0.012	549	0.001	0.12		19				8.7		13		280				0.001		1		677	0.01
CHPZ14A	Alluvium	Cheshunt	13/2/15	0.12	183	0.001	0.023		52			0	1		31		49				0.001		30		475	0.006
CHPZ14A	Alluvium	Cheshunt	14/8/15	0.11	197	0.001	0.032		65				1.3		38		66				0.001		36		490	0.023
CHPZ14D	Mt Arthur Seam	Cheshunt	13/2/15	0.015	392	0.001	0.08		18			0	12		8.4		170				0.001		1		557	0.007

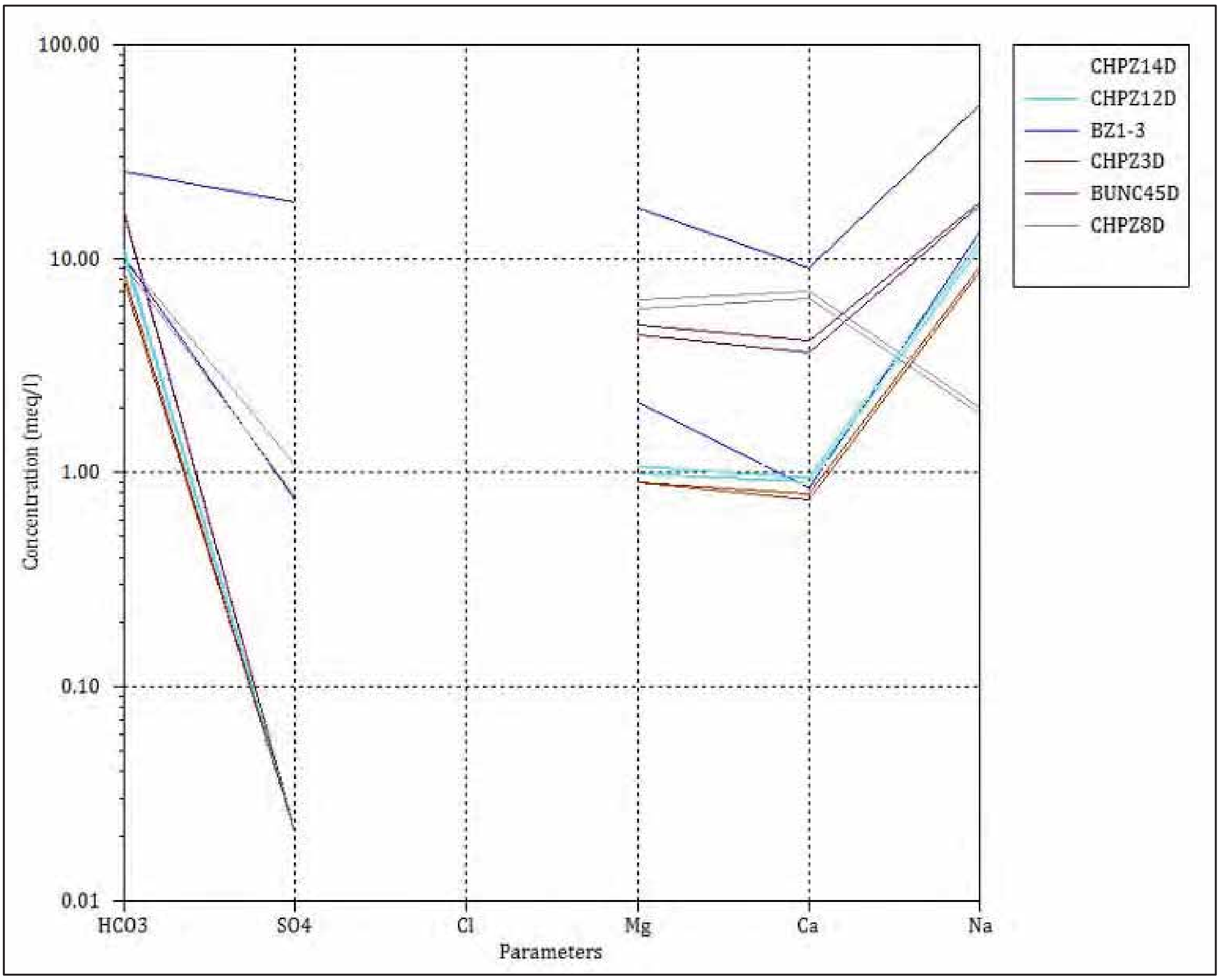
Station	Lithology	Location	Date	Al - Total (mg/l)	Alk - Total (mg/l)	As - Total (mg/l)	B (mg/l)	Ba (mg/l)	Ca - Total (mg/l)	CaCO3 - Total Hard (mg/l)	Fe - Filtered (mg/L)	Hydroxide Alk (mg/l)	K - Total (mg/l)	Li (mg/l)	Mg - Total (mg/l)	Mn - Total (mg/l)	Na - Total (mg/l)	Nitrogen Ammonia (mg/l)	P - Total (mg/l)	Rb - Total (mg/l)	Se (mg/l)	Si (mg/l)	SO4 - Total (mg/l)	Sr - Total (mg/l)	TDS - Total (mg/l)	Zn - Total (mg/l)
CHPZ14D	Mt Arthur Seam	Cheshunt	14/8/15	0.19	404	0.001	0.091		23				14		11		190				0.001		1		512	0.012
CHPZ1A	Alluvium	Cheshunt	26/2/15	0.008	225	0.001	0.022		51		0.005	0	1.9	0.005	34	0.006	51	0.05	0.13	0.003	0.001	21	21	0.47	472	0.005
CHPZ1A	Alluvium	Cheshunt	14/8/15	0.07	222	0.001	0.032		63		0.005		2.4	0.005	39	0.003	71	0.02	0.05	0.003	0.001	20	28	0.45	427	0.005
CHPZ2A	Alluvium	Cheshunt	13/2/15	0.005	238	0.001	0.037		43			0	0.8		33		80				0.001		39		505	0.005
CHPZ2A	Alluvium	Cheshunt	13/8/15	0.005	240	0.001	0.044		48				1		37		92				0.001		43		458	0.005
CHPZ3A	Alluvium	Cheshunt	19/2/15	0.04	196	0.001	0.041		40			0	0.8		30		50				0.001		27		466	0.005
CHPZ3A	Alluvium	Cheshunt	13/8/15	0.04	197	0.001	0.042		41				0.8		31		54				0.001		28		369	0.008
CHPZ3D	Mt Arthur Seam	Cheshunt	19/2/15	0.005	391	0.001	0.14		15			0	5.7		11		200				0.001		1		578	0.007
CHPZ3D	Mt Arthur Seam	Cheshunt	13/8/15	0.061	423	0.001	0.13		16				5.9		11		210				0.001		1		544	0.012
CHPZ4A	Alluvium	Cheshunt	13/2/15	0.098	198	0.001	0.024		57			0	1.7		34		49				0.001		28		515	0.005
CHPZ4A	Alluvium	Cheshunt	12/8/15	0.07	214	0.001	0.034		60				2		35		61				0.001		31		432	0.005
CHPZ8D	Mt Arthur Seam	Cheshunt	25/2/15	0.64	465	0.001	0.049		130			0	3.7		71		43				0.001		37		805	0.007
CHPZ8D	Mt Arthur Seam	Cheshunt	12/8/15	0.36	501	0.001	0.061		140				3.6		78		46				0.001		52		853	0.005
Hobden's Well	Alluvium	Cheshunt	13/8/15	0.01	278	0.001	0.037		48				1.4		47		120				0.001		38		542	0.029
Hobden's Well	Alluvium	Cheshunt	13/8/15	0.01	278	0.001	0.037		48				1.4		47		120				0.001		38		542	0.029



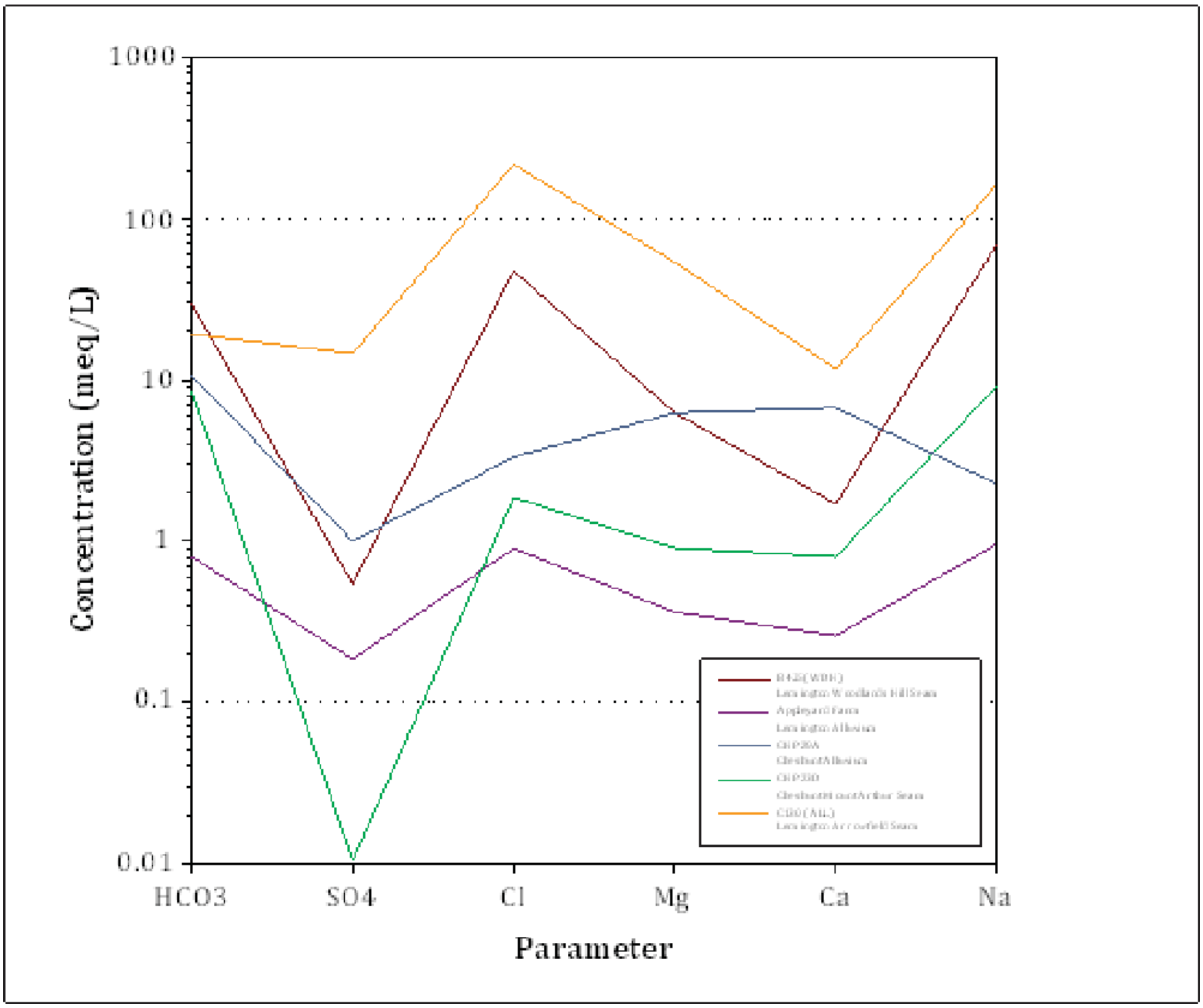
Schoeller Plot - Cheshunt Alluvium



Schoeller Plot - Cheshunt Interburden and Regolith

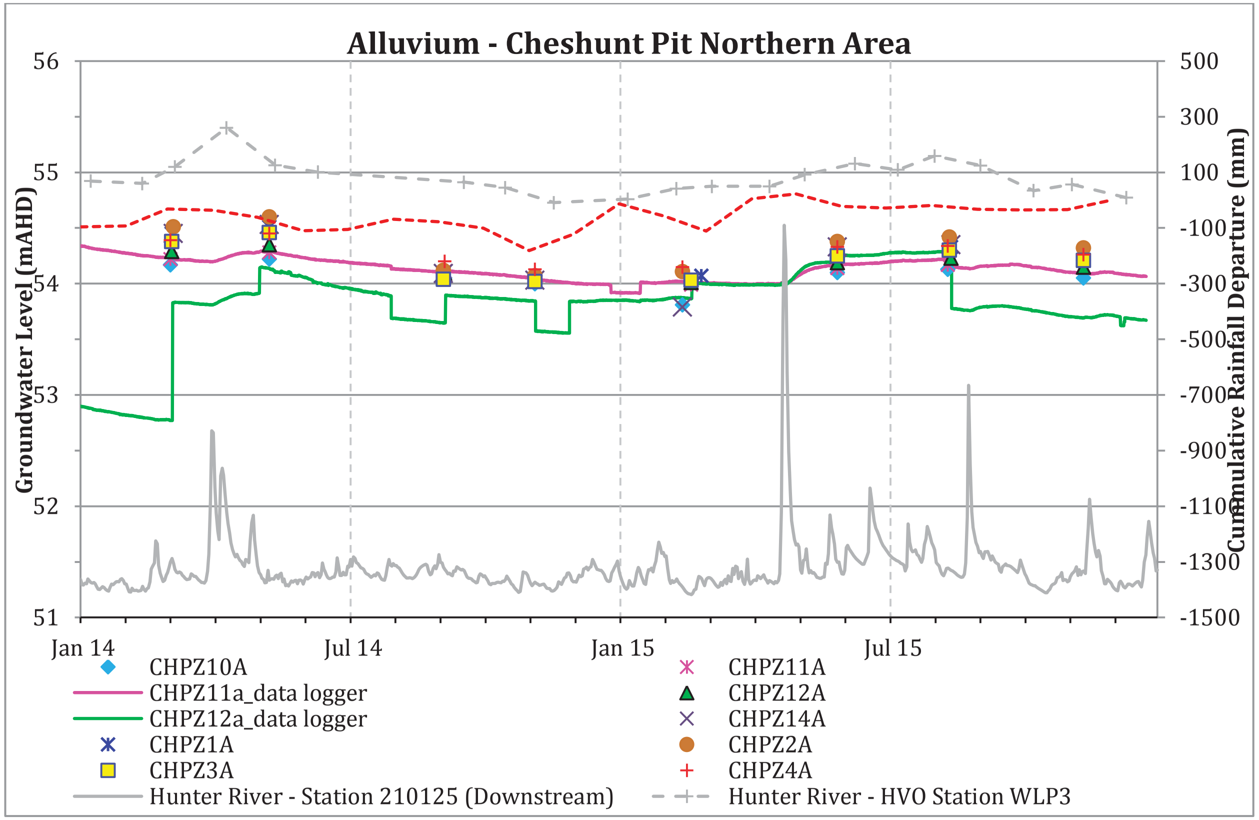


Schoeller Plot - Cheshunt (BZ1-3) Mt. Arthur Seam

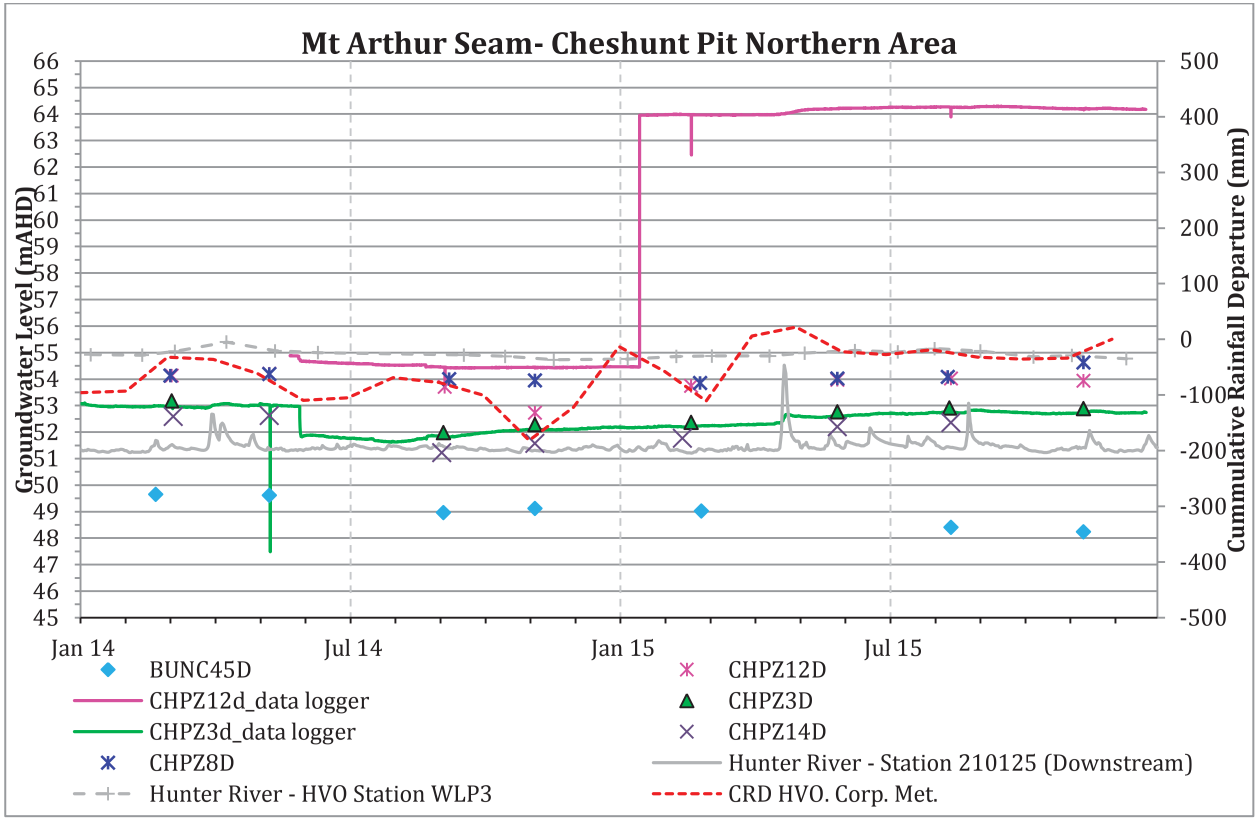


Schoeller Plot – Typical chemistry - Lemington and Cheshunt bores

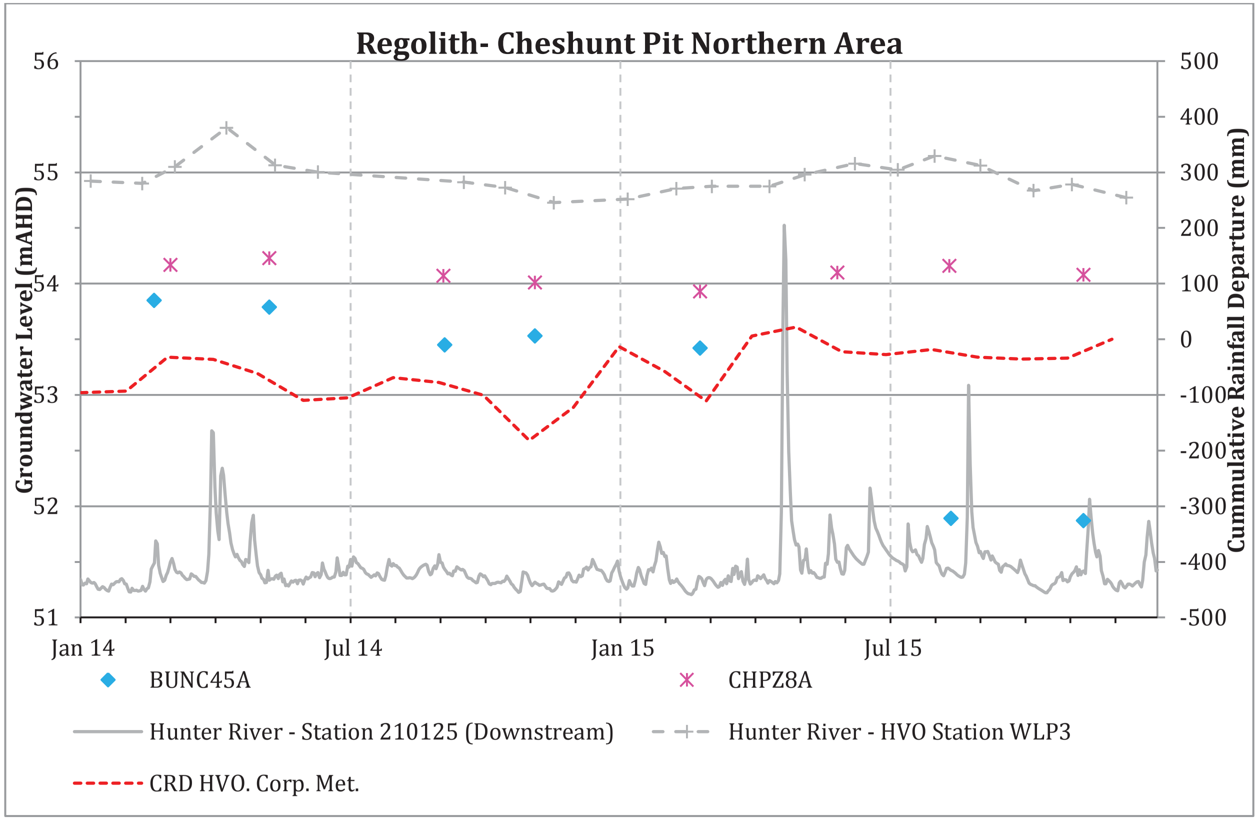
Appendix D Hydrographs



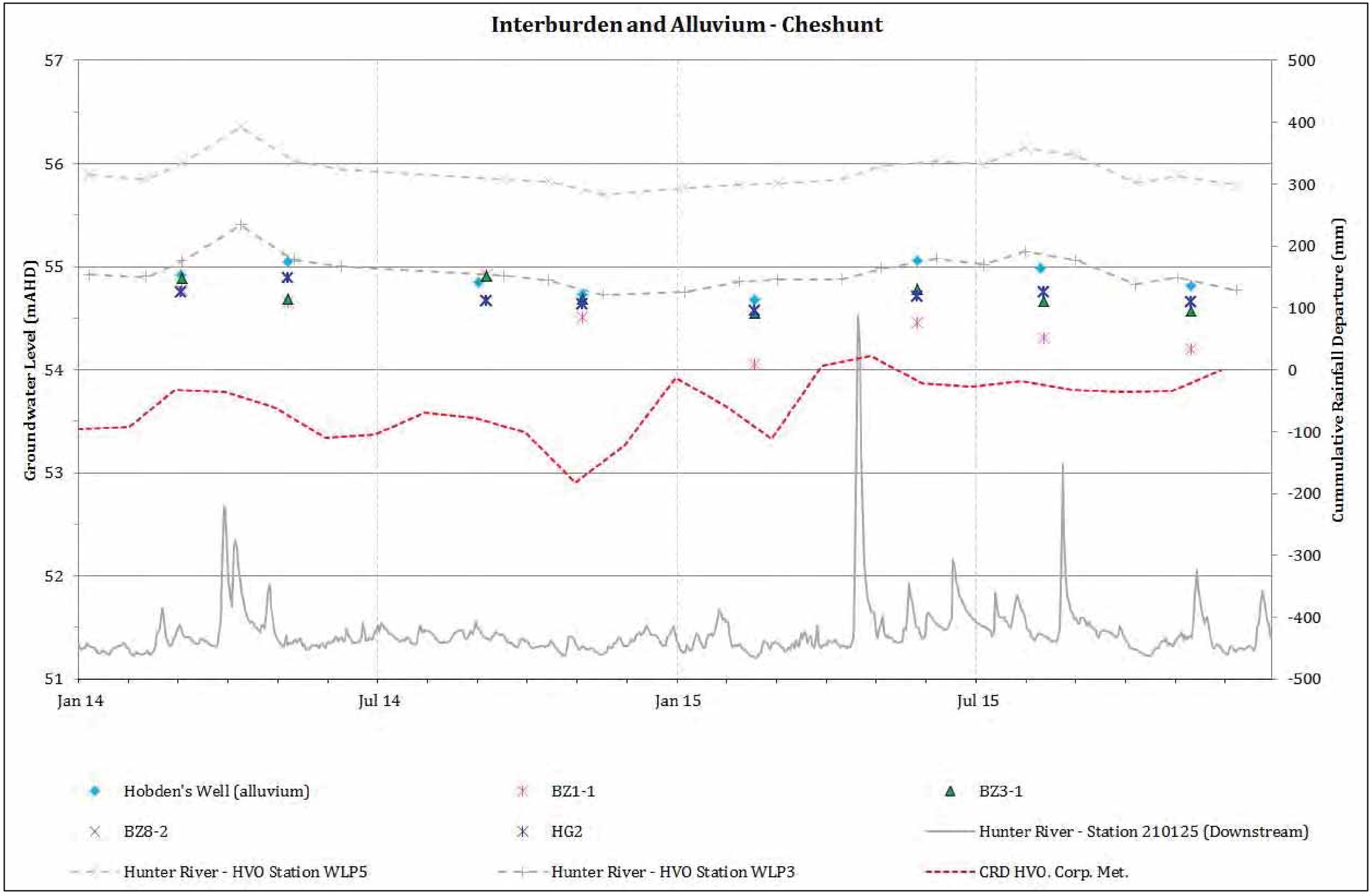
Alluvium - Cheshunt Pit Northern Area
Groundwater Level (mAHD)
Cumulative Rainfall Departure (mm)
56
55
54
53
52
51
500
300
100
-100
-300
-500
-700
-900
-1100
-1300
-1500
Jan 14
Jul 14
Jan 15
Jul 15
CHPZ10A
CHPZ11a_data logger
CHPZ12a_data logger
CHPZ1A
CHPZ3A
Hunter River - Station 210125 (Downstream)
CHPZ11A
CHPZ12A
CHPZ14A
CHPZ2A
CHPZ4A
Hunter River - HVO Station WLP3

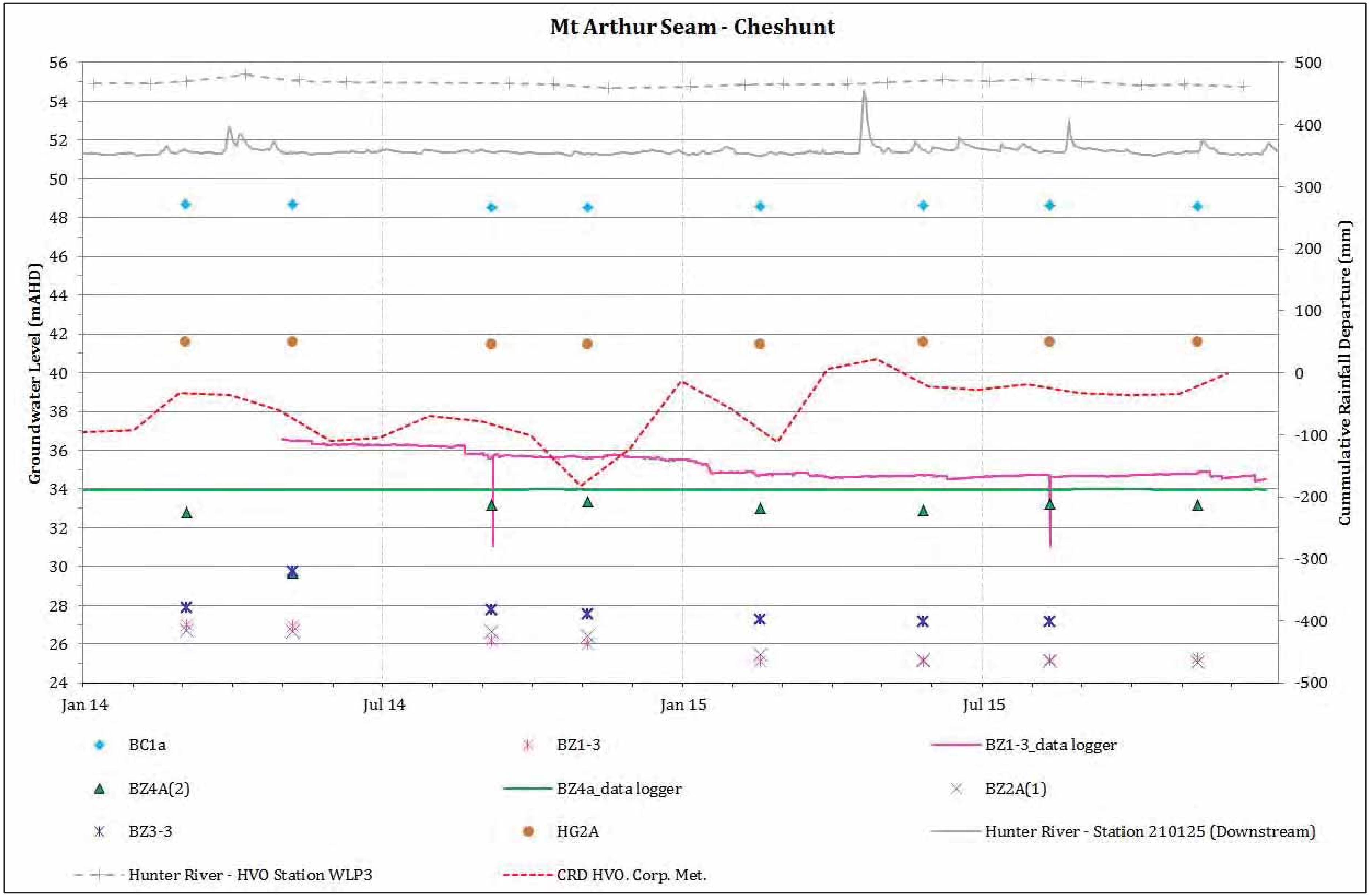


Mt Arthur Seam- Cheshunt Pit Northern Area
Groundwater Level (mAHD)
Cummulative Rainfall Departure (mm)
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
BUNC45D
CHPZ12d_data logger
CHPZ3d_data logger
CHPZ8D
Hunter River - HVO Station WLP3
CHPZ12D
CHPZ3D
CHPZ14D
Hunter River - Station 210125 (Downstream)
CRD HVO. Corp. Met.

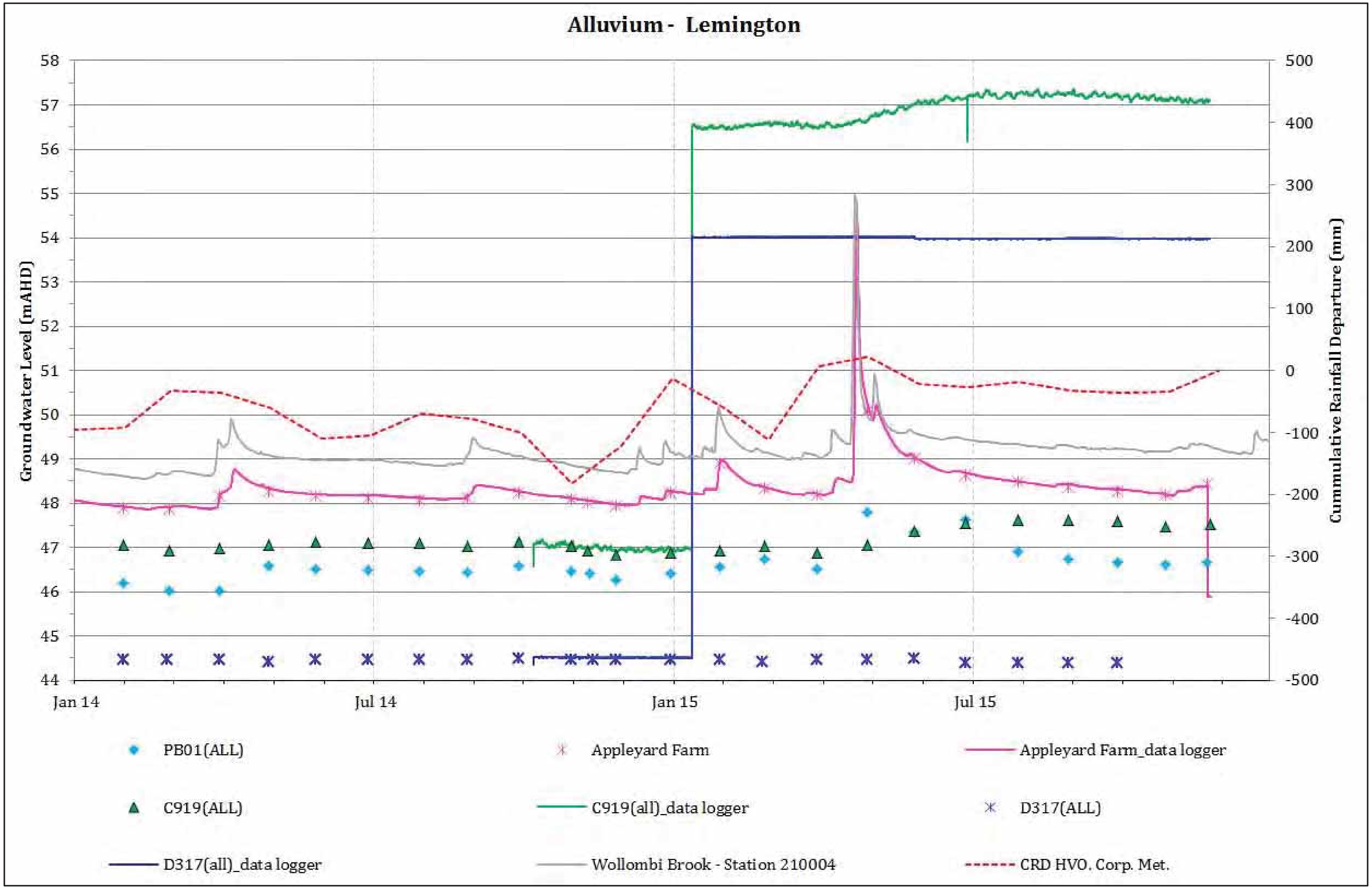


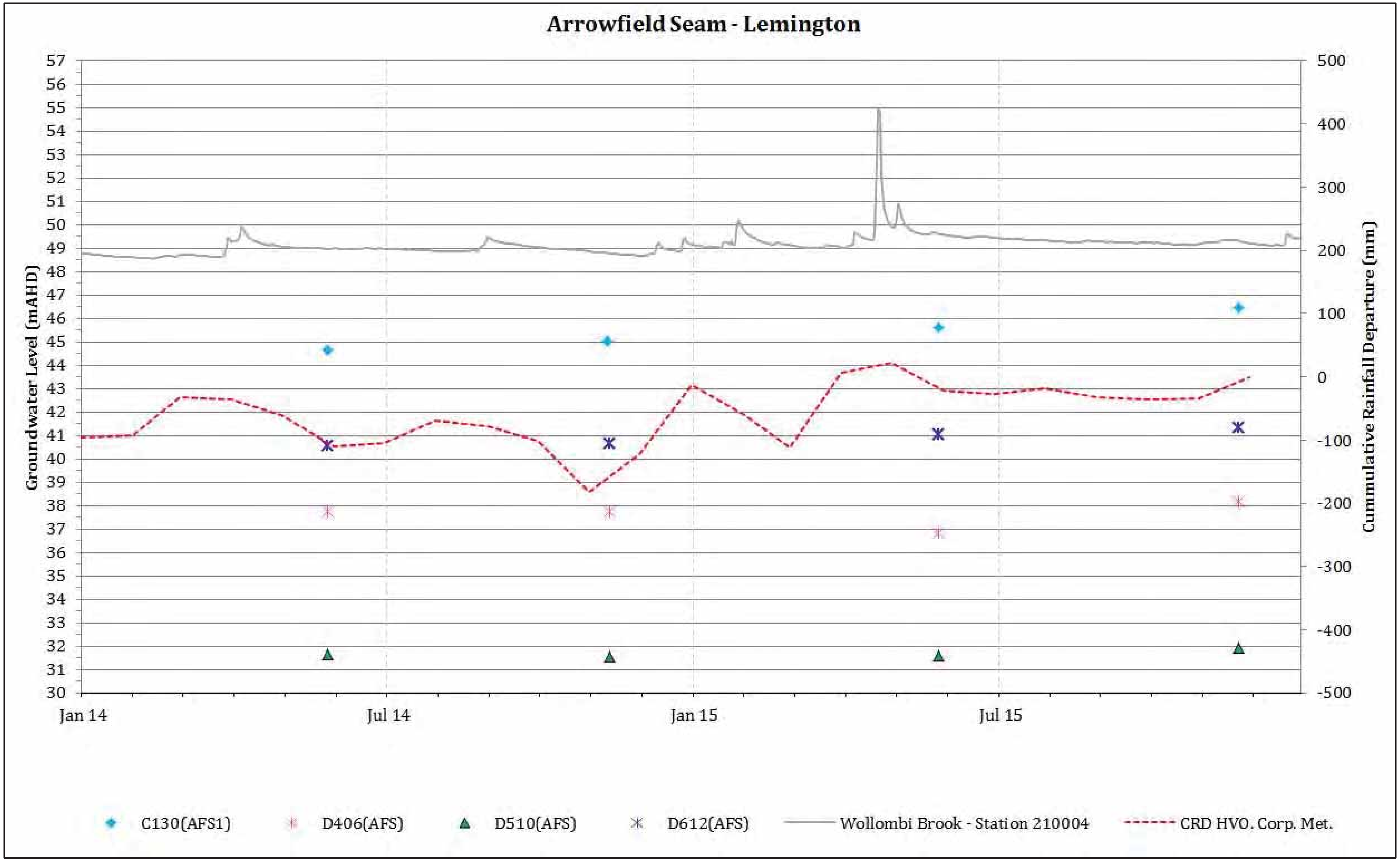
Regolith- Cheshunt Pit Northern Area
Groundwater Level (mAHD)
56
55
54
53
52
51
Cummulative Rainfall Departure (mm)
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
BUNC45A
CHPZ8A
Hunter River - Station 210125 (Downstream)
Hunter River - HVO Station WLP3
CRD HVO. Corp. Met.

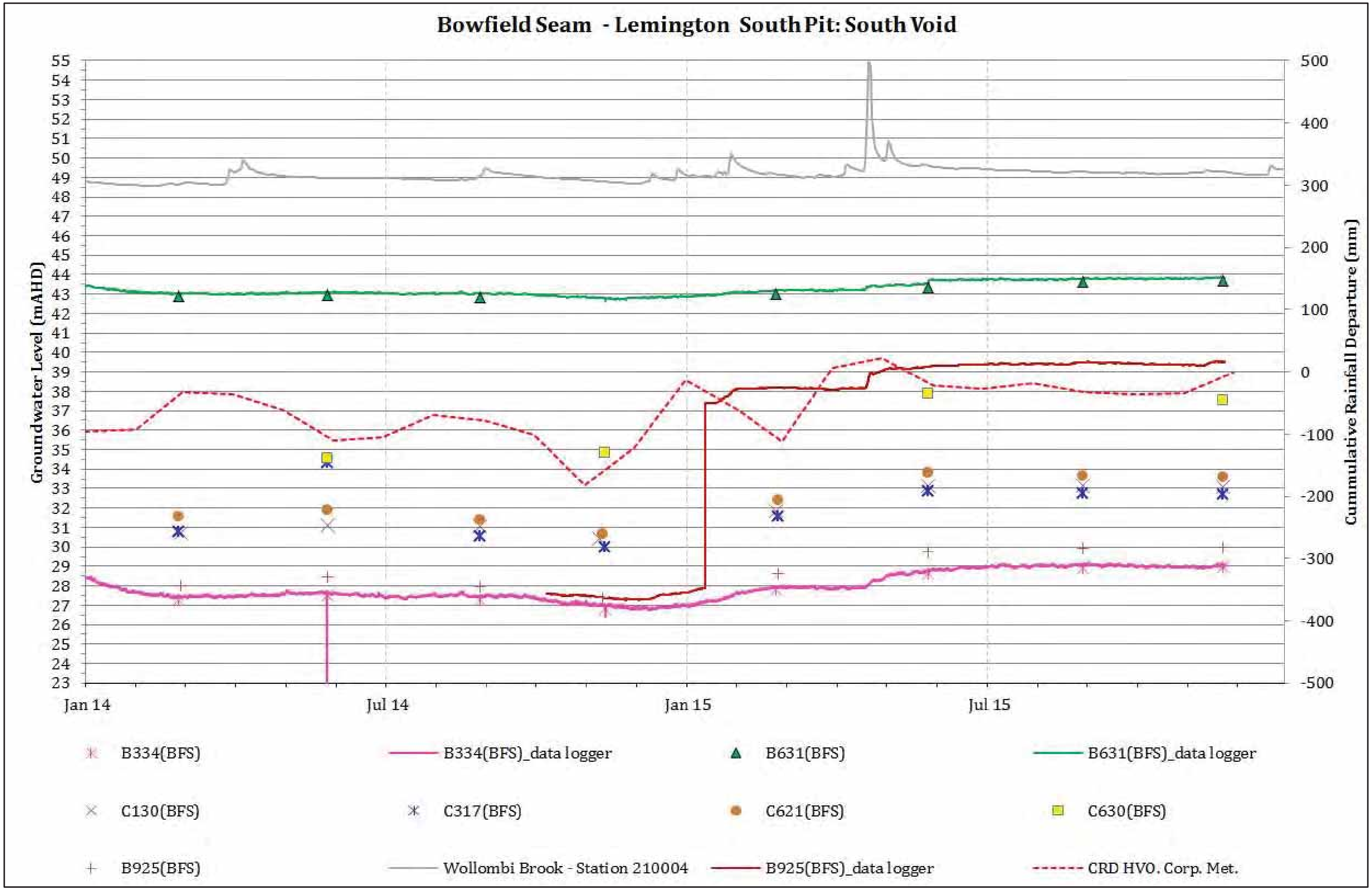

Interburden and Alluvium - Cheshunt
57
56
55
54
53
52
51
Groundwater Level (mAHD)
500
400
300
200
100
0
-100
-200
-300
-400
-500
Cummulative Rainfall Departure (mm)
Jan 14
Jul 14
Jan 15
Jul 15
Hobden's Well (alluvium)
BZ1-1
BZ3-1
BZ8-2
HG2
Hunter River - Station 210125 (Downstream)
Hunter River - HVO Station WLP5
Hunter River - HVO Station WLP3
CRD HVO. Corp. Met.

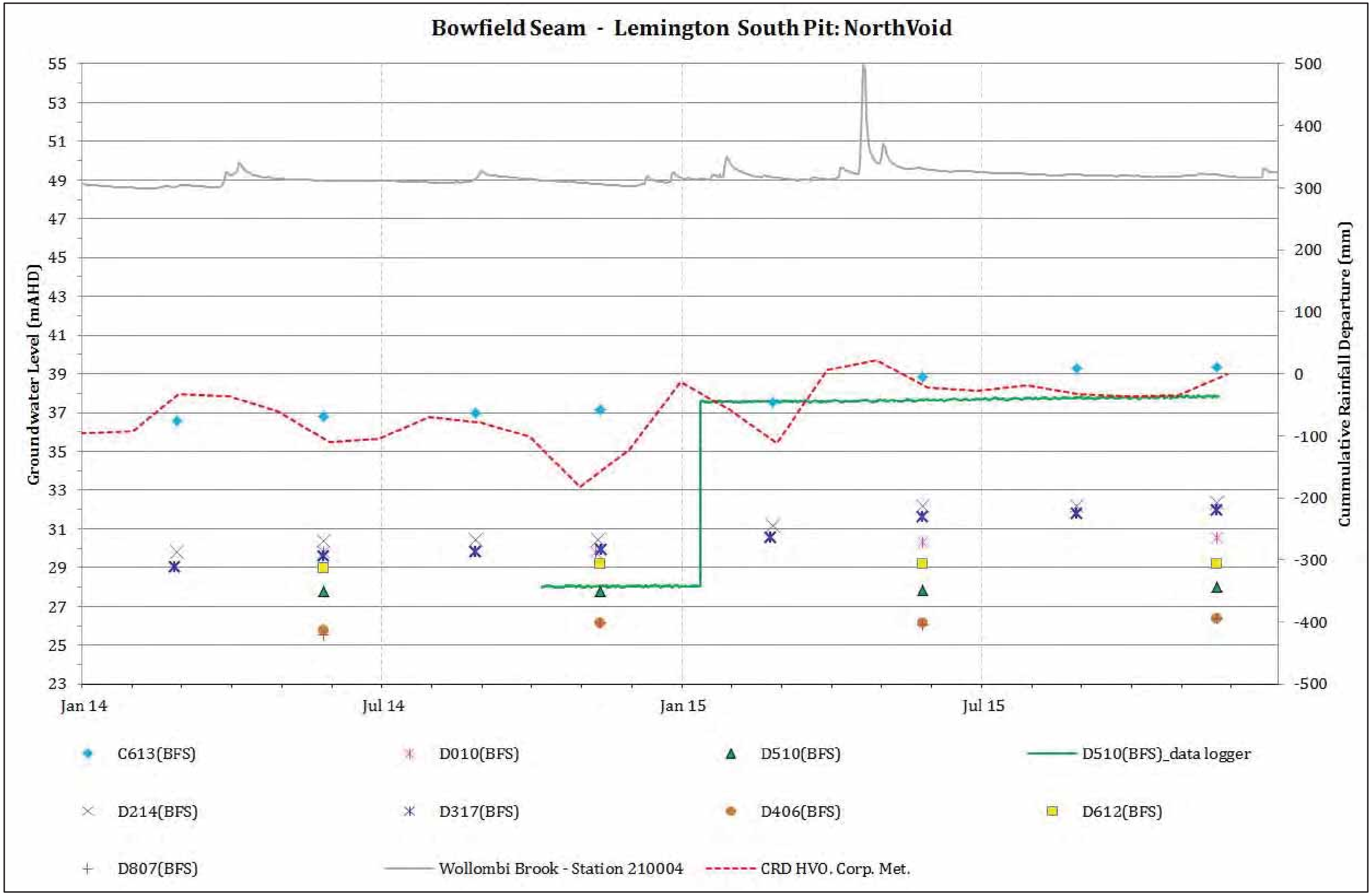


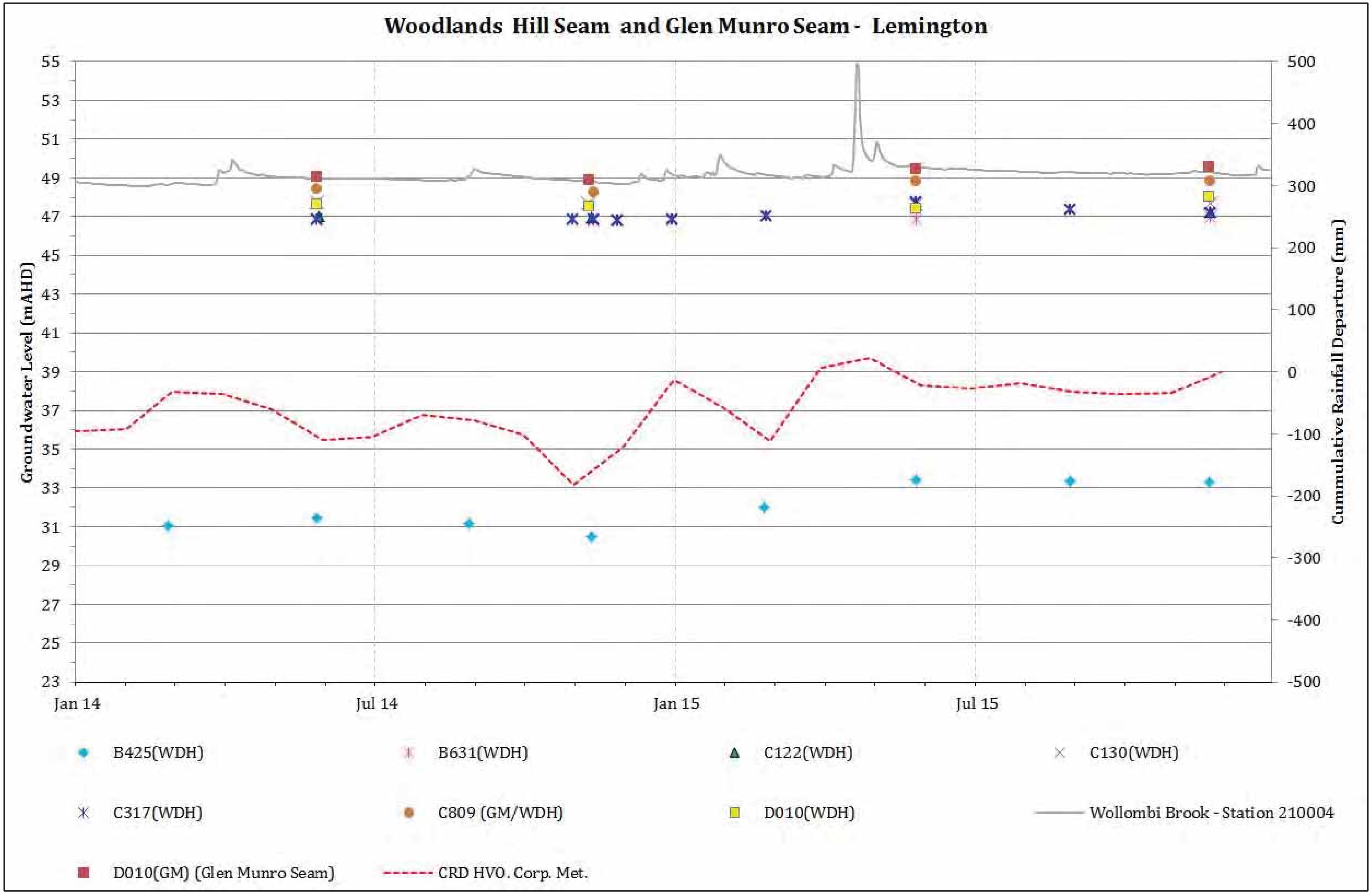
Mt Arthur Seam - Cheshunt
Groundwater Level (mAHD)
Cummulative Rainfall Departure (mm)
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
BC1a
BZ1-3
BZ1-3_data logger
BZ4A(2)
BZ4a_data logger
BZ2A(1)
BZ3-3
HG2A
Hunter River - Station 210125 (Downstream)
Hunter River - HVO Station WLP3
CRD HVO. Corp. Met.


Alluvium - Lemington
Groundwater Level (mAHD)
Cummulative Rainfall Departure (mm)
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
PB01(ALL)
Appleyard Farm
Appleyard Farm_data logger
C919(ALL)
C919(all)_data logger
D317(ALL)
D317(all)_data logger
Wollombi Brook - Station 210004
CRD HVO. Corp. Met.

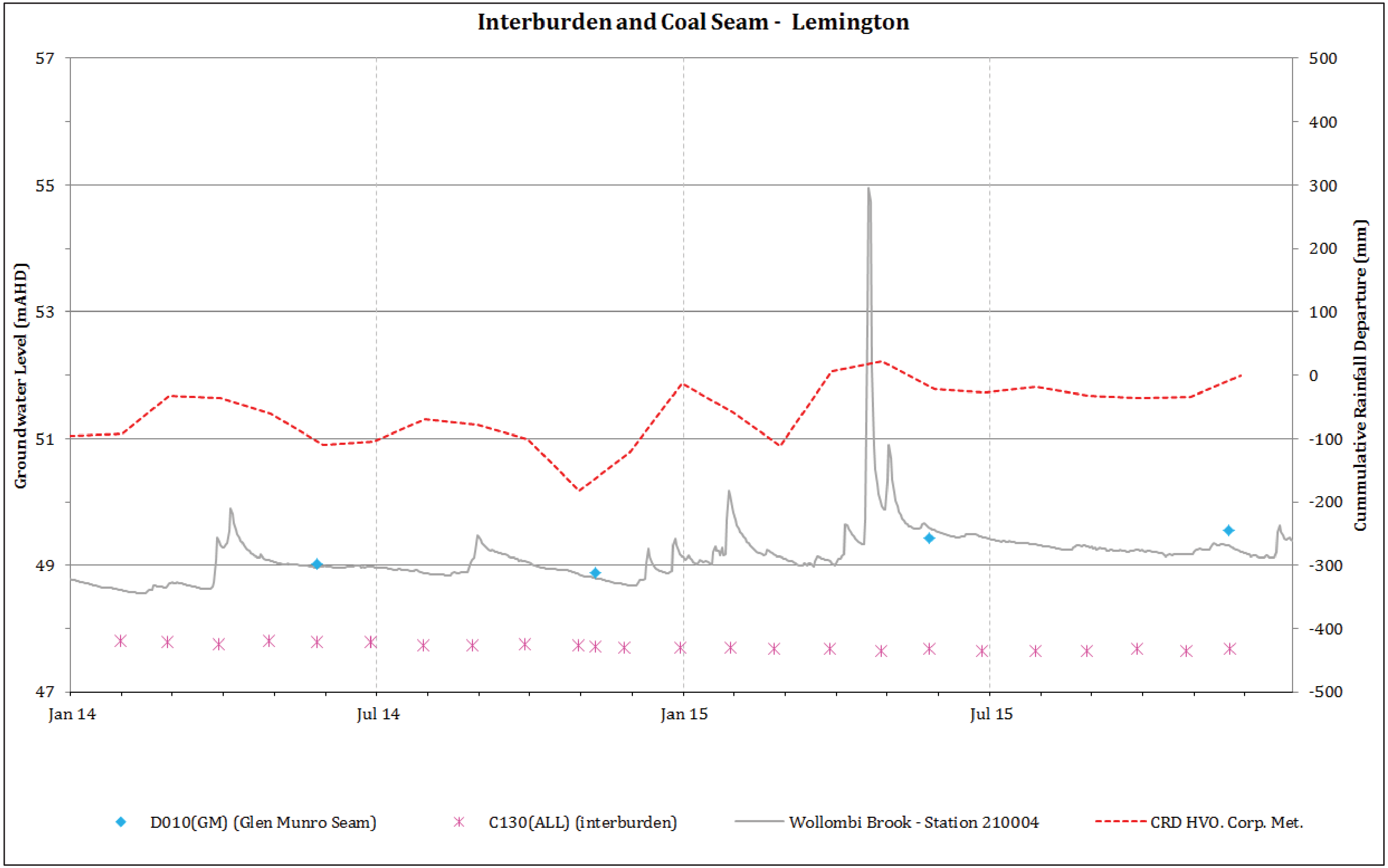

Arrowfield Seam - Lemington
Groundwater Level (mAHD)
Cummulative Rainfall Departure (mm)
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
C130(AFS1)
D406(AFS)
D510(AFS)
D612(AFS)
Wollombi Brook - Station 210004
CRD HVO. Corp. Met.


Bowfield Seam - Lemington South Pit: South Void
Groundwater Level (mAHD)
Cummulative Rainfall Departure (mm)
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
B334(BFS)
B334(BFS)_data logger
B631(BFS)
B631(BFS)_data logger
C130(BFS)
C317(BFS)
C621(BFS)
C630(BFS)
B925(BFS)
Wollombi Brook - Station 210004
B925(BFS)_data logger
CRD HVO. Corp. Met.


Bowfield Seam - Lemington South Pit: NorthVoid
Groundwater Level (mAHD)
Cummulative Rainfall Departure (mm)
55
53
51
49
47
45
43
41
39
37
35
33
31
29
27
25
23
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
C613(BFS)
D010(BFS)
D510(BFS)
D510(BFS)_data logger
D214(BFS)
D317(BFS)
D406(BFS)
D612(BFS)
D807(BFS)
Wollombi Brook - Station 210004
CRD HVO. Corp. Met.



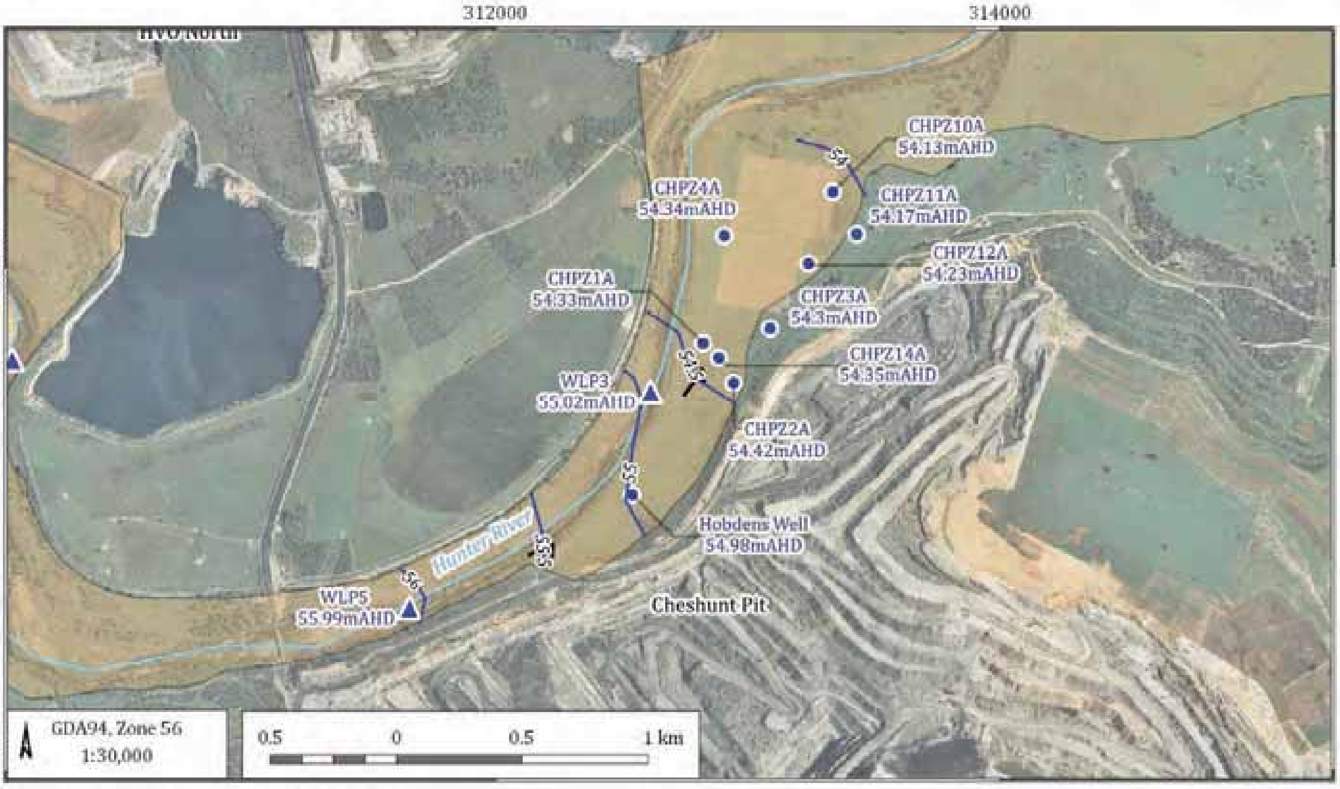
Woodlands Hill Seam and Glen Munro Seam - Lemington
Groundwater Level (mAHD)
Cummulative Rainfall Departure (mm)
55
53
51
49
47
45
43
41
39
37
35
33
31
29
27
25
23
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
B425(WDH)
B631(WDH)
C122(WDH)
C130(WDH)
C317(WDH)
C809 (GM/WDH)
D010(WDH)
Wollombi Brook - Station 210004
D010(GM) (Glen Munro Seam)
CRD HVO. Corp. Met.



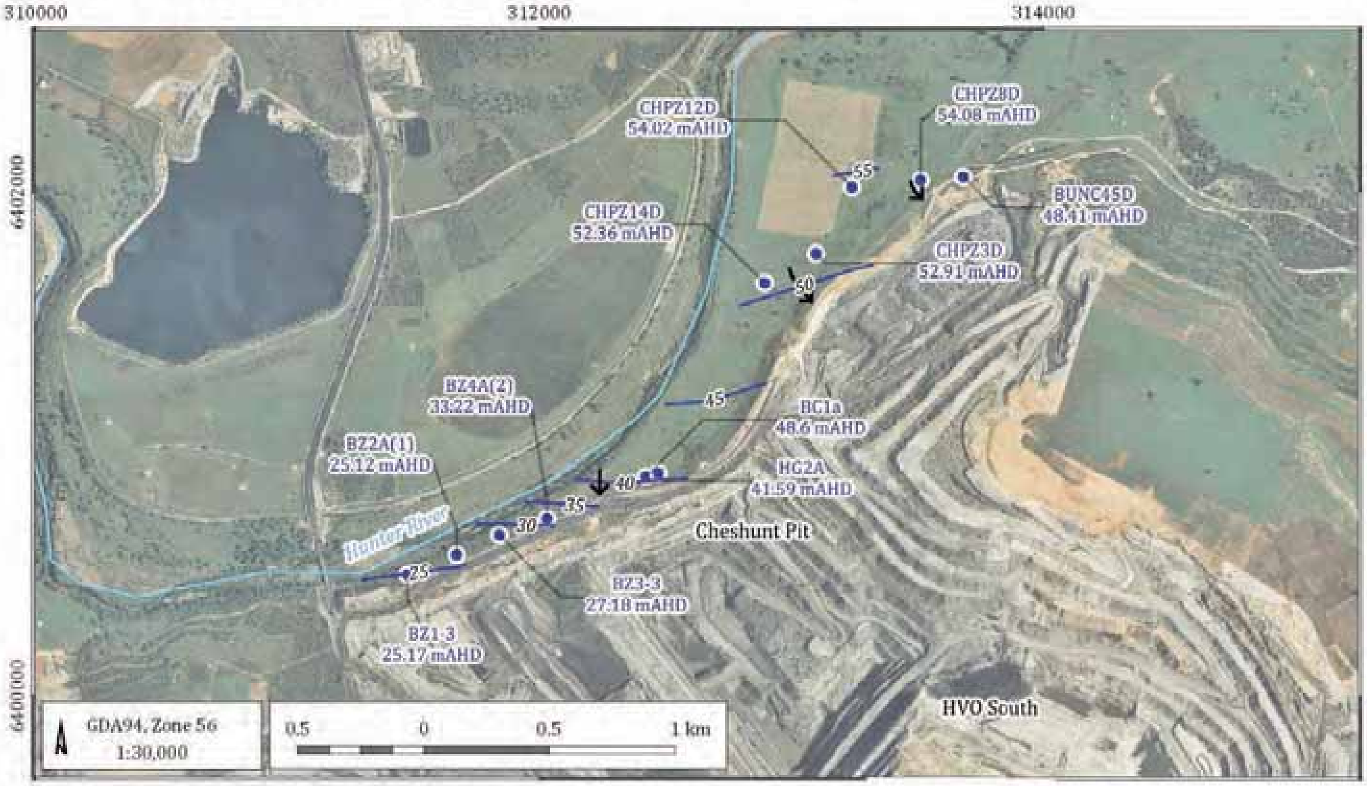
Interburden and Coal Seam - Lemington
Groundwater Level (mAHD)
57
55
53
51
49
47
Cummulative Rainfall Departure (mm)
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan 14
Jul 14
Jan 15
Jul 15
D010(GM) (Glen Munro Seam)
C130(ALL) (interburden)
Wollombi Brook - Station 210004
CRD HVO. Corp. Met.

Appendix E Groundwater contours

Alluvium groundwater contours



Mt Arthur Seam groundwater contours



LEGEND

- ▲ Surface water monitoring sites
- ● Groundwater monitoring bore, Observed water level (mAHD)
- → Groundwater flow direction
- Groundwater contour, Interpolated water level (mAHD)
- Quaternary alluvium (1:25k AGE)
- Major drainage

HVO South - 2015 Annual Groundwater Impacts Review (G1810)

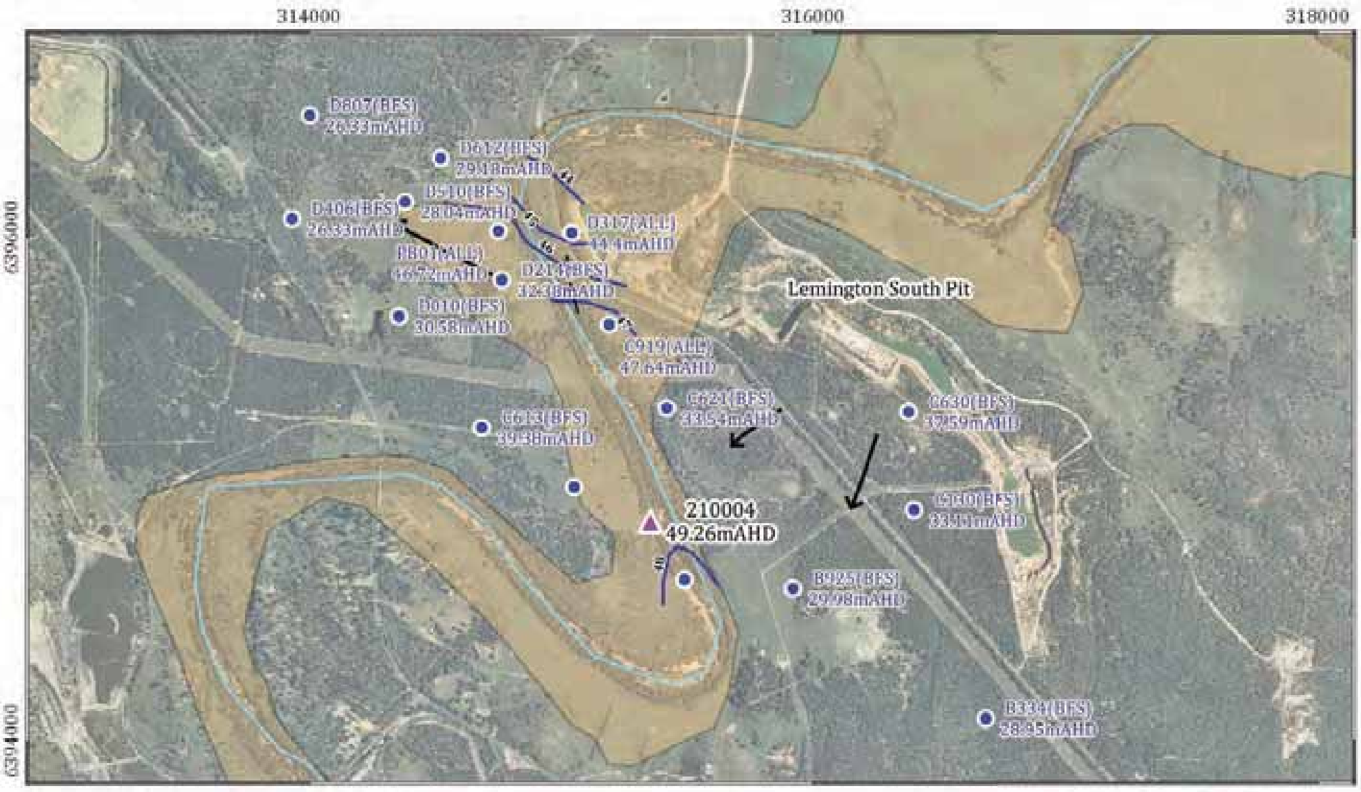
Cheshunt Pit groundwater contours

AGE

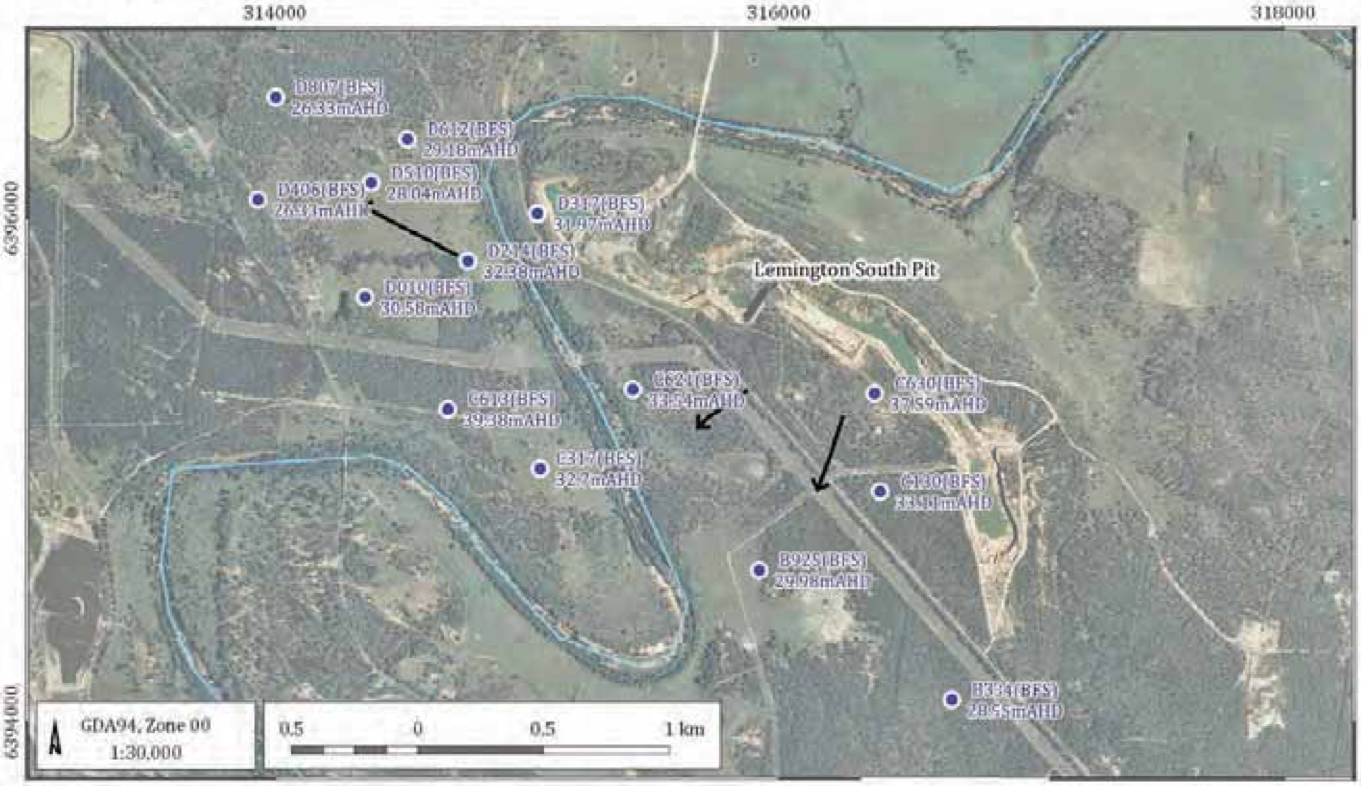
DATE: 22/02/2016

FIGURE No: **E-1**

Alluvium groundwater contours



Bowfield Seam groundwater contours



LEGEND

- ▲ Surface water monitoring sites
- ● Groundwater monitoring bore, Observed water level (mAHD)
- Groundwater contour, Interpolated water level (mAHD)
- Groundwater flow direction
- Quaternary alluvium (1:25k AGE)
- Major drainage

HVO South - 2015 Annual Groundwater Impacts Review (G1810)

Lemington South groundwater contours

DATE: 22/02/2016

FIGURE No: **E-2**

Appendix F Flow loss calculations assumptions

In order to apply Darcy's Law, several assumptions were made in order to calculate the hydraulic conductivity (K), hydraulic gradient (i) and area (A). These assumptions are detailed below.

Hydraulic Conductivity (K)

Geological cross-sections from the MER report show that the Quaternary alluvium unconformably overlies the shallow dipping Permian coal measures. This has resulted in variability in the thickness and composition of interburden between the alluvium and coal seams. This natural variation creates a level of complexity in the calculations that are not dealt with using Darcy's Law. Several numerical groundwater models have been undertaken around the project area that include this complexity; however, there is a degree of variability in the hydraulic conductivities used in the models (refer to Table F 1). From Table F 1, the values from Rust PPK (1997) relate to the Bowfield Seam (BFS) at Lemington South Pit 1, while MER (2005 and 2010) and AGE (2010b) relate to the Mount Arthur Seam (MTA).

Vertical groundwater leakage from the alluvium into the main coal seam for Cheshunt Pit northern area and Lemington South Pit was calculated using the vertical hydraulic conductivity (Kz) for the intervening interburden, sourced from Rust PPK (1997). In the Cheshunt Pit area, it has been documented that in places, the MTA sub-crops beneath the alluvium (MER, 2005 and Groundsearch Australia, 2008). To reflect this variability in stratigraphy, the Kz used in the calculations, for vertical discharge from the alluvium to the coal seam was 1x10-3 m/day, compared to 1x10-4 m/day used for Cheshunt Pit North and Lemington South Pit.

Vertical groundwater leakage from the alluvium to the MTA through the anticline structure at Cheshunt Pit was based on values presented by MER (2005) and AGE (2010b). This conservative estimate was carried out to account for faulting and sub-cropping of the coal measures beneath the alluvium and any additional recharge through the anticline.

Horizontal groundwater discharge from the MTA coal seam into Cheshunt Pit , and from the BFS into Lemington South Pit, were calculated using a horizontal hydraulic conductivity (Kxy) of 0.05 m/day from Rust PPK (1997). Horizontal groundwater discharge from the MTA seam into Cheshunt Pit anticline was based on estimated pump rates of between 5L/s - 20L/s, (giving an estimated horizontal conductivity of 2.3 to 9.1 m/day) documented by JP Environmental (2011b). This is considered to be a conservative estimate, as the pump rates encompass incident rainfall and seepage from adjacent pit areas, as well as limiting factors due to part pump flow and flow meter calibration, which would cause over estimation of anticline inflow rates.

Table F 1 Hydraulic properties

KDirection	Target	Rust PPK, 1997 (m/day)	MER, 2005 (m/day)	MER, 2010 (m/day)	AGE, 2010b (m/day)	Value Used (m/day)
K_{XY}	Coal Seam	0.05	0.041	3.7×10^{-3}	-	0.05
	Alluvium	-	0.86	1 – 95†	0.2 – 1.6‡	0.86
K_Z	Coal Seam	1×10^{-03}	1.2×10^{-03}	2.10×10^{-6}	-	1×10^{-3}
	Interburden (above Coal Seams)	1×10^{-04}	2.0×10^{-5}	-	1×10^{-05}	1×10^{-4}
	Alluvium	-	0.86	1	-	0.86

Note: † *Average of Permian Coal Measure (PCM) Layers 2 to 5 (MER, 2010)*

K_{xy}: Horizontal permeability

K_z: Vertical hydraulic conductivity

Hydraulic Gradient (*i*)

The hydraulic gradient has been calculated using groundwater levels taken during August 2015 for Cheshunt Pit and September 2015 for Lemington South Pit. Equation 2 was used to calculate the horizontal hydraulic gradient (ixy) by calculating the head difference between bores BZ1-3 (Cheshunt - Money Box Pit), BZ3-3 (Cheshunt anticline), BZ2A (1) (Cheshunt Pit), BUNC45D, CHPZ14D, CHPZ8D (Cheshunt Pit Northern Area) and D317 (BFS) (Lemington South Pit 1), and the pit floor elevation (encompassing all coal seams). Pit floor elevations were derived from cross-sections in the MER (2005) report (Appendix 2). The results are summarised in Table F 2.

Horizontal Hydraulic Gradient Equation:

$$i_{xy} = \frac{\Delta h}{\Delta L} = \frac{h_2 - h_1}{length} \qquad \textit{(Equation 2)}$$

where:

i_{xy}	is the horizontal hydraulic gradient (dimensionless)
Δh	is the difference between the hydraulic heads (m)
ΔL	is the flow path length between the piezometer and edge of the pit (m)

Equation 3 was used to calculate the vertical hydraulic gradient (iz) between the alluvium and the coal seam. Since coal seam bores BZ1-3, BZ3-3, and BZ2A (1) are not nested with alluvial bores, the groundwater elevation in the alluvial aquifer was estimated from nearby bores screened in the alluvial aquifer.

Bore D317 (ALL) is a dry bore, a conservative estimate using the base of D317 (ALL) as the SWL in the alluvium has been applied, and the thickness of the alluvium has been estimated at 20 m. The results are summarised in Table F 3. Where completion data was not available, the base of the alluvium was assumed to be equivalent to the total depth of the alluvial bores. The surface of the coal seam was derived from cross-sections in the MER (2005) report.

Vertical Hydraulic Gradient Equation:

$$i_z = \frac{\Delta h}{\Delta L} \qquad \textit{(Equation 3)}$$

where:

i_z	is the vertical hydraulic gradient (dimensionless),
Δh	hydraulic head in the alluvial bore (mRL) minus the hydraulic head in the coal seam bore (mRL),
ΔL	thickness of interburden calculated from the depth of the alluvial bore (assumed as the base of the alluvium (mRL) minus the estimated depth to the base of the Permian overburden (mRL).

Table F 2 Horizontal hydraulic gradients

Location	Coal Seam Bore	Pit	Distance from Bore to Discharge Point/Pit (m)	Bore GWL (mAHD)	Discharge Point/Pit Elevation (mAHD)	Horizontal Hydraulic Gradient (iXY)	Adopted Horizontal Hydraulic gradient (iXY)
Cheshunt - Money Box Pit	BZ1-3	Riverview Pit	150	25.17	-40	0.43	0.43
Cheshunt Pit Anticline	BZ3-3	Riverview Pit	150	27.18	-40	0.45	
Cheshunt Pit - East	BZ2A(1)	Cheshunt Pit	145	25.12	-20	0.31	
Cheshunt Pit Northern Area	Bunc45D	Barry's Void	140	48.41	0	0.35	
	CHPZ14D	Barry's Void	250	52.36	0	0.21	
	CHPZ8D	Barry's Void	220	54.08	0	0.25	
Lemington South Pit 1	D317(BFS)	Lemington Sth 1	50	31.73	-20	1.03	

Table F 3 Vertical hydraulic gradients

Location of Nested Piezometer Bores	Alluvial Bore	Coal Seam Bore	Elevation of base of alluvium (mAHD)	Elevation of top of coal (mAHD)	Depth to base of alluvium minus depth to coal ΔL (m)	Groundwater elevation in alluvium bore (mAHD)	Groundwater level in coal seam bore (mAHD)	Hydraulic head difference Δh (m)	Vertical Hydraulic Gradient (iz)
Cheshunt - Money Box Pit	BZ1-1	BZ1-3	50.78	15	35.78	54.3	25.17	29.13	0.81
Cheshunt Pit Anticline	BZ3-1	BZ3-3	50	15	35	54.67	27.18	27.49	0.79
Cheshunt Pit	BZ2A(2)	BZ2A(1)	50	20	30	54.5	25.12	29.38	0.98
Cheshunt Pit Northern Area	CHPZ14A	CHPZ14D	55	42	13	54.35	52.36	1.99	0.15
	CHPZ8A	CHPZ8D	55	42	13	54.16	54.08	0.08	0.01
	Bunc45A	Bunc45D	52	49	3	51.89	48.41	3.48	1.16
Lemington South Pit 1	D317(ALL)*	D317(BFS)	39	20	19	44.4	31.73	12.67	0.67

Note:

SWL - Standing Water Level

***Depth to base of alluvium at Lemington Sth Pit 1 based on conservative 20 m thickness, SWL in alluvium base of D317(ALL)*

BZ1-1, BZ3-1, BZ2A(2) and BUNC45A are screened within the interburden, water level in BZ2A(2) assumed 54.50 mAHD

Area (A)

The area (A) used to calculate leakage of alluvial groundwater into coal measures (Qz) was based on the length of the pit wall and the width of the alluvium. The width of the alluvium was estimated from aerial photography measurements of the distance between the Hunter River or Wollombi Brook and the edge of the pit wall. This method of calculating area is considered to be conservative, as the extent of alluvium was interpreted based on 1:25,000 geological mapping, which has locally been found to over-estimate the extent of alluvium (Groundsearch Australia, 2006).

The area (A) used to calculate leakage of coal seam groundwater into the pits (Qxy) was calculated based on the length of the pit wall and the thickness of the target coal seam (MTA and BFS). The coal seam width was derived from cross-sections by MER (2005). Mining at Cheshunt Pit and Lemington South Pit accessed underlying coal seams. The thickness values used were only based on the MTA and BFS Seams respectively, due to limited availability of groundwater data for other seams. This may result in under-estimation of total flow loss (Qxy); however, AGC (1984) and MER (2002) have stated that the hydraulic conductivity in the coal measures reduces with depth.

The area (A) used to calculate vertical and horizontal leakage associated with the anticline structure on the northern high-wall of Cheshunt Pit, was based on observations made in the field. It was estimated that the main area of influence along the crest of the anticline and associated faulting is approximately 10 m wide and 40 m high (from the top of the coal seam to the pit floor). The 250 m width of alluvium was based on the distance from the high-wall to the Hunter River. This is illustrated in Figure F 1.

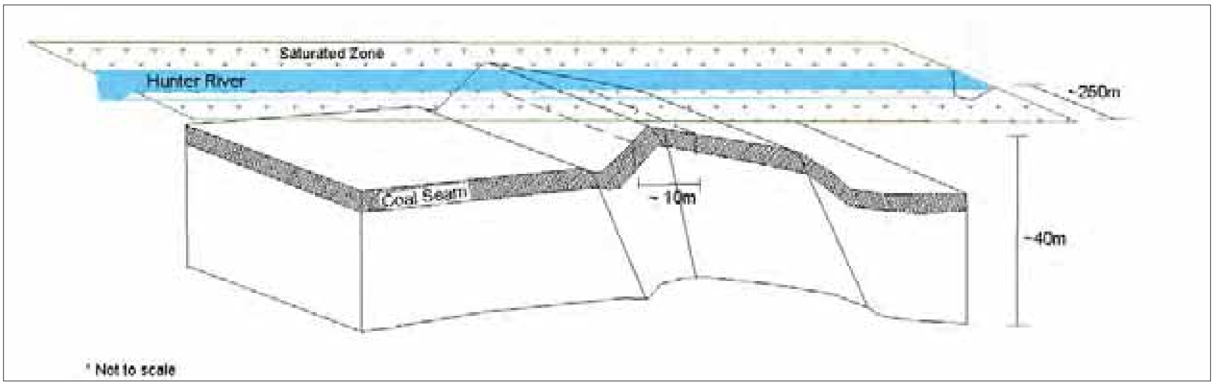


Figure F 1 Schematic showing Cheshunt Pit anticline

Appendix G Flow loss calculations

Groundwater Flow Calculations (using August groundwater levels)

Vertical Hydraulic Gradient Calculation (iz)

Location of Nested Piezometer Bores	Alluvial Bore	Coal Seam Bore	Elevation of base of alluvium (mAHD)	Elevation of top of coal (mAHD)	Depth to base of alluvium minus depth to coal ΔL (m)	Groundwater elevation in alluvium bore (mAHD)	Groundwater level in coal seam bore (mAHD)	Hydraulic head difference Δh (m)	Vertical Hydraulic Gradient (i_z)
Cheshunt - Money Box Pit	BZ1-1	BZ1-3	50.8	15.0	35.8	54.3	25.17	29.13	0.81
Cheshunt Pit Anticline	BZ3-1	BZ3-3	50.0	15.0	35.0	54.67	27.18	27.49	0.79
Cheshunt Pit	BZ2A(2)	BZ2A(1)	50.0	20.0	30.0	54.5	25.12	29.38	0.98
Cheshunt Pit Northern Area	CHPZ14A	CHPZ14D	55.0	42.0	13.0	54.35	52.36	1.99	0.15
	CHPZ8A	CHPZ8D	55.0	42.0	13.0	54.16	54.08	0.08	0.01
	Bunc45A	Bunc45D	52.0	49.0	3.0	51.89	48.41	3.48	1.16
Lemington South Pit 1	D317(ALL)*	D317(BFS)	39.0	20.0	19.0	44.4	31.73	12.67	0.67

Note: *Depth to base of alluvium at Lemington Sth Pit 1 based on conservative 20 m thickness, SWL in alluvium base of D317(ALL)

Note: BZ1-1, BZ3-1,BZ2A(2) and BUNC45A are screened within the interburden, water level in BZ2A(2) assumed 54.5 mAHD

Horizontal Hydraulic Gradient Calculation (ixy)

Location	Coal Seam Bore	Pit	Distance from Bore to Discharge Point/Pit (m)	Bore GWL (mAHD)	Discharge Point/Pit Elevation (mAHD)	Horizontal Hydraulic Gradient (i_{XY})	Adopted Horizontal Hydraulic gradient (iXY)
Cheshunt - Money Box Pit	BZ1-3	Riverview Pit	150	25.17	-40	0.43	0.43
Cheshunt Pit Anticline	BZ3-3	Riverview Pit	150	27.18	-40	0.45	
Cheshunt Pit - East	BZ2A(1)	Cheshunt Pit	145	25.12	-20	0.31	
Cheshunt Pit Northern Area	Bunc45D	Cheshunt Pit	140	48.41	0	0.35	
	CHPZ14D	Cheshunt Pit	250	52.36	0	0.21	
	CHPZ8D	Cheshunt Pit	220	54.08	0	0.25	
Lemington South Pit 1	D317(BFS)	Lemington Sth 1	50	31.73	-20	1.03	

Vertical Leakage from Target Coal Seam to Pit (Qz)

Leakage from Alluvium to Target Coal Seam	Location	Flow Direction	Vertical Hydraulic Conductivity of Interburden Above Coal Seam K_Z (m/d)	Vertical Hydraulic Gradient (i_z)	Pit Wall Length (m)	Width of Alluvium (m)	Vertical Discharge from Alluvial to Coal Seams Q_Z (L/s)	Vertical Discharge from Alluvial to Coal Seams Q_Z (ML/d)
Mt Arthur	Cheshunt - Money Box Pit	Vertical	0.001	0.81	650	250	1.5	0.13
Mt Arthur	Cheshunt Pit Anticline	Vertical	1.00	0.79	10	250	22.7	1.96
Mt Arthur	Cheshunt Pit	Vertical	0.001	0.98	1,010	250	2.9	0.25
Mt Arthur	Cheshunt Pit Northern Area	Vertical	0.0001	0.44	1,100	250	0.1	0.01
						Cheshunt Area Total	27.3	2.36
Bowfield	Lemington South Pit 1	Vertical	0.0001	0.67	350	360	0.1	0.01

Horizontal Leakage From Alluvium to Target Coal Seam (Qxy)

Leakage from Target Coal Seam to Pit	Location	Flow Direction	Horizontal Hydraulic Conductivity of Coal Seam K_{XY} (m/d)	Horizontal Hydraulic Gradient (i_{XY})	Pit Wall Length (m)	Coal Seam Thickness (m)	Horizontal Discharge from Coal Seams to Pit Q_{XY} (L/s)	Horizontal Discharge from Coal Seams to Pit Q_{XY} (ML/d)	Percentage of Pit Inflow from Alluvium Q_Z/Q_{XY} (%)
Mt Arthur	Cheshunt - Money Box Pit	Horizontal	0.05	0.43	650	10	2	0.14	94%
Mt Arthur	Cheshunt Pit Anticline	Horizontal	2.3 - 9.1	0.45	10	40	4.8 - 18.9	0.41 - 1.63	~99%
Mt Arthur	Cheshunt Pit	Horizontal	0.05	0.31	1,010	10	2	0.16	~99%
Mt Arthur	Cheshunt Pit Northern Area	Horizontal	0.05	0.27	1,100	10	2	0.15	8%
						Cheshunt Area Total	9.9-24.0	0.9-2.1	-
Bowfield	Lemington South Pit 1	Horizontal	0.05	1.03	350	7	1	0.13	7%

Notes

i_{XY}	Horizontal hydraulic gradient
i_Z	Vertical hydraulic gradient. Head difference between nested bores.
K_{XY}	Horizontal hydraulic conductivity (m/d)
K_Z	Vertical hydraulic conductivity (m/d)
Q_{XY}	Estimated leakage of groundwater from target coal seams into pits (ML/d)
Q_Z	Estimated leakage groundwater from alluvium, through the interburden and into target coal seams (ML/d)

Groundwater Flow

Q=KiA

Q	Discharge (m^3/d)
K	Hydraulic Conductivity (m/d)
i	Hydraulic Gradient
A	Area Intersected (m^2)

Appendix H LUG Bore monitoring data

Table H 1 Summary of monitoring bores near LUG Bore

Bore ID	Easting	Northing	Ground elevation (mAHD)	Collar height (maGL)	Bore depth (mbGL)	Top of screen (mbGL)	Base of screen (mbGL)	Lithological description
Appleyard Farm	315491	6394639	43.4	0.8	10.0	7.0	10.0	Alluvium
C919(ALL)	315192	6395655	58.0	0.3	11.5	-	-	Alluvium
D317(ALL)	315044	6396018	59.5	0.3	14.7	9.2	12.2	Alluvium
PB01(ALL)	314754	6396026	55.0	-	-	-	-	Alluvium
C130(AFS1)	316400	6394916	63.0	0.3	42.2	-	-	Arrowfield Seam
D406(AFS)	313931	6396074	57.0	0.3	-	-	-	Arrowfield Seam
D510(AFS)	314380	6396141	54.8	0.3	30.5	25.5	30.5	Arrowfield Seam
D612(AFS)	314524	6396314	62.0	0.4	0.0	-	-	Arrowfield Seam
B334(BFS)	316684	6394088	73.0	0.3	51.8	58.5	-	Bowfield Seam
B631(BFS)	316425	6394319	72.0	0.3	36.1	78.0	-	Bowfield Seam
B925(BFS)	315921	6394604	65.0	0.4	41.2	81.0	-	Bowfield Seam
C130(BFS)	316400	6394916	63.0	0.0	64.5	55.0	61.0	Bowfield Seam
C317(BFS)	315054	6395007	60.0	0.4	76.2	-	-	Bowfield Seam
C613(BFS)	314688	6395243	63.0	0.3	85.5	-	-	Bowfield Seam
C621(BFS)	315421	6395321	58.0	0.3	57.5	-	-	Bowfield Seam
C630(BFS)	316378	6395306	69.0	0.3	49.1	-	-	Bowfield Seam
D010(BFS)	314355	6395687	56.0	0.4	68.1	-	-	Bowfield Seam
D214(BFS)	314768	6395831	56.5	0.3	53.5	43.0	52.5	Bowfield Seam
D317(BFS)	315043	6396019	59.5	0.3	44.0	39.0	44.2	Bowfield Seam
D406(BFS)	313931	6396074	57.0	0.3	61.3	-	-	Bowfield Seam
D510(BFS)	314380	6396141	54.8	0.3	38.0	34.0	38.0	Bowfield Seam
D612(BFS)	314524	6396314	62.0	0.3	35.1	-	-	Bowfield Seam
D807(BFS)	314002	6396484	59.7	0.4	41.0	36.0	41.0	Bowfield Seam
D010(GM)	314355	6395687	56.0	-	-	-	-	Glen Munro Seam
C130(ALL)	316400	6394916	63.0	0.3	17.0	-	-	Interburden?
B425(WDH)	316010	6395024	58.0	-	55.0	-	-	Woodlands Hill Seam
B631(WDH)	316424	6394319	72.0	-	30.7	-	-	Woodlands Hill Seam
C122(WDH)	315501	6395007	58.0	0.3	22.7	-	-	Woodlands Hill Seam
C130(WDH)	316400	6394916	63.0	0.4	21.6	-	-	Woodlands Hill Seam
C317(WDH)	315054	6395007	60.0	0.2	33.9	-	-	Woodlands Hill Seam
C809 (GM/WDH)	314207	6395493	59.0	0.3	28.7	28.0	38.0	Woodlands Hill Seam
D010(WDH)	314355	6395687	56.0	0.3	17.0	-	-	Woodlands Hill Seam

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Appendix 3

Rehabilitation Tables

Annual Rehabilitation Report Form, Rehabilitation Maps and Rehabilitation Summary

Annual Rehabilitation Report Form – Mines
Year Ending: 2015
Mine: Hunter Valley Operations
Company: Rio Tinto Coal Australia – Coal and Allied
Plans Attached:
Hunter Valley Operations – AEMR 2015
Approved Mining Operations Plan:
HVO South MOP (2016 – 2018) – Approval Date 17/12/2015
HVO North MOP (2016 – 2018) – Approval Date 6/09/2012
Total Area Covered by Mining Operations Plan:
HVO North MOP – 5,434ha
HVO South MOP – 5,221ha
Total Area Covered by Mining Lease for This Mine: 10,655ha

Table 1: Rehabilitation Progress 2015
HVO North includes Newdell

Rehabilitation Activity Type	Domain Identifier	Primary Domain	Secondary Domain	Total Area Last Reported (ha)	Total Area to date (ha)
1.1 Active mining and infrastructure area, facilities, including roads and tracks	1A	Final Void	Final Void	194.5	211.19
	2B	Water Management Areas	Water Management Areas	19.5	16.19
	3D	Infrastructure Area	Rehabilitation Area - Pasture	58.6	166.6
	3E	Infrastructure Area	Rehabilitation Area - Woodland	3	3.56
	4D	Tailings Storage Facility	Rehabilitation Area - Pasture	68.7	113.11
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland	96.2	62.64
	5D	Overburden Emplacement Area	Rehabilitation Area - Pasture	835.1	718.27
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland	500.7	674.17
	5F	Overburden Emplacement Area	Rehabilitation Area - Class 2 and 3 Land	0.0	2.76

	Outside Domain Area	N/A - Outside Domain Boundary	N/A - Outside Domain Boundary	0.0	40.21
	Total Active			1776.3	2008.7
1.2 Decommissioning	Total - Decommissioning			0.0	0
1.3 Landform Establishment	Total - Landform Establishment			0 (Included in 1.1)	(Included in 1.1)
1.4 Growth Medium Development	Total - Growth Medium Development			0 (Included in 1.1)	(Included in 1.1)
1.5 Ecosystem and Land Use Establishment	1A	Final Void	Final Void	0	7.48
	3D	Infrastructure Area	Rehabilitation Area - Pasture	0	0
	4D	Tailings Storage Facility	Rehabilitation Area - Pasture	0.3	0.00
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland	0	0.27
	5D	Overburden Emplacement Area	Rehabilitation Area - Pasture	72.2	141.16
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland	18.4	80.67
	Total - Ecosystem and Land Use Establishment			90.9	229.58
1.6 Ecosystem and Land Use Development	1A	Final Void	Final Void	4.7	0
	3D	Infrastructure Area	Rehabilitation Area - Pasture	37.9	0
	4D	Tailings Storage Facility	Rehabilitation Area - Pasture	52.2	93.91
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland	18	28.28
	5C	Overburden Emplacement Area	Rehabilitation Area - Class 1 and 2 Land	72.3	72.3
	5D	Overburden Emplacement Area	Rehabilitation Area - Pasture	1144.8	918.47
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland	354	469.71
	Total - Ecosystem and Land Use Development			1865.7	1582.67
1.7 Rehabilitation Complete	Total - Rehabilitation Complete			0	0
1.8 Total Area Disturbed (items 1.1 to 1.7)	1A	Final Void	Final Void	199.2	218.67
	2B	Water Management Areas	Water Management Areas	16.2	16.19
	3D	Infrastructure Area	Rehabilitation Area - Pasture	96.5	166.6

	3E	Infrastructure Area	Rehabilitation Area - Woodland	3	3.56
	4D	Tailings Storage Facility	Rehabilitation Area - Pasture	121	207.02
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland	114.3	91.19
	5C	Overburden Emplacement Area	Rehabilitation Area - Class 1 and 2 Land	72.3	72.30
	5F	Overburden Emplacement Area	Rehabilitation Area - Class 2 and 3 Land	0	2.76
	5D	Overburden Emplacement Area	Rehabilitation Area - Pasture	2053.7	1777.9
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland	871.6	1224.55
	Outside Domain Area	N/A - Outside Domain Boundary	N/A - Outside Domain Boundary	0	40.21
	Total Footprint			3547.8	3820.95

HVO South

Rehabilitation Activity Type	Domain Identifier	Primary Domain	Secondary Domain	Total Area Last Reported (ha)	Total Area to date (ha)
1.1 Active mining and infrastructure area, facilities, including roads and tracks	1A	Final Void	Final Void	NA	264.26
	2B	Water Management Areas	Water Management Areas	NA	20.29
	3D	Infrastructure Area	Rehabilitation Area - Pasture	NA	99.67
	3E	Infrastructure Area	Rehabilitation Area - Woodland	NA	8.12
	4D	Tailings Storage Facility	Rehabilitation Area - Pasture	NA	1.94
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland	NA	8.4
	5D	Overburden Emplacement Area	Rehabilitation Area - Pasture	NA	732.72
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland	NA	584.34
	Total Active			1545.3	1719.7
1.2 Decommissioning	Total - Decommissioning			0.0	0

1.3 Landform Establishment	Total - Landform Establishment			0 (Included in 1.1)	25.69 (Included in 1.1)
1.4 Growth Medium Development	Total - Growth Medium Development			0 (Included in 1.1)	6.02 (Included in 1.1)
1.5 Ecosystem and Land Use Establishment	3D	Infrastructure Area	Rehabilitation Area - Pasture	NA	0
	4D	Tailings Storage Facility	Rehabilitation Area - Pasture	NA	18.21
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland	NA	40.74
	5D	Overburden Emplacement Area	Rehabilitation Area - Pasture	NA	236.15
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland	NA	132.52
	Total - Ecosystem and Land Use Establishment			102.1	427.62
1.6 Ecosystem and Land Use Development	1A	Final Void	Final Void	NA	0
	3D	Infrastructure Area	Rehabilitation Area - Pasture	NA	0.69
	4D	Tailings Storage Facility	Rehabilitation Area - Pasture	NA	21.73
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland	NA	17.71
	5D	Overburden Emplacement Area	Rehabilitation Area - Pasture	NA	222.71
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland	NA	230.84
	Total - Ecosystem and Land Use Development			862.7	493.68
1.7 Rehabilitation Complete	Total - Rehabilitation Complete			0	0
1.8 Total Area Disturbed (items 1.1 to 1.7)	1A	Final Void	Final Void	NA	264.26
	2B	Water Management Areas	Water Management Areas	NA	20.29
	3D	Infrastructure Area	Rehabilitation Area - Pasture	NA	100.36
	3E	Infrastructure Area	Rehabilitation Area - Woodland	NA	8.12
	4D	Tailings Storage Facility	Rehabilitation Area - Pasture	NA	41.88
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland	NA	66.85
	5D	Overburden Emplacement Area	Rehabilitation Area - Pasture	NA	1191.58
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland	NA	947.7

Total Footprint	2509.9	2641.04

Note: Primary and Secondary Domains were developed for HVO South MOP in 2015

Table 2: Soil Management and Erosion, 2015

	Soil Used This Period (m3)	Soil Pre-stripped This Period (m3)	Soil Stockpiled to Date (m3)	Soil Stockpiled Last Report (m3)
2.1 Soil Stockpiling/Use	129,000	172,900	1,798,013	1,841,913
	Total Area to Date	**Total Area Last Report (ha)**	**Total Area This Report (ha)**	**Area Retreated This Period (ha)**
2.2 Erosion Treatment	Not Available	Not Available	5.7	
Approx. area of sheet or gully erosion requiring reshaping, topdressing and/or resowing	Not Available			

Table 3: Weed Control

3.1 Approx. area adversely affected by weeds as of the date of this report	Not Available
3.2 Area treated for weed control during the period covered by the report	516.8
3.3 Give summary of control strategies used and verification by approval agency(s)	Species targeted in rehabilitation areas during 2015 included: galenia, African boxthorn, mother of millions, opuntia species (pear), castor oil, and golden dodder.

Table 4: Management of Rehabilitation Areas

4.1 Area treated with maintenance fertiliser	89ha
4.2 Area treated by rotational grazing, cropping or slashing	1,003ha

Give Summary	719ha HVO North rehabilitation area licence agreement in place for grazing. Temporary grazing licences aimed at reducing fuel loads are in place for a further 212ha of rehabilitated land across HVO North.

Table: 5 Variations to Rehabilitation Program

Has rehabilitation work proceeded generally in accordance with the conditions of an accepted Mining Operations Plan.	HVO North - Substantially HVO South – Yes
If not please cite any approval granted for variations, or briefly describe the seasonal conditions or other reasons for any changes and the nature of any changes which have been made.	Actual rehabilitation completed in HVO North during period 2012 to 2015 = 239.2ha. MOP target for rehabilitation in HVO North during period 2012 to 2015 = 328.7ha. Spoil dump areas at Carrington that were planned to be rehabilitated in the HVO North MOP by the end of 2015 have not been completed due to uncertainty surrounding the possible interacting uses of Carrington as an in-pit tailings storage facility and evaporative sink. Dump progress in West Pit Centre Dump area has also been slower than the MOP forecast.

Table 6: Planned Operations During the Next Repot Period

6.1 Area estimated to be disturbed	468.9
6.2 Area estimated to be rehabilitated	57.5

Appendix 4

Rehabilitation and Disturbance Summary and Maps

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	Rehabilitation Summary
Cheshunt Barrys	Woodland	313,953.8 E 6,401,880.8 N	24.4	▪ The landform was constructed from a waste emplacement. ▪ Typical slope of the landform is 10 degrees with a primarily northerly aspect. ▪ Drainage is via westerly draining contours reporting to an engineered rock chute (to be constructed). ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Mixed waste compost (20.7ha) and Green Waste (timber mulch) (3.7ha) were applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included windrowing, rock picking, and aerating as required. ▪ Spring Summer Rehab Blend (millet/legume/herb) was broadcast into an aerated pattern at 36kg/ha.
Cheshunt RL155	Woodland	313,904.2 E 6,400,913.6 N	9.0	▪ Topsoil stockpile overlies the landform surface. The underlying landform was constructed from a waste emplacement. ▪ Typical slope of the landform is flat (0-2 degrees) and without dominant aspect. ▪ Drainage is via overland flow to adjacent active mine and rehabilitation areas according to localised informal drainage. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. Placed topsoils were shaped to a flat mound with gently sloping sides. ▪ Sandy clay loam soil from the topsoil stockpile surface was prepared as a growth medium. ▪ Mixed Waste Compost was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included rock picking and aerating as required.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	Rehabilitation Summary
				▪ Native Grass Mix was drilled into an aerated pattern at 20kg/ha.
Lemington South	Woodland	316,990.4 E 6,394,475.0 N	14.5	▪ The landform was constructed from a waste emplacement. ▪ The sloping area of the landform has South Westerly aspect with slopes of 8-10 degrees while the flat area (0-2 degrees) is without dominant aspect. ▪ Sloping areas are drained by contours, flat areas with occasional drainage swales or via overland flow. Drainage reports to formed drains and discharges to the Lemington Void storage. ▪ Landform surface preparation comprised bulk shaping, shallow ripping, rock raking, and removal of rock material as necessary. ▪ Loamy sand topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Green Waste was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included rolling, rock & timber picking, and aerating as required. ▪ Diverse Native Woodland Mix was drilled into an aerated pattern at 17kg/ha.
Riverview RL145	Woodland	311,061.7 E 6,398,463.1 N	6.2	▪ The landform was constructed from a waste emplacement. ▪ The area is typically flat (0-2 degrees) and without dominant aspect. ▪ Drainage is via overland flow. Drainage reports to formed drains which discharge to the Riverview Void storage. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from ahead of mining topsoil clearance was spread at a nominal thickness of 100mm. ▪ Mixed Waste Compost was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included windrowing, rock picking and aerating as required. ▪ Spring Summer Rehab Blend (millet/legume/herb) was broadcast into

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	Rehabilitation Summary
				an aerated pattern at 33kg/ha.
Riverview RL155	Woodland	312,260.9 E 6,397,994.7 N	2.4	▪ The landform was constructed from a waste emplacement. ▪ The area is flat plateau and without dominant aspect. ▪ Primary drainage is overland to the north-east and east, and subsequently via contour/drainage channel to engineered rock chute and basal dam. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from Glider Pit topsoil stripping was spread at a nominal thickness of 100mm. ▪ Mixed waste compost was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included windrowing, rock picking, and aerating as required. ▪ Autumn Winter Rehab Blend (oats/ryegrass/legume/herb) was broadcast into an aerated pattern at 85kg/ha.
Riverview Void Slope	Woodland	311861.2 E 6398101.4 N	8.5	▪ The landform was constructed from a waste emplacement. ▪ The landform is steeply sloping (13-14 degrees) with south-westerly aspect. ▪ Drainage is via westerly draining contours to an engineered rock chute which reports to the Riverview Void via further drains. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from Glider Pit topsoil stripping was spread at a nominal thickness of 100mm. ▪ Mixed waste compost was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included windrowing, rock picking, and aerating as required. ▪ Autumn Winter Rehab blend comprising (oats/ryegrass/legume/herb) was broadcast into an aerated pattern at 85kg/ha.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	Rehabilitation Summary
West Pit North	Woodland & Pasture	309,542.3 E 6,410,422.8 N	35.5	▪ The landform was constructed from a waste emplacement. ▪ The north-eastern area of the landform (~8ha) is predominantly sloping (10 degrees) with north-eastern aspect while the remainder of the area is flat plateau with localised variation and without dominant aspect. ▪ North-eastern area drainage is via northerly draining contours to an engineered rock chute which reports to the established downstream drainage network. Slope crests and near areas report to upper contours. Plateau drainage is overland flow to small drainage swales and drainage depressions. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Silty clay loam topsoils from a combination of West Pit North topsoil stripping and existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Mixed waste compost was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included windrowing, rock picking and aerating as required. ▪ Seasonal cover crops comprising Autumn Winter Cereal (barley/ryegrass, 8.7ha, 35kg/ha), Spring Summer Rehab Blend (millet/legumes/herbs, 21.8ha, 33kg/ha), and Summer Cereal (millet, 5.0ha, 30kg/ha) were drilled into an aerated pattern across successive releases.
West Pit South	Pasture	308,142.4 E 6,408,251.0 N	29.2	▪ The landform was constructed from a waste emplacement. ▪ The area is flat plateau without dominant aspect. ▪ The southern portion of the area drains overland to a drainage depression and then to an engineered rock chute. The chute reports to the existing lower contour drainage network. Overland drainage of the northern portion currently reports to adjacent mine areas via low lying drainage swales and drainage depressions. Integrated drainage of this area will be formalised with rehabilitation of adjacent areas.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	Rehabilitation Summary
				▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Silty Clay Loam topsoils from a combination of West Pit Centre topsoil stripping and existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Mixed waste compost was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included windrowing, rock picking and aerating as required. ▪ Seasonal cover crops comprising Spring Summer Rehab Blend (millet/legumes/herbs, 9.6ha, 33kg/ha), and Summer Cereal (millet, 19.6ha, 30kg/ha) were drilled into an aerated pattern across successive releases.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	Rehabilitation Summary
CD RL160	Woodland	319,432.7 E 6,389,893.7 N	6.7	▪ The landform was constructed from a waste emplacement. Topsoil stockpile overlies 5.0ha of the landform surface. ▪ The area is a flat plateau and without dominant aspect. ▪ Drainage is to local low lying areas or via overland flow to adjacent active mine and rehabilitation areas. Areas adjacent to the South Pit North slope crest drain to slope contours and then to the engineered rock chute. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from an existing topsoil stockpile was spread at a nominal thickness of 100mm across 1.7ha. Relocated clay loam topsoil from forward mine areas is stockpiled to 3m across the 5.0ha. ▪ Mixed waste compost was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included windrowing, rock picking, and aerating as required. ▪ Autumn Winter Cereal was drilled into an aerated pattern at 35kg/ha across 1.7ha. ▪ Spring Summer Rehab Blend (millet/legume/herb) was broadcast into an aerated pattern at 36kg/ha across 5.0ha (topsoil stockpile).
CD RL160 West	Woodland	319,053.9 E 6,389,938.9 N	7.2	▪ The landform was constructed from a waste emplacement. ▪ The area is a flat plateau with localised slope variation and without dominant aspect. ▪ Drainage is via overland flow and contour swales reporting to local drainage depressions and dams. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ A substrate of mine spoil was used for 4.6ha of the area. Clay loam topsoil from an existing topsoil stockpile was spread on the spoil base at a nominal thickness of 100mm across 2.6ha. ▪ Mixed Waste Compost (6.3ha) and Green Waste (0.9ha) were applied

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	Rehabilitation Summary
				at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included rock rolling, rock picking and aerating as required. ▪ Diverse Native Woodland Mix was drilled to 6.4ha of spoil/compost area at 18kg/ha. Autumn Winter cereal (barley/ryegrass) was drilled to topsoil areas at 35kg/ha. Spring Summer Rehab Blend (millet/legume/herb) was broadcast to 0.8ha of spoil/compost at 36kg/ha. All seeding was to an aerated surface pattern.
NOOP	Grassland	320,357.6 E 6,392,179.0 N	6.7	▪ The landform is *in-situ* natural subsoil (5.9ha) with a small adjacent area of waste emplacement toe (0.8ha). ▪ The area predominantly comprises flat to gentle sloping natural ground with minor slopes associated with the emplacement toe. All areas have easterly aspect. ▪ Drainage is via overland flow to adjacent dams. ▪ Landform surface preparation comprised bulk shaping and shallow ripping of the natural soil area, and bulk shaping, deep ripping, rock raking and removal of oversize rock material from the emplacement toe. ▪ A clay loam substrate of stockpiled topsoil was spread on the emplacement toe to a nominal depth of 100mm. Substrate of *in-situ* clay subsoil was retained in the area occurring. ▪ Green Waste was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included rock windrowing, rock picking, and aerating as required. ▪ Native Grass Mix was drilled into an aerated pattern at 20kg/ha.
South Pit North		320,625.9 E 6,389,909.3 N	13.8	▪ The landform was constructed from a waste emplacement. ▪ The area generally slopes to the east and north-east at 10 degrees with concave top upper slope areas of lesser steepness transitioning to the landform plateau adjacent west.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	Rehabilitation Summary
				▪ The area is drained by contours which flow to a centrally located engineered rock chute. The chute traverses the full slope length and reports to basal dams. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from an existing topsoil stockpile was spread at a nominal thickness of 100mm across the slope. ▪ Mixed Waste Compost was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included windrowing, rock picking, and aerating as required. ▪ Summer Cereal (millet) was broadcast into an aerated pattern at 36kg/ha.
Tailings Dam 1		319,648.1 E 6,392,392.8 N	41.0	▪ The landform is predominantly the engineered waste rock capping layer of a decommissioned Tailings Storage Facility (TSF). The capping landform extends into adjacent waste emplacement areas to the south and west, and onto the TSF embankment in the north and east. ▪ The area slopes gently (0.5-1.5% fall) to a central drainage channel (20% batter slopes fall, 0.8% longitudinal channel grade) which reports to dams external to the TSF footprint. Slopes at outer edges steepen to tie-in with the adjacent emplacement (concave slope tie-in) and embankment (convex slope tie-in) features. ▪ Drainage is via overland flow to the central drainage channel which reports to storage dams located to the south-east of the rehab area. ▪ Landform surface preparation comprised waste emplacement in two 2m layers, bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ A substrate of mine spoil was used for the 29.9ha comprising the substantive central areas of the former TSF. ▪ Clay loam topsoil from an existing topsoil stockpile was spread at a nominal thickness of 100mm across the remaining 11.1ha which

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	Rehabilitation Summary
				comprised edge areas and the central drainage channel. ▪ Mixed Waste Compost (37ha) and Green Waste (4ha) was applied at a rate of 100t/ha. ▪ Gypsum was applied at a rate of 10t/ha. ▪ Growth medium preparation included rock rolling, windrowing, rock picking, and aerating as required. ▪ Native Woodland Mix was drilled to 29.9ha of spoil/compost area at 18kg/ha. Spring Summer Rehab Blend (millet/legume/herb) was broadcast on topsoil areas at 36kg/ha. All seeding was to an aerated surface pattern.
Woodlands		319,890.7 E 6,388,349.3 N	0.4	▪ This area of rehab is an engineered rock chute only. ▪ The landform was constructed from a waste emplacement. ▪ The chute slopes to the south-east at 10 degrees. ▪ The chute receives runoff from south and east flowing contours located to the north and west respectively, and conveys waters to a basal surge dam which spills to South Pit South void. ▪ Landform surface preparation comprised bulk shaping, bulk and detailed excavation, surface compaction, geofabric installation and rock placement.

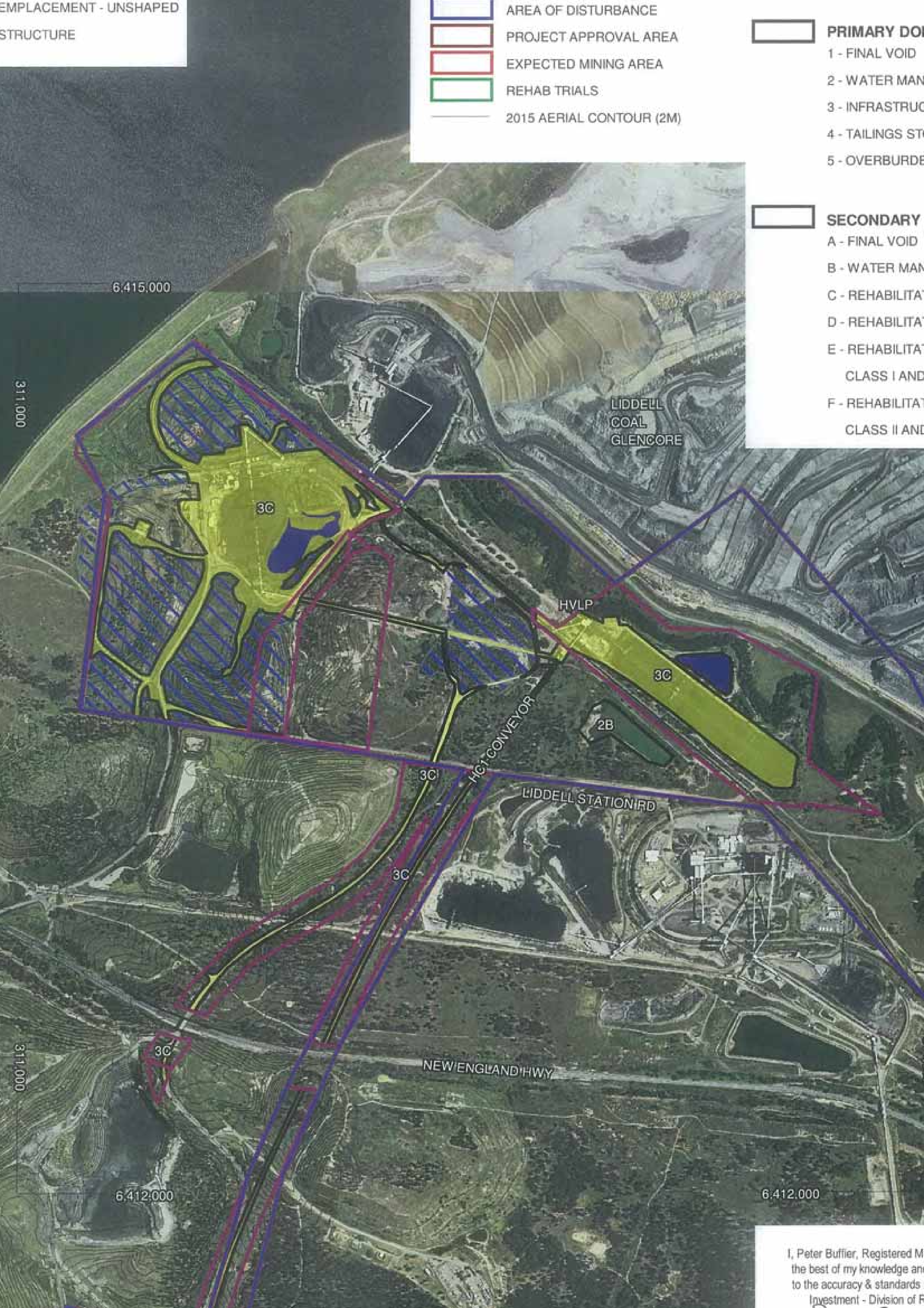
Autumn Winter Cereal Mix 1	Composition (%)
Oats	75
Italian Ryegrass	25

Autumn Winter Cereal Mix 2	Composition (%)
Schooner Barley	75
Italian Ryegrass	25

Autumn Winter Rehab Blend	Composition (%)
Yarran Oats	68
Italian Ryegrass	22
L91 Lucerne	5
Arrowleaf Clover	5

Spring Summer Cereal	Composition (%)
Rebound Millet	100

Spring Summer Rehab Blend	Composition (%)
Rebound Millet	58
Balance Chicory	5
Renegade Red Clover	8
L70 Lucerne	21
Burgundy Bean	8



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2 - WATER MAN
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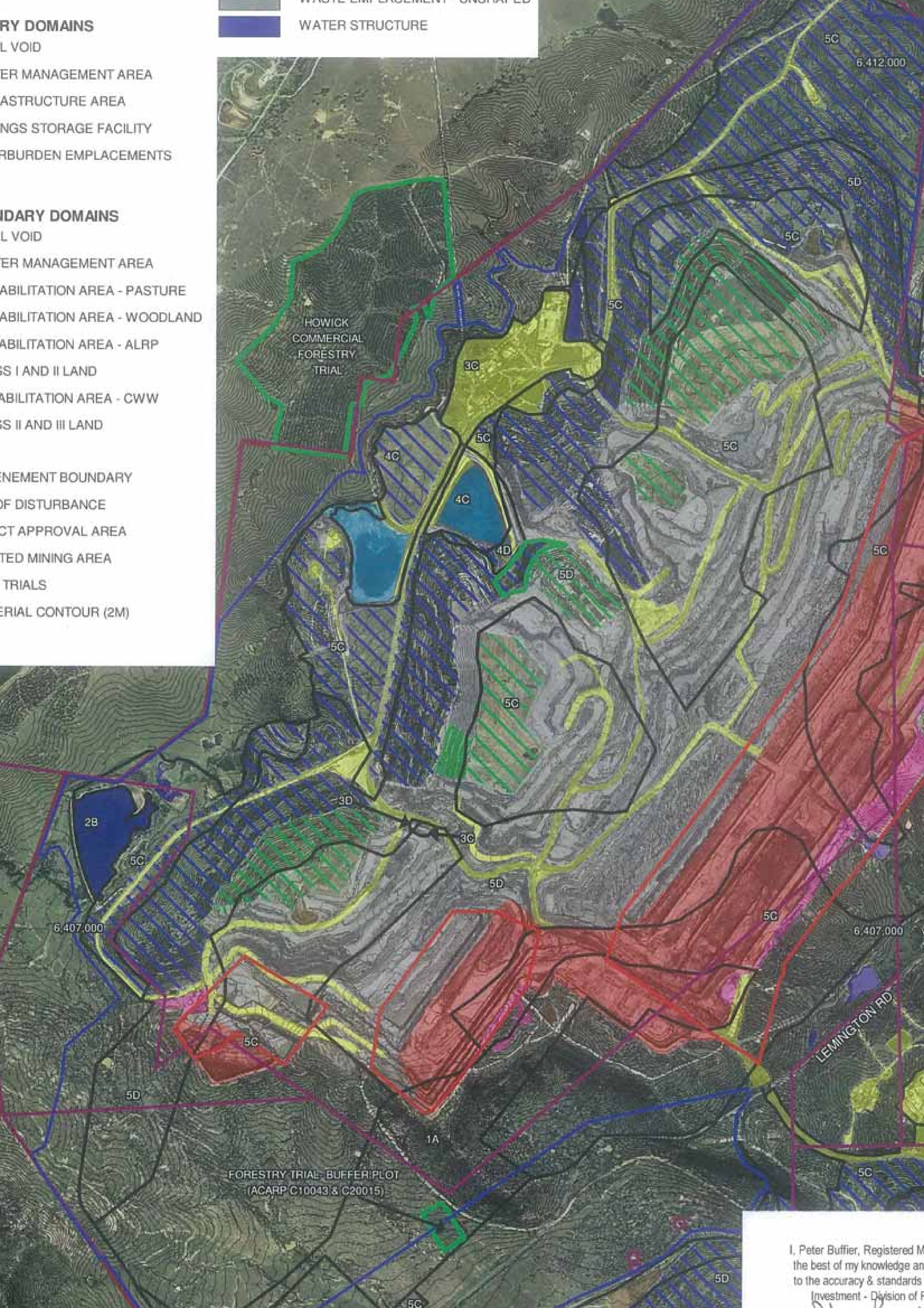

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ABILITATION AREA - ALRP
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ABILITATION AREA - CWW
SS II AND III LAND
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OF DISTURBANCE
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TRIALS
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WATER STRUCTURE
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FORESTRY TRIAL BUFFER PLOT (ACARP C10043 & C20015)
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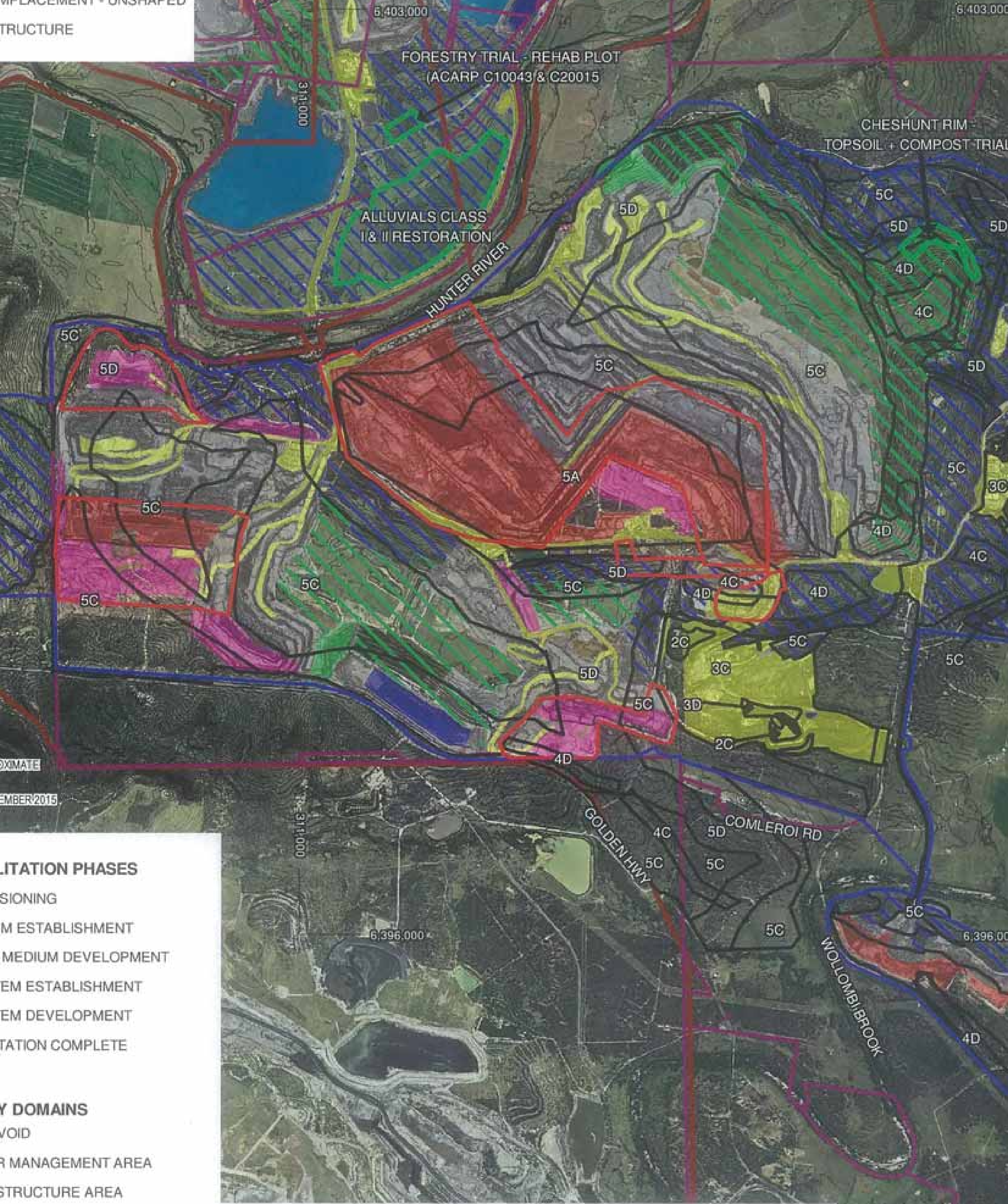

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BILITATION AREA -

1 AND 2 LAND

SCHEDULE OF ENDORSEMENTS

REF	DATE	DESCRIPTION / REFERENCES	SIGNED
Full Plan	22/03/2016	Mine surveying content depicted on the plan supplied by others	P. Buffier
Full Plan	22/03/2016	Domain boundaries supplied by others	P. Buffier
Full Plan	22/03/2016	Disturbance limits supplied by others	P. Buffier
Full Plan	22/03/2016	Mining tenement & lease boundaries supplied by others	P. Buffier
Full Plan	22/03/2016	Expected mining area supplied by others	P. Buffier
Full Plan	22/03/2016	Rehabilitation data & phases supplied by others	P. Buffier
Full Plan	22/03/2016	Vegetation information supplied by others	P. Buffier

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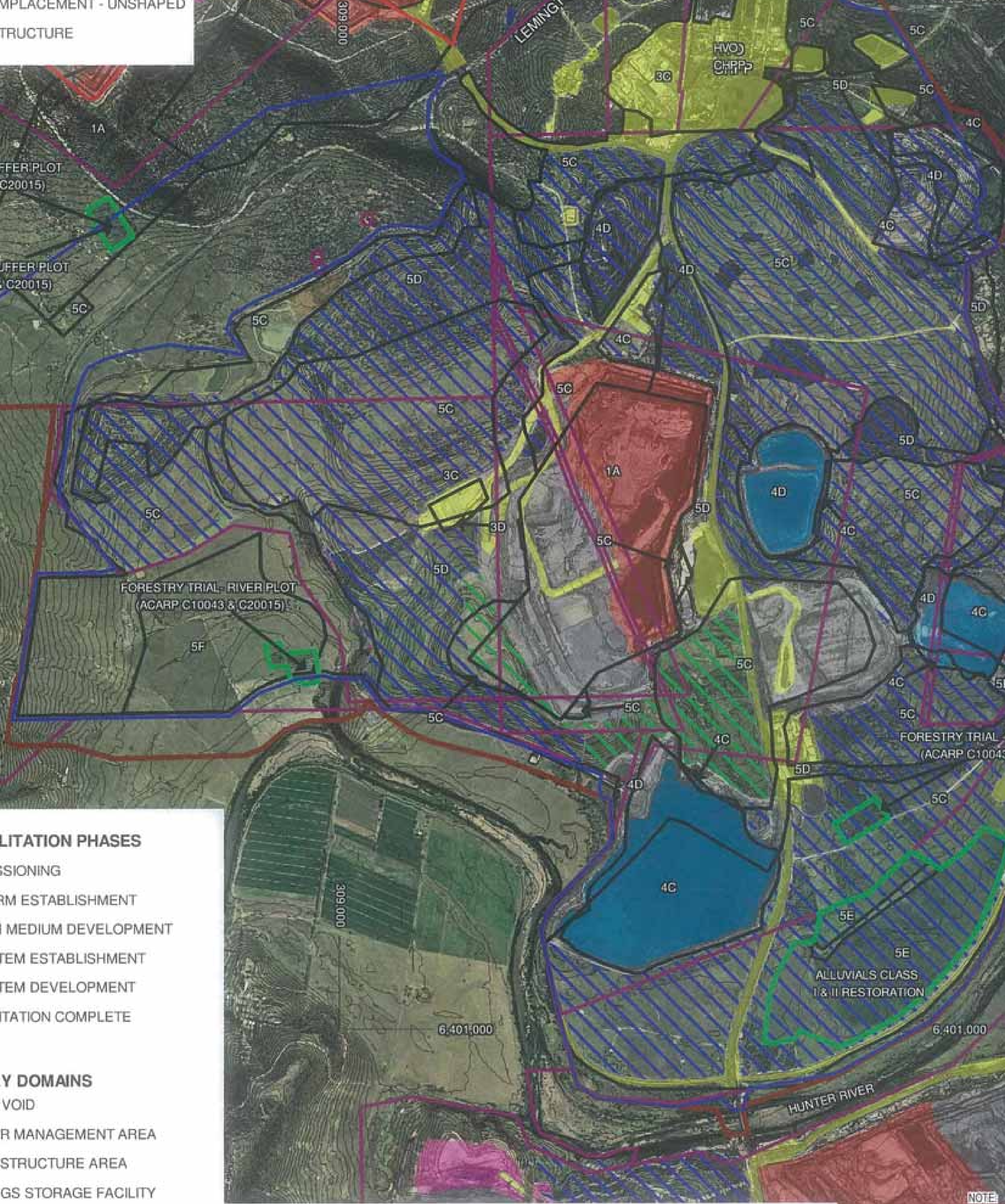

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BURDEN EMPLACEMENTS

DARY DOMAINS

VOID

ER MANAGEMENT AREA

BILITATION AREA - PASTURE

BILITATION AREA - WOODLAND

SCHEDULE OF ENDORSEMENTS

REF	DATE	DESCRIPTION / REFERENCES	SIGNED
Full Plan	22/03/2016	Mine surveying content depicted on the plan supplied by others	P. Buffier
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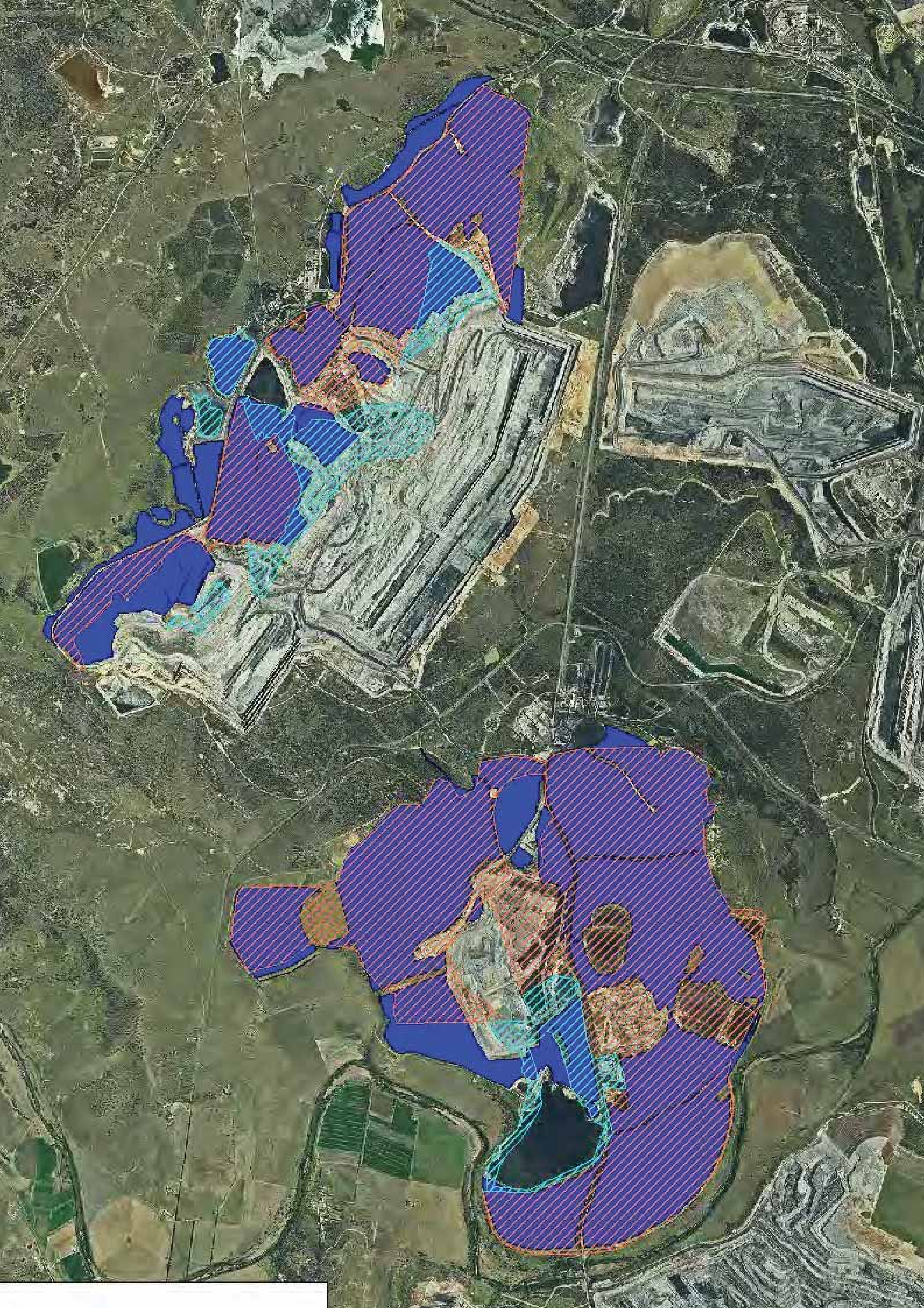

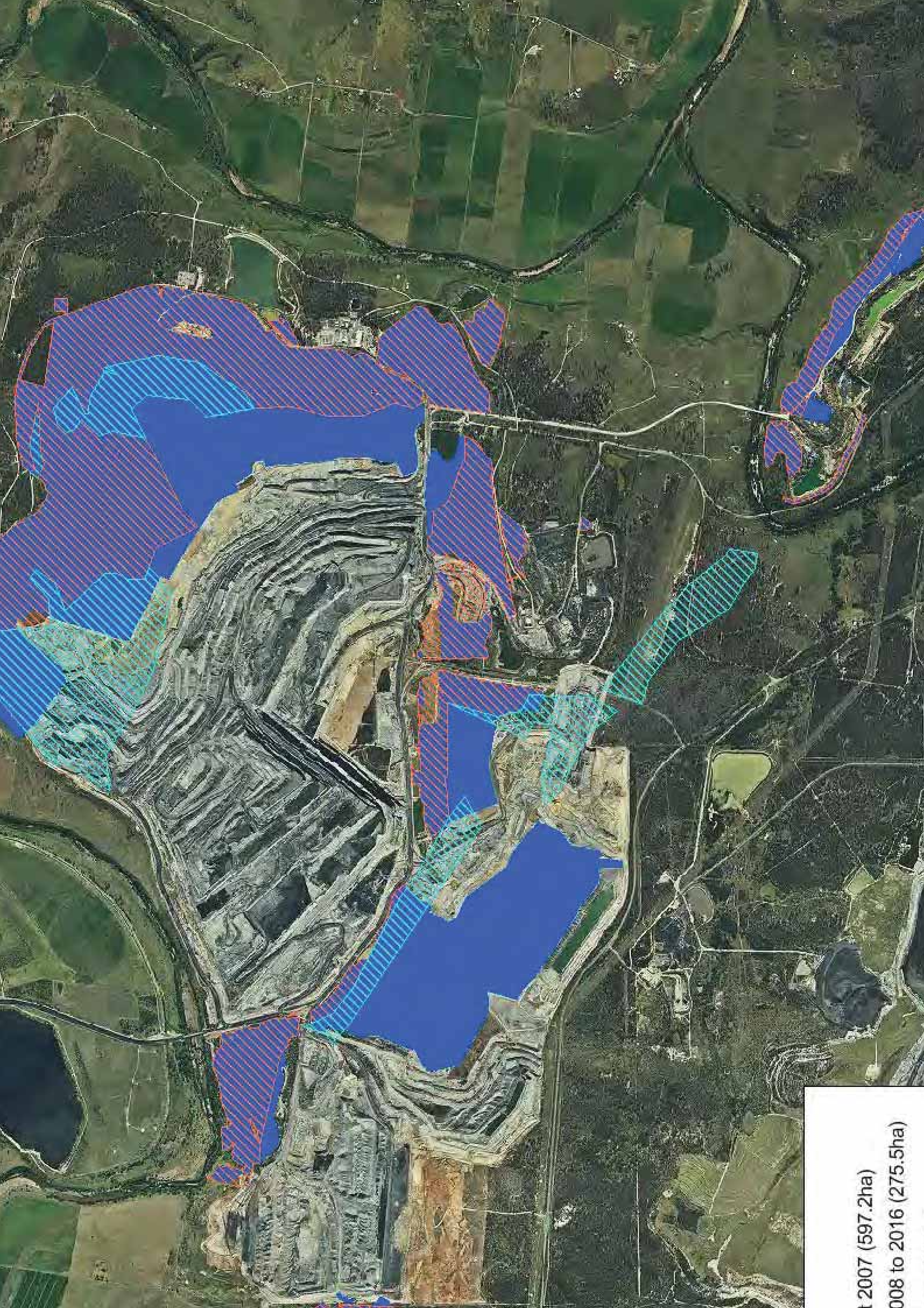
t 2007 (597.2ha)
008 to 2016 (275.5ha)

COAL & ALLIED

Managed by Rio Tinto Coal Australia

Appendix 5

Rehabilitation Monitoring Report

Native Vegetation Rehabilitation Monitoring 2016

Mount Thorley Warkworth and Hunter Valley Operations

Prepared for Coal and Allied

29 March 2016

Document control

Project no.:	2766
Project client:	Coal and Allied Pty Ltd
Project office:	Mudgee
Document description:	Monitoring of native vegetation within rehabilitation areas at Mt Thorley Warkworth Operations (MTW) and Hunter Valley Operations (HVO) as part of the Rehabilitation Monitoring Program.
Project Director:	Dr Rhidian Harrington
Project Manager:	Vivien Howard
Authors:	Vivien Howard and Luke Baker
Internal review:	Rhidian Harrington
Document status:	Revision 2
Document address:	P:\Projects\2000s\2700s\2766 Coal & Allied Rehabilitation Monitoring\Report\Final

Author	Revision number	Internal review	Date issued	Signature
Vivien Howard, Luke Baker	Draft 1	Rhidian Harrington	7 March 2016	RH
Luke Baker and Vivien Howard	Rev1	Rhidian Harrington	16 March 2016	RH
Vivien Howard	Rev2	Vivien Howard	29 March 2016	VH

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Cover photograph: Native rehabilitation at monitoring site MTWMTO2000

Executive summary

Context

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by Coal and Allied Operations Pty Ltd (C&A) to undertake the first year of native rehabilitation post-mining monitoring sites at the Mt Thorley Warkworth (MTW) and Hunter Valley Operations (HVO) mine sites. The monitoring forms part of the MTW and HVO monitoring program, which aims to assess the recovery of native rehabilitation across 19 individual HVO rehabilitation areas, and 17 individual MTW rehabilitation areas.

Methods

This monitoring report provides the results of the progress of the native vegetation in accordance with the methodology detailed in AECOM (2012) Monitoring Methodology - Post-mined Lands MTW and HVO North Mine Sites.

Aims

The aim of the monitoring program is to undertake monitoring in accordance with AECOM (2012) and establish permanent monitoring sites across the rehabilitation areas, and 12 reference sites in unmined areas aimed at capturing the two target Biometric Vegetation Types (BVTs) specified in the respective Mining Operations Plans (MOP) for MTW and HVO:

1. HU701 Central Hunter Grey Box-Ironbark Woodland.
2. HU632 Central Hunter Ironbark-Spotted Gum-Grey Box Forest.

The data obtained during the monitoring has been presented in this report to assist C&A in setting target levels for the performance criteria for the native vegetation rehabilitation which have not been finalised in the MOP's for MTW, HVO North and HVO South.

Results

A total of 35 rehabilitation monitoring sites were established across HVO and MTW native vegetation rehabilitation areas. Twelve reference sites were established in target vegetation types in a number of locations.

Key findings include the following:

- There is significant variation in the types and ages of the rehabilitation sites which were part of the monitoring project, and therefore there is a high degree of variability in monitoring results - this includes native plant species richness, exotic cover, percentage cover, and projected cover of all strata.
- Data was collected from each reference site and compared to the NSW Office of Environment and Heritage (OEH) benchmarks for the two target BVTs. Notable differences include low values for native mid-storey, native ground cover (shrubs), and number of trees with hollows within the local reference sites. The low reference site values for these attributes may not provide C&A with a performance indicator suitable to measure rehabilitation progress.
- Generally the rehabilitation sites fell below reference site and benchmark values for both of the target communities. This means that management should aim to increase those attributes for each rehabilitation site for which it is lacking.
- Rehabilitation sites were achieving local benchmark values for some of the ten Biobanking site attribute values.

- Weed abundance was high across all monitoring sites. This is to be expected for some sites given they were still in the early phases of weed clean-up prior to sowing native seed mixes.
- Generally there was limited variation in regards to the ground cover assessment scores between different soil treatments.
- Landscape Function Analysis (LFA) scores (Landscape Organisation Index (LOI) and soil surface indicators) were high for reference sites, and variable for rehabilitation sites.
- The Landscape Organisation Index (LOI) averages show that the sites treated with Spoil/ Compost have a lower average LOI than the reference sites or other soil treatments. Topsoil/ Compost contained the greatest average LOI (0.93), which was similar to that at Reference sites (0.97).
- Many of the rehabilitation sites with a LOI of 1, achieved this result due to the high density of grass species (whether native or exotic), including sites HVORIV201405 and HVORIV201406.
- Sites which achieved relatively low LOI were sites that had only recently been established and exhibited little grass or plant cover. These sites had been seeded with native seed mix but the sites were still in the early phases of seed germination and vegetation establishment.
- The Spoil/ Compost site contained the lowest average stability score, whilst the remaining soil treatments were quite similar.
- The Reference sites contained the highest average infiltration scores. Both Subsoil/ Compost and Topsoil treatments had similar results, with Topsoil/ Compost having s slightly higher infiltration score. Spoil/ Compost was relatively low compared to the other soil treatments.
- The variability in values at the rehabilitation sites is likely to be influenced by the seed treatments applied to sites and the age of the rehabilitation.

Recommendations

Key recommendations from monitoring presented in this report include the following:

- Amend the monitoring methodology to allow the collection of more meaningful data that would assist in management of the rehabilitation sites. Potential changes may include:
  - Replacing the groundcover assessment with a nested 20 x 20 m floristic plot. Recording all species (native and exotic) and recording cover abundance scores for each.
  - Ceasing the use of AECOM's 'Groundcover Assessment' and only rely on LFA for information on surface cover (plants, rocks and litter) and use the cover abundance scores (recommended above) to provide information on the proportion of weed and native cover.
  - Ceasing the use of the AECOM's 'Species Composition Assessment' and rely on a 20 x 20 m floristic plot data instead. This would provide a more robust list of species present (i.e. every species in the plot). Dominant species could be discerned via the cover abundance scores. Eliminating this assessment would reduce field and data management time by reducing duplication with the Biobanking methodology.
  - Stipulating in the methodology that Diameter at Breast Height (DBH) and tree height is recorded for ten canopy trees at each sample site, and replicating this process at reference sites. Data from the reference sites is needed to inform performance criteria setting as tree maturity is not reflected in BioBanking benchmark data.
  - Undertaking monitoring during spring and/or autumn to increase opportunities for more thorough identification. Species identification at early stage rehabilitation sites is limited by the maturity of the plants present.
- Consider using OEH benchmark data for native mid-storey cover, native ground cover (shrubs), and number of trees with hollows, as the local reference sites had values ranging to zero for these attributes.

It is noted that without more accurate data on the rehabilitation measures implemented (i.e. seed mixes used and seeding rate), it is difficult to discern accurate information regarding the efficacy of particular rehabilitation techniques. It is recommended that C&A compile data on the particular rehabilitation techniques implemented at each site and target aspect of the monitoring program to enable the efficacy of rehabilitation techniques to be better determined.

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Abbreviations

Acronym	Term/Definition
BBAM	BioBanking Assessment Methodology
BVT	Biometric Vegetation Type
C&A	Coal & Allied Operations
Dbh	Diameter at breast height
EPC	Exotic Plant Cover
FL	Fallen logs
ha	Hectare/s
HVO	Hunter Valley Operations
Km	Kilometre
LFA	Landscape Function Analysis
LOI	Landscape Function Index
LOI	Land Organisation Index
MOP	Mining Operations Plan
MTW	Mount Thorley-Warkworth
NGCG	Native ground cover grasses
NGCO	Native ground cover other
NGCS	Native ground cover shrubs
NMS	Native midstorey
NOS	Native overstorey
NPS	Native plant species
NTH	Number trees with hollows
NPWS	National Parks and Wildlife Service
OEH	NSW Office of Environment and Heritage (formerly DECCW, DECC, DEC)
OR	Overstorey regeneration
PCT	Plant Community Type
TSC Act	Threatened Species Conservation Act 1995 (NSW)

1. Introduction

1.1 Overview

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by Coal and Allied Operations Pty Ltd (C&A) to undertake the first year of native rehabilitation post-mining monitoring sites at the Mt Thorley-Warkworth (MTW) and Hunter Valley Operations (HVO) mine sites (Figure 1 to Figure 12). The monitoring forms part of the MTW and HVO monitoring program, which aims to assess the recovery of native rehabilitation across 19 individual HVO rehabilitation areas, and 17 individual MTW rehabilitation areas.

This monitoring report provides the results of the progress of the native vegetation in accordance with the methodology detailed in Monitoring Methodology - Post-mined Lands MTW and HVO North Mine Sites (AECOM 2012).

To date, the performance criteria targets for the native vegetation rehabilitation have not been finalised in the Mining Operations Plan (MOP) for MTW, HVO North or HVO South. The results of this monitoring report will assist C&A in determining suitable targets for performance criteria against which rehabilitation areas can be assessed.

1.2 Background to the rehabilitation monitoring

Rehabilitation monitoring at MTW and HVO is undertaken to satisfy the following regulatory obligations:

- Schedule 4 – Condition 70(h) of Development Consent DA-300-9-2002i (Warkworth Mine)
- Schedule 3 – Condition 42(g) of Development Consent DA 34/95 (Mount Thorley Mine)
- Schedule 4 – Condition 62C(j) of Development Consent DA 450-10-2003 (HVO North)
- Schedule 3 – Condition 36(e) of Project Application PA 06_0261 (HVO South)
- Commitments made in respective Mining Operations Plans (MOPs) for MTW, HVO North and HVO South.

Rehabilitation activities at MTW and HVO are generally divided into areas of post-mined lands being returned to either a native ecosystem or a grazing pasture (or grassland) final land use. C&A has committed to recreating Endangered Ecological Communities (EEC) to a standard comparable to similar reference EECs. The EECs include Central Hunter Grey Box-Ironbark Woodland and Central Hunter Ironbark-Spotted Gum-Grey Box Forest, which are both listed as EECs under the NSW Threatened Species Conservation Act 1995 (TSC Act). The area of rehabilitation that is proposed to be returned to these EEC communities is 2,114ha at MTW and 4ha at HVO. Other native ecosystem rehabilitation undertaken at MTW and HVO will produce trees over grassland areas, but not necessarily conforming to any particular known or existing vegetation type.

This assessment marks the first round of native vegetation monitoring and site establishment at MTW and HVO. Biobanking benchmark site data and data obtained from monitoring of reference sites will be used by C&A to determine appropriate target values for the performance criteria for native vegetation rehabilitation as detailed in the MOPs.

1.3 Project scope and objectives

This rehabilitation monitoring report documents the 2016 survey results and subsequent data analysis.

The monitoring program has been undertaken in accordance with the methodology detailed in AECOM (2012).

The monitoring involved the following key objectives:

- Establish permanent monitoring sites within each of the rehabilitation area (19 at HVO and 17 at MTW).
- Establish permanent reference sites within target EECs (Central Hunter Grey Box-Ironbark Woodland and Central Hunter Ironbark-Spotted Gum-Grey Box Forest) to assist with target setting for MOP performance criteria.
- Complete BioBanking plots at all reference sites, and older (> 4 years) rehabilitation sites with sufficient native vegetation establishment (four sites at HVO North and five sites at MTW).
- Complete Landscape Function Analysis (LFA) at all monitoring sites.
- Complete visual monitoring at all monitoring sites.
- Complete soil analysis at all monitoring sites.
- Complete photographic monitoring at all monitoring sites.
- Complete tree health characteristic at all monitoring sites.
- Complete ground cover assessment for those monitoring sites where BioBanking plots were not completed.
- Provide an analysis of results against reference sites.
- Provide an analysis of results from those rehabilitation sites with different soil treatment.
- Provide recommendations to assist with the improvement of future monitoring and performance indicators.

1.4 Monitoring team

Data collection for the first monitoring period was undertaken on 1st to 5th and 8th to 12th of February 2016. Ecologists involved with the completion of field monitoring tasks and reporting are listed as follows:

Vivien Howard	Senior Ecologist (Field survey and reporting)
Luke Baker	Senior Botanist (Field survey and reporting)
Dr Ross Jenkins	GIS

2. Rehabilitation areas

2.1 HVO rehabilitation areas

HVO rehabilitation consists of 19 individual areas (Figure 2) comprised of different rehabilitation establishment conditions. The desired outcome of the rehabilitation is to achieve a native woodland community, or native pasture/ light wooded vegetation community. Details regarding the establishment and treatment for each site, including the desired vegetation type are provided in Table 1.

Table 1. HVO rehabilitation areas, establishment conditions and derived vegetation type

Rehabilitation area name	Area (ha)	Establishment date	Soil and seeding information[1]	Desired vegetation type
HVO WES200801	3.4	2008	Topsoil	Native woodland
HVO WES201101	4.4	2011	Compost (with spoil), native seed hydroseeded	Native woodland
HVO WES201301	3.7	2013	Compost (with spoil), native seed drilled	Native woodland
HVO WES201302	12.7	2013	Compost (with topsoil), natives not sown	Native woodland
HVO CAR200901	14.2	2009	Topsoil, native seed broadcast	Native woodland
HVO CAR200902	7.7	2009	Topsoil, native seed broadcast	Native woodland
HVO CAR201401	25.6	2014	Compost (with topsoil), natives not sown	Native woodland
HVO RIV201406	3.1	2014	Compost (with topsoil), natives not sown	Pasture/ light Wooded
HVO RIV201405	14.3	2014	Compost (with subsoil), native seed drilled	Pasture/ light Wooded
HVO RIV201404	8.4	2014	Compost (with subsoil), seed has been drilled	Pasture/ light Wooded
HVO RIV201403	4.8	2014	Compost (with subsoil), seed has been drilled	Pasture/ light Wooded
HVO RIV201402	10	2014	Compost (with subsoil), seed has been drilled	Pasture/ light Wooded
HVO RIV201401	5.8	2014	Compost (with spoil), seed has been drilled	Pasture/ Light Wooded
HVO RIV201301	10	2013	Compost (with topsoil), natives not sown	Pasture/ Light Wooded
HVO CHE201201	20.8	2012	Compost (with topsoil), native seed drilled	Native woodland
HVO CHE201202	6.1	2012	Topsoil (with spoil), native grass sown	Native woodland
HVO CHE201203	26.6	2012	Compost (with topsoil), natives not sown	Native woodland

[1] Soil and seeding information provided by Bill Baxter (C&A)

Rehabilitation area name	Area (ha)	Establishment date	Soil and seeding information[1]	Desired vegetation type
HVO CHE201301	12.6	2013	Compost (with topsoil), natives not sown	Native woodland
HVO CHE201401	9.8	2014	Compost (with topsoil), natives not sown	Native woodland

2.2 MTW rehabilitation areas

The MTW rehabilitation area consists of 17 individual areas (Figure 7) comprised of different rehabilitation establishment conditions listed below in Table 2.

The desired outcome of the rehabilitation is to achieve a native woodland community, or native pasture/ light wooded vegetation community.

Table 2. MTW rehabilitation areas, establishment and derived vegetation type

Rehabilitation area name	Area (ha)	Establishment date	Soil and seeding information[2]	Desired vegetation type
MTWNPN201301	23.1	2013	Compost (with topsoil), natives drilled Winter 2015	Native woodland
MTWNPN201402	1.9	2014	Compost (with fresh sand topsoil), natives drilled 2014	Native woodland
MTWNPN201401	7.1	2014	Compost (with topsoil), natives drilled 2014	Native woodland
MTWNPN201403	5.5	2014	Compost (with subsoil), natives drilled 2014	Native woodland
MTWNPN201101	43.3	2011	Topsoil, natives hydroseeded 2011	Native woodland
MTWNPN200901	21.8	2009	Topsoil, using an 'old seed mix'	Native woodland
MTWCDD201101	8.1	2011	Topsoil, native seed hydroseeded	Native woodland
MTWCDD201301	9.1	2013	Compost (with topsoil), natives not sown	Native woodland
MTWCDD201501	6.4	2015	Compost (with spoil), natives drilled	Native woodland
MTWSPN201401	37.7	2014	Compost (with topsoil), natives not sown	Native woodland
MTWWDL201401	4.7	2014	Compost (with topsoil), natives drilled 2015	Native woodland
MTWWDL201402	8.9	2014	Compost (with topsoil), natives not sown	Native woodland
MTWMTO200001	6.3	2000	Topsoil	Pasture/ light wooded
MTWTD1201501	20.6	2015	Compost (with spoil), native seed drilled 2015	Native woodland
MTWNPN200501	13.2	2005	Topsoil	Pasture/ light wooded

[2] Soil and seeding information provided by Bill Baxter (C&A)

Rehabilitation area name	Area (ha)	Establishment date	Soil and seeding information[2]	Desired vegetation type
MTWNPN200502	4.8	2005	Topsoil	Pasture/ light wooded
MTWMTO200503	11.7	2005	Topsoil	Native woodland

2.3 Native rehabilitation performance criteria, measures and associated indicators

As previously discussed in Section 1.2, performance criteria for the native rehabilitation areas have been detailed in the MOP (Coal & Allied 2012a and 2012b), however, target values for some of the criteria are yet to be developed. The data provided from the reference sites established during this monitoring program will assist C&A in assessing rehabilitation against the performance criteria targets and triggers. In the absence of performance criteria targets this monitoring report will provide a comparison of results for rehabilitation sites against reference site and Biobanking benchmark values, where available).

3. Monitoring methodology

3.1 Monitoring dates

Monitoring was undertaken on 1st to 5th and 8th to 12th of February 2016.

Details regarding the dates, personnel and sites completed for each day during the monitoring is provided in Appendix 1.

3.2 Design

Monitoring was undertaken in accordance with AECOM (2012) Monitoring Methodology. Niche has summarised the techniques used from AECOM's Monitoring Methodology below.

3.2.1 Rehabilitation monitoring sites

A total of 35 rehabilitation monitoring sites were established:

- 18 monitoring sites at HVO North (Figure 2, and Figures 3 to 6)
- 17 monitoring sites within rehabilitation sites at MTW (Figure 7, and Figures 8-12).

For each monitoring site, a marker post was placed at the start and end point, with the end point established downslope. Waypoints were taken at the start and end point for each monitoring site location (Appendix 2).

Monitoring at each rehabilitation site included the collection of the following data: photo points, visual assessment, Landscape Function Analysis (LFA) and soil analysis. Those sites with native vegetation established also required the collection of BioBanking data.

The locations of the monitoring sites, along with their associated descriptions and coordinates have been provided in Appendix 2.

3.2.2 Reference monitoring sites

The project resulted in the establishment of 12 reference monitoring sites, aimed at capturing the two BVTs specified in the MOP:

1. HU701 Central Hunter Grey Box-Ironbark Woodland
2. HU632 Central Hunter Ironbark-Spotted Gum-Grey Box Forest.

The selection of the reference sites for the monitoring program was undertaken with consideration of the following:

- The rehabilitation objectives and commitments – to ensure that the reference sites are representative of what is trying to be achieved on post-mined rehabilitated lands (i.e. the same vegetation types).
- To ensure that the suite of reference sites making up the monitoring programme appropriately capture the range of environmental and biophysical conditions occurring in the region.

A preliminary assessment of potential reference sites was undertaken based on regional vegetation mapping and based on discussions with staff from OEH, and environmental staff from C&A and other mine sites. A larger (based on range and number) list of potential sites was developed and then reduced based largely on access limitations.

Three of the Central Hunter Ironbark-Spotted Gum-Grey Box Forest sites were established at Belford National Park (Figure 13) and another three established within land managed by Wambo Coal Mine (Figure 14).

Two of the Central Hunter Grey Box-Ironbark Woodland reference sites were established within land managed by Wambo Coal (Figure 14), with another four established in land managed by C&A (Figure 15).

The coordinates for the location of each reference site is provided in Appendix 2.

BioBanking data collected at each of the reference sites was input into the OEH BioBanking Benchmark Calculator to provide the lower and upper benchmark ranges for each attribute. The reference site ranges were then compared to the OEH benchmarks for both BVTs.

3.3 Sampling techniques

3.3.3 Landscape Function Analysis (LFA)

LFA is a monitoring procedure developed by the CSIRO (Tongway & Hindley, 1997, last revised in 2004) that uses rapidly acquired field-assessed indicators to assess the biogeochemical functioning of landscapes at the hillslope scale. It provides a rapid, reliable, and easily applied method for assessing and monitoring landscape restoration or rehabilitation projects. LFA examines the way physical and biological resources are acquired, used, cycled and lost from a landscape.

Eleven Soil Surface Condition Indicators (SSCIs) (Table 3), each focusing on the measurement of specific biological and/or physical processes, are used to calculate three LFA indices: soil stability, soil infiltration and nutrient cycling. The three indices have scores of 0 to 100, which represent the ecosystem function of the area. These scores provide quantitative measures that may be used to compare rehabilitated areas with reference sites throughout the course of a monitoring program.

An LFA plot and transect was completed at each rehabilitation and reference site.

Table 3. Soil Surface Condition Indicators (SSCI) used to assess the effect of biological and physical processes on ecosystem function

Indicator	Related process
Rainsplash Protection	Rainsplash erosion
Perennial Vegetation Cover	Below ground biomass
Litter	Nutrient cycling of organic matter
Cryptogam Cover	Indication of soil stability and presence of nutrients
Crust Brokenness	Potential for wind and water erosion
Soil Erosion Type and Severity	Type and severity of existing soil erosion
Deposited Materials	Soil stability upslope
Soil Surface Roughness	Water infiltration and retention
Surface Resistance to Disturbance	Effect of mechanical disturbance
Slake Test	Soil stability when wet
Texture	Soil permeability and water storage

3.3.4 BioBanking – site value scores

The NSW Biodiversity Banking and Offsets Scheme – known as 'BioBanking', was introduced by the NSW government in 2008. The BioBanking Assessment Methodology (BBAM) assesses biodiversity values as defined by the TSC Act. These values include the composition, structure and function of ecosystems. They also include (but are not limited to): threatened species, threatened populations and threatened ecological communities, and their habitats.

AECOM (2012) refers to the use of 'site value' to provide a quantitative measure of the condition of the vegetation within each rehabilitation area. The site value for a particular zone is calculated based on quantitative measures of ten sites attributes which are measured along a transect or within a survey plot, and assessed against benchmarks values (Table 4). A minimum number of plots are required based on the area of the site being assessed. Given this is the first year of monitoring, it was thought to be more valuable to present results for each of the Biobanking criteria rather than just the site value score. The results for the rehabilitation areas have been compared to the reference site benchmarks.

BioBanking plots were undertaken at all reference sites, and those sites with native vegetation established (four sites at HVO North and five sites at MTW as identified in Appendix 1).

Table 4. The ten site value scores recorded as part the BioBanking assessment

Attribute	Explanation
Native plant species richness (NPS)	Number of native species recorded within a nested 20 x 20 m quadrat.
Native over-storey % cover (NOS)	Recorded at 5 m intervals along a 50 m tape
Native mid-storey % cover NMS)	Recorded at 5 m intervals along a 50 m tape
Native ground cover (grass) % cover (NGCG)	Recorded at 1 m intervals along a 50 m tape
Native ground cover (other) % cover (NGCO)	Recorded at 1 m intervals along a 50 m tape
Native ground cover (shrubs) % cover NGCS)	Recorded at 1 m intervals along a 50 m tape
Exotic plant cover % cover (EPC)	Recorded at 1 m intervals along a 50 m tap
Overstorey regeneration	Regeneration is measured as the proportion of over-storey species present in the zone that are regenerating (i.e. with diameter at breast height < 5 cm). For example, if there are three tree species present in the zone but only one of these species is regenerating, then the value is 0.33. The maximum value for this measure is 1.
Fallen logs (m) Length of logs (m) (FL)	Total length of logs recorded within the 20 x 50 m quadrat. To be eligible for inclusion, logs must be >10 cm diameter and longer than 50 cm
Number of trees with hollows (NTH)	Number of trees with hollows within the 20 x 50 m quadrat

3.3.5 Visual monitoring

Species composition

The dominant species present in the monitoring area were identified to obtain a 'picture' of the species composition for a specific vegetation community. In rehabilitation areas, this allowed confirmation that the species establishing conformed to the vegetation types being re-established.

Additionally, notes were made on the general health and sustainability of vegetation as indicated by presence/absence of flowering/fruiting adult plants. The presence of plants at reproductive stage is an indication that the ecosystem is recruiting and as such capable of self-regeneration.

Habitat and fauna monitoring

Artificial habitat features installed throughout the site as part of the rehabilitation activities (e.g. stag trees) were recorded.

Notes were also made on the presence and extent of habitat features such as free standing water, coarse woody debris, rocks mistletoes and weather plants were flowering or fruiting.

Disturbance monitoring

Disturbance monitoring was undertaken using the visual monitoring tool developed by AECOM (2012). This technique is a field-based, rapid assessment tool to visually assess and award a score to various contributors. The objective of this monitoring is to identify factors and processes that occur at the landscape/catchment scale and have the potential to impact on the monitoring site. The disturbance monitoring aims to cover those aspects that are not adequately covered in the BioBanking and LFA monitoring tools. The following disturbance categories (and associated disturbance factors) were monitored and assessed at each site:

- Disturbance related to mining activities, including:
    - Evidence of wheeled vehicles, tracked vehicles and foot disturbance
    - Excavation
    - Presence of mine rubbish
- Disturbance related to non-mining activities, including:
    - Evidence of grazing
    - Presence of animal pads
- Presence of exotic weeds and feral animal species
- Presence of domestic litter / rubbish
- Fire disturbance
- Evidence of nearby maintenance activities (i.e. chemical treatments, fencing, earthworks)
- Surface stability and erosion issues, including:
    - Eroding factor (i.e. wind, water).
    - Erosion type (i.e. sheet, rill/gully, pedestal, terracette, scalding (Tongway & Hindley 2004)).

3.3.6 Ground cover assessment

Ground cover assessment was undertaken at sites where native vegetation is not yet well established (i.e. where the BioBanking monitoring was not undertaken). The ground cover assessment involved a plot based assessment, conducted at 5-metre intervals along the 50 m transect line (for a total of 10 sampling points per transect). The following information was visually assessed and recorded in 1 x 1 m quadrats:

- The percentage cover of protective ground cover components (dead and live plant material, rocks and logs)
- The percentage cover of bare ground
- The percentage cover of weeds
- The number of ground cover species present.

At each sampling point, percentage cover is visually estimated to the nearest 10% using a 1 x 1 m frame divided into a 0.1 x 0.1 m grid. The overall percentage cover for the site is calculated by averaging results from all ten sampling points.

3.3.7 Soil analyses

Soil characterisation and analyses are performed to determine the physical and chemical properties of the growing media. Soil samples were collected from all monitoring sites (rehabilitation and reference sites). A composite sample consisting of a minimum of nine sub-samples collected 10 to 15 m apart was collected within a 20 m radius. The radius was based on a central point five metres in from the 20 metre quadrat tape. All samples were placed in a bucket, and were mixed. The sample was then placed in a plastic bag, labelled, and sent to SESL Australia for analysis.

The following soil parameters were determined:

- pH
- Sodicity
- Electrical conductivity (EC)
- Electrochemical Stability Index (ESI)
- Plant available nutrients
- Cation balance
- Soil organic matter content
- Soil texture including clay content
- Fertiliser application rates as relevant for the proposed plant community.

Soil analysis was undertaken by SESL Australia, results were analysed and tabulated by them and included comparisons of soil parameters based on soil treatment and the rehabilitation outcome trying to be achieved at each site.

At a further 36 sites, soil microbial testing was also undertaken, to gain a relative measure of microbial fungal associations. This was undertaken at all 12 reference sites and 18 rehabilitation sites. Appendix 1 identifies those monitoring sites where soil microbial testing was undertaken. Appendix 6 includes the raw soil data.

3.3.8 Photographic monitoring

Photographic monitoring is a simple and useful tool that allows for direct visual comparison of a specific site between monitoring events. Digital photographs were taken at the start and finish transect points at each monitoring site. Photographs were taken to allow a panorama of each end of the transects to be established. This included:

- A photograph to the left of the tape (with the tape just in the frame in the far right)
- A photograph with the tape (and star picket) in the centre of the frame
- A photograph to the right of the tape (with the tape just in the frame in the far left.

3.3.9 Rill survey

In accordance with the LFA methodology (Tongway and Hindley, 2004), rill surveys are to be carried out where rills are observed at less than 30 m spacing across the slope.

None of the monitoring sites were impacted by rill erosion at the time of the survey, and therefore no rill surveys were undertaken.

3.3.10 Weather

Temperatures and rainfall in the four months preceding the field monitoring period are listed in

Table 5.

Conditions during the field surveys were dry and hot, with high humidity levels. Low rainfall occurred overnight and intermittent throughout the 4th and 6th of February (approximately 4 mm) during the field survey. Daily temperatures ranged from 17°C to 34°C.

Most plants had just finished their flowering growth phase at the time of monitoring.

Table 5. Weather conditions preceding and during the monitoring period (BoM Station # 061397)

	Monthly mean			Historical average (2002-2016)		
Month	Min Temp (°C)	Max Temp (°C)	Rainfall (mm)	Min Temp (°C)	Max Temp (°C)	Rainfall (mm)
October 2015	10.0	26.8	42.6	14.1	26.4	44.7
November 2015	14.0	28.8	839	17.8	28.8	83.6
December 2015	15.8	29.9	73.9	19.4	29.9	70.5
January 2016	17.7	29.3	208.8	20.2	31.5	69.9
February 2016	17.6	29.0	10.0	18.6	32.7	91.9

3.4 Limitations

Given this round of monitoring will inform the native rehabilitation performance criteria, no discussion or analysis in regards to the performance objectives detailed in the MOP was undertaken.

Soil slake and texture test was not able to be conducted for some sites (MTWD1201501, MTWCDD201301, MTWNPN2009, MTWCDD201501) due to wet weather during the 4th and 6th of February.

A site value assessment using the BBAM, as per the AECOM (2012), was not undertaken during this round of monitoring as MOP performance criteria targets have not been finalised by C&A. Analysis of each benchmark attribute is a far more beneficial assessment tool in this instance, as it provides greater detail on how sites scored for each attribute.

Whilst monitoring of HVOCHE201202 was anticipated as part of the monitoring project, it was advised by C&A during the survey period that monitoring at this site was no longer required.

Many of the flora recorded in the rehabilitation monitoring sites were in a juvenile or seedling state. As such, identification may need to be updated in later monitoring years and analyses corrected.

Whilst the reference sites were located within BVTs that were within a good condition and within the general region of the study they have been impacted by historic clearing, and thus old growth forms of these BVTs were not able to be sampled as reference sites.

Data analysis was limited to comparison of rehabilitation sites with reference sites, and to areas of different soil treatment. Details regarding weed management history and seeding rates were not available so data analysis based on these parameters was not undertaken.

4. Results

4.1 Reference sites

4.1.1 OEH Benchmark values

The OEH Benchmark Values for both Central Hunter Grey Box-Ironbark Woodland, and Central Hunter Ironbark-Spotted Gum-Grey Box Forest are provided in the Table 6

Based on the two OEH benchmark values, the following can be concluded:

- Grey-Box Ironbark Woodland has higher NPS compared to Ironbark Spotted Gum-Grey Box Forest.
- NOS cover differed slightly between the two communities.
- Ironbark Spotted Gum-Grey Box Forest has a greater NMS range compared to Grey-Box Ironbark Woodland.
- Grey-Box Ironbark Woodland has a greater NGCG and a greater range compared to Ironbark Spotted Gum-Grey Box Forest.
- Both communities had the same NGCS.
- Grey-Box Ironbark Woodland has a greater NGCO compared to Ironbark Spotted Gum-Grey Box Forest.
- NTH is greater in Grey-Box Ironbark Woodland.
- FL is far greater within Ironbark Spotted Gum-Grey Box Forest.

Table 6. OEH Benchmark values for Central Hunter Grey Box-Ironbark Woodland and Central Hunter Ironbark-Spotted Gum-Grey Box Forest

Plot name	NPS	NOS		NMS		NGCG		NGCS		NGCO		EPC	NTH	OR	FL
Grey-Box Ironbark Woodland OEH Benchmark Upper and Lower Limits	≥41	15	40	5	20	30	50	5	10	20	40	0	3	1	≥5
Spotted Gum – Grey Box Forest OEH Benchmark Upper and Lower Limits	≥25	20	50	10	60	5	16	5	10	5	15	0	1	1	≥66
Average	≥33	17.5	45	7.5	40	17.5	33	5	10	12.5	27.5	0	2	1	≥35.5

NPS: Native Plant Species, NOS: Native overstorey, NMS: Native midstorey, NGCG: Native ground cover grasses, NGCS: Native ground cover shrubs, NGCO: Native ground cover other, EPC: Exotic Plant Cover, NTH: Number trees with hollows, OR: Overstorey Regeneration, FL: Fallen Logs, .

4.1.2 Reference site and OEH Benchmark values

The OEH Benchmarks values have been compared to the reference values in Table 7.

Based on the results, the following can be concluded:

Central Hunter Grey Box-Ironbark Woodland - based on a comparison of the reference site benchmarks to the OEH benchmarks, the following conclusions can be made:

- Reference sites have a lower limit for most attributes (except NGCG).

- NPS for the reference site benchmark had a total of ten species less than OEH benchmark.
- NOS for reference site benchmark has a smaller range than the OEH benchmark. This may be attributed to the historic clearing of the reference sites.
- NMS for the reference site benchmark has a lower value of zero, whilst the OEH benchmark has a lower value of 5 percent.
- NGCG for the reference site benchmark is higher compared to the OEH benchmark.
- NGCS for the reference site benchmark has a lower value of zero and a higher upper value compared to OEH benchmark.
- NGCO for the reference site benchmark has a lower value of zero and a higher upper value compared to OEH benchmark.
- FL has a greater reference site benchmark than the OEH benchmark.

Central Hunter Ironbark-Spotted Gum-Grey Box Forest - based on a comparison of the local benchmarks to the OEH benchmark, the following conclusions can be made:

- NPS for the local benchmark had a total of nine species more than OEH benchmark.
- NOS for reference site benchmark has a smaller range than the OEH benchmark. This may be attributed to the historic clearing of the reference sites.
- NMS for the reference site benchmark has a lower benchmark value of zero compared to a lower OEH benchmark of 10. The reference site benchmark also has a significantly lower upper value compared to the OEH benchmark.
- NGCG for the reference site benchmark is significantly higher compared to the OEH benchmark.
- NGCS for the reference site benchmark has a lower low value and high value compared to OEH benchmark.
- NGCO for the reference site benchmark has a higher low value and a significantly higher upper value compared to OEH benchmark.
- FL has a lower reference site benchmark than the OEH benchmark.

Table 7. OEH Benchmarks and Rehabilitation sites

Reference site name	NPS	NOS		NMS		NGCG		NGCS		NGCO		EPC	NTH	OR	FL
Central Hunter Grey Box-Ironbark Woodland															
WamboGB01	34	13		7		50		6		32		0	0	1	7
WamboGB02	35	19		0		62		12		12		0	0	1	23
WARKGB01	28	15		23		38		0		38		2	0	1	4.5
WARKGB02	31	14.5		1		70		0		62		0	0	1	22
WarkGB03	31	18.5		0		54		0		16		0	0	1	27
WarkGB04	29	2		0		64		28		16		4	1	1	3
Reference Site Benchmark Upper and Lower Limits	≥31	7.5	18.8	0	15.0	44.0	67.0	0	20.0	14.0	50.0	0	≥0	1	≥15
OEH Benchmark Upper and Lower Limits	≥41	15	40	5	20	30	50	5	10	20	40	0	3	1	≥5
Central Hunter Ironbark-Spotted Gum-Grey Box Forest															
BEL1	34	10.5		0		56		2		22		0	0	1	60
BEL2	35	38		2		56		6		50		0	0	1	13.5
BEL3	33	26.5		0		36		2		50		0	0	1	64
WamboSpot1	32	27		14		38		4		12		0	4	1	74
WamboSpot2	27	21		7.5		40		6		12		0	0	1	12
WamboSpot3	34	29		15		30		8		16		0	4	1	13
Reference Site Benchmark Upper and Lower Limits	≥34	15.8	33.5	0.0	14.5	33.0	56.0	2.0	7.0	12.0	50.0	0	≥0	1	≥37
OEH Benchmark Upper and Lower Limits	≥25	20	50	10	60	5	16	5	10	5	15	0	1	1	≥66

4.1.3 Landscape Function Analysis

The LFA scores for the Central Hunter Grey Box-Ironbark Woodland and Central Hunter Ironbark-Spotted Gum-Grey Box Forest reference sites were tabulated and are provided in Table 8. Key results include the following:

- Most sites scored a LOI of 1.0.
- WARKGB03 had the lowest LOI (0.84) across all reference sites.
- The average LOI for Ironbark-Spotted Gum-Grey Box Forest was similar to the average for Grey Box-Ironbark Woodland.
- Stability ranged from 57.9 to 72.5 for Grey Box-Ironbark Woodland. WAMBOGB2 and WARKGB04 both had the highest stability score at 72.5.
- Stability ranged from 66.7 to 81.8 for Ironbark-Spotted Gum-Grey Box Forest.
- BELSPOT2 had the highest stability scores (81.8) across all Reference sites.
- The average stability for Ironbark-Spotted Gum-Grey Box Forest was similar to the average for Grey Box-Ironbark Woodland.
- Infiltration ranged from 48.4 to 57.6 for the Grey Box-Ironbark Woodland Reference sites. Most of the sites scored below 50.
- Infiltration ranged from 51.6 to 69.9 for the Ironbark-Spotted Gum-Grey Box Forest.
- The average infiltration for Ironbark-Spotted Gum-Grey Box Forest was higher than the average for Grey Box-Ironbark Woodland.
- Nutrient cycling ranged from 38.7 to 52.1 for the Grey Box-Ironbark Woodland Reference sites. Only WARKGB02 scored above 50.
- Nutrient cycling ranged from 43.6 to 65.6 for Ironbark-Spotted Gum-Grey Box Forest. WAMBOSPOT1 had the highest score.
- The average nutrient cycling value for Ironbark-Spotted Gum-Grey Box Forest was higher than the average for Grey Box-Ironbark Woodland.

Table 8. LFA for Reference sites

Site name	Landscape Organisation Index (LOI)	Stability	Infiltration	Nutrient Cycling
Central Hunter Grey Box-Ironbark Woodland				
WAMBOGB1	1	58.3	56.2	46.3
WAMBOGB2	1	72.5	48.4	48.4
WARKGB01	1	69.8	49.7	43.2
WARKGB02	1	70	57.6	52.1
WARKGB03	0.84	57.9	49.8	38.7
WARKGB04	0.97	72.5	48.4	48.4
Average	0.96	66.8	51.7	46.2
Central Hunter Ironbark-Spotted Gum-Grey Box Forest				
BELSPOT1	1	66.7	51.6	43.6
BELSPOT2	0.94	81.8	69.9	54.2
BELSPOT3	1	63.9	65.3	54.9
WAMBOSPOT1	1	62.5	74	65.6
WAMBOSPOT2	0.96	72.7	64.2	62.1
WAMBOSPOT3	1	69.7	67.2	59.7

Average	1.0	69.6	65.4	56.7
Average scores for both Grey Box-Ironbark Woodland and Ironbark-Spotted Gum-Grey Box Forest	0.98	68.19	58.53	51.43

4.1.4 Visual monitoring, photo monitoring

The results of the visual monitoring, DBH and photo monitoring area provided in Appendix 4.

4.1.5 Soil analysis

The results of the soil analyses for key soil chemistry parameters for the reference sites are summarised in Table 9. This table includes a summary of the most significant indicators of soil condition.

Maximum, minimum and mean values for core soil attributes at the reference sites is provided in Table 10 , below. For reference, the detailed results as provided by SESL are included in Appendix 6.

Table 9. Summary of soil condition indicators at Reference Sites

Site	Texture	Soil Infiltration Rate	pH CaCl 2	EC (dS/ m)	Ece (dS/ m)	ECEC (Meq)	Ca (%)	Mg (%)	K (%)	Na (%)	NO3 (mg/k g)	PO4 (mg/k g)	K (mg/ kg)	Ca (mg/ kg)	Mg (mg/k g)	SO4 (mg/k g)	Na (mg/k g)	B (mg/ kg)	Cu (mg/ kg)	Fe (mg/ kg)	Mng (mg/k g)	Zn (mg/ kg)	OM (%)
Bel1	Loam Fine Sandy	Rapid	4.64	0.05	0.5	12	15.2	21.6	3.3	2.1	8.82	8.3	156	365	315	10	57.6	0.1	0.64	293	30	5.6	6.4
Bel2	Loam Fine Sandy	Rapid	5.72	0.07	0.7	10.3	73.7	20.8	3.8	1.5	18	6.4	152	1522	260	11	34.9	0.4	0.64	198	39	5.2	7.1
Bel3	Loam Fine Sandy	Rapid	5.03	0.07	0.7	17	31.2	22.4	2.6	2.9	6.93	6.4	170	1064	463	11	116	0.3	0.64	257	24	6.6	9.3
WarkGB01	Fine Sandy Clay Loam	Moderate	5.06	0.05	0.4	15.6	43.1	16	3.7	1	3.51	10	226	1346	303	14	34.1	0.2	0.6	196	43	6.1	6.8
WarkGB02	Light Sandy Clay Loam	Rapid	4.6	0.04	0.4	8.7	20.8	16	3.8	1.7	1.96	6.8	130	363	169	11	33.7	0.1	0.64	254	29	1.7	2.9
WarkGB04	Sandy Clay Loam	Moderate	5.14	0.06	0.6	13.2	23.4	25	2.4	2	1.4	13.2	125	619	401	11	62.9	0.1	0.64	241	21	2.5	3.9
WAMBO GB01	Clay Loam	Moderate	5.22	0.05	0.4	15.7	30.7	27.5	3.5	2.3	1.94	6.3	216	967	525	9.7	83.3	0.1	0.64	188	28	4	4.6
WAMBO GB 02	Clay Loam	Moderate	6.06	0.06	0.5	14.2	44.9	46.7	5.6	3.2	2.58	3.3	309	1277	806	8.2	104	0.2	0.64	130	37	4.6	5.3
WAMBO SPOT 1	Sandy Loam	Rapid	5.08	0.04	0.6	10.7	38.4	11.8	3.3	0.2	10.1	8.3	138	823	154	9.4	4.5	0.1	0.64	173	138	3	4.6
WAMBO SPOT 2	Clay Loam	Moderate	5.6	0.12	1	17.9	47	40.6	3.6	8.7	0.942	4.1	256	1688	884	12	359	0.2	0.64	162	22	2.3	4.9
WAMBO SPOT 3	Sandy Loam	Rapid	5.52	0.03	0.4	5.2	64.8	27.3	7.1	0.6	2.18	12.6	143	674	173	7.6	6.5	0.1	0.64	129	138	2.2	2.8
WarkGB03	Sandy Loam	Rapid	4.72	0.12	1.7	7.4	14.9	15.6	3.2	6.6	0.265	4.2	94.4	220	140	12	113	0.1	0.64	237	27	0.9	2.8

Table 10.Minimum, maximum and average values for measured soil parameters.

Vegetation community		pH (H_2O)	pH $CaCl_2$	Ece (dS/m)	ECEC (Meq)	Ca (%)	Mg (%)	K (%)	Na (%)	H (%)	OM (%)
Central Hunter Ironbark-Spotted Gum-Grey Box Forest	AVERAGE	6.10	5.27	0.65	12.2	45.1	24.1	3.9	2.7	23.8	5.9
	MAX	6.60	5.72	1.00	17.9	73.7	40.6	7.1	8.7	55.8	9.3
	MIN	5.60	4.64	0.40	5.2	15.2	11.8	2.6	0.2	0.0	2.8
	AVERAGE	5.78	5.13	0.67	12.47	29.6	24.5	3.7	2.8	39.1	4.4

Central Hunter Grey Box-Ironbark Woodland	**MAX**	6.60	6.06	1.70	15.70	44.9	46.7	5.6	6.6	58.8	6.8
	MIN	5.40	4.60	0.40	7.40	14.9	15.6	2.4	1.0	0.0	2.8

4.2 Rehabilitation monitoring sites

A total of 18 HVO rehabilitation monitoring sites, and 17 MTW monitoring site were established as described in Section 2.1.

BioBanking plots were undertaken at the following sites: MTWNPN2005-01, MTWNPN2005-02, MTWNPN2009-01, MTWCDD2011-01, MTWMTO2005-03, MTWMTO2000-01, HVOCAR200901, HVOCAR200902, HVOWES200801 and HVOWES201101.

The remainder of the sites were assessed by a Ground Cover Assessment as per the methodology discussed in Section 3.3.6.

4.2.1 Vegetation and condition

Descriptions for each site, including structure, dominant species and site photographs have been provided in Appendix 5.

Based on the BioBanking data collection, a total of 104 flora species across 30 families were recorded (Appendix 3). Of the 104 flora recorded, 31 were introduced species (30%).

Common native species across both MTW and HVO included:

- Trees: *Corymbia maculata*, *Eucalyptus crebra*, *Eucalyptus punctata.*
- Shrubs: *Acacia longifolia*, *Acacia amblygona*, *Acacia dealbata*, *Acacia falcata*, *Acacia mearnsii*.
- Grasses: *Bothriochloa macra*, *Chloris truncata*, *Cynodon dactylon*, *Austrodanthonia racemosa.*
- Forbs/herbaceous/other: *Oxalis perennans*, *Glycine tabacina*, *Eremophila debilis*, *Portulaca oleracea*, *Vittadinia cuneata*, *Einadia nutans*, *Dichondra repens*, *Sida corrugata*, *Cheilanthes sieberi*, *Calotis lappulacea*, *Enchylaena tomentosa*, *Cyperus gracilis*, *Chrysocephalum apiculatum*, *Vittadinia sulcata*, *Wahlenbergia gracilis*, *Wahlenbergia stricta*, *Einadia trigonos*, *Carex inversa*, *Fimbristylis dichotoma*, *Hardenbergia violacea*, *Indigofera australis.*
- Common introduced species include: *Galenia pubescens*, *Gomphocarpus fruticosus*, *Bidens pilosa*, *Cirsium vulgare*, *Conyza bonariensis*, *Senecio madagascariensis*, *Medicago arabica*, *Acacia saligna*, *Mimosa pudica*, *Sida rhombifolia*, *Plantago lanceolata*, *Chloris gayana*, *Panicum maximum*, *Paspalum dilatatum*, *Pennisetum clandestinum*, *Polygonum aviculare and Verbena bonariensis.*

4.2.2 BioBanking attribute data

The BioBanking attribute data collected from the rehabilitation sites, along with the average reference site local benchmarks, have been provided in Section 5 .

Table 11. BioBanking attribute data at rehabilitation sites and average local benchmarks

Plot name	Soil treatment	NPS	NOS	NMS	NGCG	NGCS	NGCO	EPC	NTH	OR	FL
HVOCAR200901	Topsoil	9	12	23	0	0	2	38	0	0	1
HVOCAR200902	Topsoil	15	3	8	0	0	8	86	0	0	0
HVOWES200801	Topsoil	22	9	15	22	2	14	30	0	0	0
HVOWES201101	Spoil/ Compost	21	19	0	50	0	20	24	0	0	0
MTWCDC201101	Topsoil	20	0	18	26	18	22	34	0	0	0
MTWMTO200001	Topsoil	19	7.5	0	36	0	10	26	0	0	0
MTWMTO200503	Topsoil	21	5.5	0	10	0	6	14	0	0	28
MTWNPN200501	Topsoil	15	4	0	18	2	6	65	0	0	1.5
MTWNPN200502	Topsoil	15	8	9	4	0	0	36	0	0	1
MTWNPN200901	Topsoil	14	57.5	0	8	6	0	12	0	0	0
Grey Box-Ironbark Woodland Lower and Upper Average Local Benchmarks	-	≥31	7.5 18.8	0 15.0	44.0 67.0	0 20.0	14.0 50.0	0	≥0	1	≥15
Ironbark-Spotted Gum-Grey Box Forest Lower and Upper Average Local Benchmarks	-	≥34	15.8 33.5	0.0 14.5	33.0 56.0	2.0 7.0	12.0 50.0	0	≥0	1	≥37

4.2.3 Ground Cover Assessment

The average ground cover assessment for all the HVO and MTW sites is provided in Table 12, with the raw data provided in Appendix 5.

No benchmark data was collected to allow for comparison.

Based on the data, on average the HVO North sites contain 71.1 percent Protective Cover. The sites with the highest average Protective Cover included HVO WES2013-01 (97 percent), HVO CHE2013-01 (93 percent), and HVO WES2013-02 (91 percent). This is attributed to cover crops (i.e. millet) that were used for initial stabilisation and volunteer introduced grass species (i.e. Green Panic) germinating from seeds in the topsoil.

The average ground cover assessment for all the MTW sites is provided in Table 12 and raw data provided in Appendix 5. Based on the data, on average the MTW sites contain 75.9 percent Protective Cover. The sites with the highest average Protective Cover included MTWCDD2013-01 (98 percent), MTWNPN2014-03 (93 percent) and MTWNPN2011-01 (84 percent). This is attributed to cover crops (i.e. millet) that were used for initial stabilisation and volunteer introduced grass species (i.e. Green Panic (*Panicum maximum*) germinating from seeds in the topsoil.

Sites containing the highest average amount of bare cover included MTWNPN2014-01 (51 percent) and MTWCDD2015-01 (44 percent).

Generally, a high average percentage weed cover made up the Protective Cover. Sites that contain high weed cover included MTWCDD2013-01 (97 percent), MTWSPN2014-01 (94 percent) and MTWNPN2014-03 (88 percent).

The average number of species recorded across all sites was four species (3.5 species).

Table 12. Ground cover assessment data for HVO and MTW sites

Site name	Soil treatment	Protective cover (%)	Bare (%)	Weeds (%) of Protective Cover	Number of species
HVO RIV2013-01	Topsoil/ Compost	81	19	100	2
HVO RIV2014-01	Spoil/ Compost	47	53	94	3
HVO RIV2014-02	Subsoil/ Compost	27	73	26	3
HVO RIV2014-03	Spoil/ Compost	39	61	97	6
HVO RIV2014-04	Subsoil/ Compost	74	26	70	5
HVO RIV2014-05	Subsoil/Compos t	77	23	100	2
HVO RIV2014-06	Topsoil/ Compost	73	27	70	5
HVO WES2013-01	Spoil/ Compost	97	3	55	5
HVO WES2013-02	Topsoil/ Compost	91	9	13	3
HVO CAR2014-01	Topsoil/ Compost	54	45	55	2
HVO CHE2012-01	Topsoil/ Compost	87	13	84	4

Site name	Soil treatment	Protective cover (%)	Bare (%)	Weeds (%) of Protective Cover	Number of species
HVO CHE2013-01	Topsoil/ Compost	93	7	46	4
HVO CHE2014-01	Topsoil/ Compost	74	26	81	3
HVO CHE2012-03	Topsoil/ Compost	81	19	63	3.7
MTWNPN2011-01	Topsoil	84	16	68	4
MTWTDI2015-01	Spoil/ Compost	77	23	5	2
MTWSPN2014-01	Topsoil/ Compost	81	19	94	2
MTWNPN2014-01	Topsoil/ Compost	49	51	42	4.6
MTWNPN2014-03	Subsoil/ Compost	93	7	88	7
MTWNPN2013-01	Topsoil/ Compost	76	24	74	2.6
MTWWDL2014-01	Topsoil/ Compost	71	29	73	5
MTWWDL2014-02	Topsoil/ Compost	74	26	51	3
MTWCDD2015-01	Spoil/ Compost	56	44	9	2.3
MTWCDD2013-01	Topsoil/ Compost	98	2	97	1.1
Average		**73.1**	**26.9**	**61.9**	**3.5**

4.2.1 Landscape Function Analysis

The raw data and average LFA scores for all the HVO and MTW sites is provided in Table 13.

HVO rehabilitation sites

Based on the data, LFA scores across all indices were fairly consistent for all sites, with no conspicuous outliers. The average LOI score was .89, across all the sites. High LOI scores, particularly at younger rehabilitation sites was generally driven by extensive grass cover, rather than development of leaf litter or shrub species.

MTW rehabilitation sites

The raw data and average LFA scores for all MTW sites is provided in Table 13.

Results include the following:

- LOI ranged from 0.14 to 1.0.
- Stability ranged from 47.8 to 85.4.
- Infiltration was highly variable and ranged from 10.3 to 71.4
- Like Infiltration, nutrient cycling was also variable and ranged from 10.3 to 77.8.
- MTWCDD201501 had the lowest LFA score. It was an outlier in the dataset. The cause for this low score is likely due to the site being in the early stages of rehabilitation, with foliage cover at the site being extremely low. This is evident from the photo monitoring results provided in Appendix 4.

Table 13. LFA for HVO and MTW Rehabilitation sites

Site name	LOI	Stability	Infiltration	Nutrient Cycling
HVO RIV201406	1	74.4	63.3	75.6
MTWWDL201401	0.97	63.7	40.6	36.8
MTWWDL201402	0.98	66.5	71.4	67.2
HVO RIV201301	0.94	73.1	48.7	52.4
HVO CHE201301	1	64.2	46.3	67
HVO CAR200901	0.83	66.5	47.4	44.2
HVO CAR200902	0.99	68	46.2	40.1
HVO CAR201401	0.86	61.4	43.3	50.2
HVO WES200801	0.61	58.8	47.1	46
HVO WES201302	0.93	55	33.8	25.5
HVO CHE201203	0.91	64.3	57.3	57.5
HVO CHE201401	0.82	55.6	40.2	34.1
HVO CHE201201	0.98	65.4	56.1	76.5
HVO RIV201405	1	73.1	64.1	77.8
HVO RIV201404	0.96	56	21.3	15.9
HVO RIV201403	0.86	50.8	22	16
HVO RIV201402	0.77	53.9	22.1	13.5
HVO RIV201401	0.69	49	33.2	22.6
HVO WES201101	0.95	61.4	35.9	25.7
HVO WES201301	0.88	50.4	27	18.8
MTWWDL201401	0.97	63.7	40.6	36.8
MTWWDL201402	0.98	66.5	71.4	67.2
MTWNPN200901	0.93	66.2	40.5	45.8
MTWCDD201101	0.98	85.4	65.2	72.1
MTWCDD201301	1	78.7	77.8	64.6
MTWSPN201401	1	73.7	40.7	37.2
MTWNPN200502	0.95	61.3	37	32.4
MTWNPN201301	1	63.5	57.1	53.3
MTWNPN201402	0.96	59.8	39.5	47
MTWNPN201401	0.67	61.9	32.8	21.4
MTWNPN201101	1	58.7	57.1	53.5
MTWNPN200501	0.92	63.3	43.3	39.9
MTWMTO200001	0.89	58.2	31.8	33.9
MTWMTO200503	0.54	54	28.5	21.4
MTWCDD201501	0.14	47.8	10.3	10.3
MTWNPN201403	0.98	74.6	66.8	65.5
MTWTD1201501	0.61	54.4	24	22

4.2.2 Visual monitoring, photo monitoring

The results of the visual monitoring and photo monitoring for the HVO North sites area provided in Appendix 5.

4.2.3 Soil analysis

The results of the soil analyses for key soil chemistry parameters for the HVO site MTW sites are summarised in Table 14. This table includes a summary of the most significant indicators of soil condition. For reference, the detailed results provided by SESL Australia are included in Appendix 6.

Table 14. Summary of soil condition indicators at MTW and HVO rehabilitation sites

Site	Texture	Soil Infiltration Rate	pH (H2O)	pH CaCl2	EC (dS/m)	Ece (dS/m)	ECEC (Meq)	Ca (%)	Mg (%)	K (%)	Na (%)	NO3 (mg/kg)	PO4 (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	SO4 (mg/kg)	Na (mg/kg)	B (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mng (mg/kg)	Zn (mg/kg)	OM (%)
MTWCDC201301	Clay Loam	Moderate	7.8	7.3	0.32	2.8	19.9	75.3	18.7	3.5	2.7	9.7	110.4	269	3002	452	210	123	0.8	5.1	247	50	30	6
MTWCDD201101	Clay Loam	Moderate	7.3	6.59	0.09	0.8	12.1	50.6	38.4	5.5	5.7	9.68	1	262	1225	564	15	159	0.3	1.3	265	42	4.5	3.7
MTWCDD201501	Clay Loam	Moderate	8	7.55	0.21	1.8	14.8	70.3	24.5	3.2	2.1	13.4	153	186	2087	441	83	72	0.5	5.7	237	16	30	3.7
MTWMTO200503	Sandy Clay Loam	Moderate	7.8	7.38	0.26	2.5	12.3	44.5	44.8	2.2	8.6	2.24	6	104	1095	670	96	244	0.1	0.64	131	27	1.8	3.3
MTWNPN200501	Clay Loam	Moderate	7.4	7.05	0.08	0.7	10.9	47.7	44.6	6.8	1.3	13.7	2.7	289	1042	591	9.9	33.3	0.3	0.9	166	41	2.4	2.7
MTWNPN200502	Sandy Clay Loam	Moderate	6.6	6.19	0.08	0.8	10.7	46.4	47.4	5.2	1.2	13.1	1.8	220	994	616	15	30.1	0.3	0.9	227	26	5.6	6
MTWNPN200901	Clay Loam	Moderate	6.8	6.36	0.08	0.7	12.6	59	35.5	4.4	1	2.7	0.9	220	1490	543	17	26.7	0.3	1.7	221	31	4.6	4
MTWNPN201101	Clay Loam	Moderate	7.9	7.39	0.07	0.6	12.9	63.5	32.2	3.6	0.4	2.01	1.2	184	1641	505	11	11.7	0.4	1.8	129	65	6	3.4
MTWNPN201301	Sandy Clay Loam	Moderate	7	6.96	0.16	1.5	8.9	73.9	19.8	4.6	1.3	1.07	28.7	159	1319	214	66	27.3	0.3	1.7	291	19	10	3
MTWNPN201401	Fine Sandy Clay Loam	Moderate	6.9	6.55	0.18	1.5	11.4	59	33.3	4.1	3.9	0.9	31.2	184	1348	462	54	102	0.3	3.3	263	44	11	3.8
MTWNPN201403	Clay Loam	Moderate	7.6	7.3	0.17	1.5	16.6	70.9	23.2	4.7	1.3	3.72	148	304	2359	468	51	47.5	0.7	4.8	251	52	24	6.1
MTWNPN201405	Loamy Sand	Very Rapid	6.7	6.27	0.03	0.7	4.2	83.1	13	3.3	0.5	0.157	25.4	55.5	700	66	7.6	3.6	0.1	1	115	27	6.9	3.8
MTWSPN201401	Clay Loam	Moderate	8.1	7.27	0.11	0.9	13.8	67.8	26.5	3.8	2	2.09	29.7	208	1877	444	21	62.3	0.5	3.7	226	42	17	4.8
MTWTDI201501	Clay Loam	Moderate	9.6	8.66	0.49	4.2	16.5	24.1	28	4.2	43.6	0.05	7.5	268	795	560	124	1654	0.4	9.3	262	7.9	26	8.3
MTWTO200001	Sandy Clay	Slow	7.6	7.02	0.13	1.1	12	39.9	47.7	2.7	9.6	4.67	15.7	126	959	696	20	263	0.1	1.1	186	21	18	2.4
MTWWDL201401	Clay Loam	Moderate	7.1	7.08	0.37	3.2	14.3	59.4	29.4	5.3	5.9	3.74	90.5	298	1702	510	167	196	0.3	2.2	307	23	18	6.1
MTWWDL201402	Clay Loam	Moderate	8	7.43	0.27	2.3	17.9	59.1	31.9	4.1	5	8.65	67.2	284	2118	693	127	205	0.6	4.7	310	55	21	8.7

Site	Texture	Soil Infiltration Rate	pH (H2O)	pH CaCl2	EC (dS/m)	Ece (dS/m)	ECEC (Meq)	Ca (%)	Mg (%)	K (%)	Na (%)	NO3 (mg/kg)	PO4 (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	SO4 (mg/kg)	Na (mg/kg)	B (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mng (mg/kg)	Zn (mg/kg)	OM (%)
HVOCAR200901	Light Clay	Slow	7.7	6.98	0.07	0.6	15.9	35.7	53.6	5	5.8	1.79	2.8	314	1137	1035	8.8	213	0.5	1.7	143	95	2	2.1
HVOCAR200902	Light Medium Clay	Slow	7.9	7.53	0.14	1.1	1.9	61.1	33	4.2	3.2	2.18	3.4	32.1	232	76	3.2	14.2	0.1	0.64	18.5	13	1.1	1.5
HVOCAR201401	Clay Loam	Moderate	7.5	6.76	0.17	1.5	20.1	59.5	32.1	4.6	3.8	1.3	42.2	361	2398	783	50	177	1.4	3.3	192	122	10	5.4
HVOCHE 201201	Clay Loam	Moderate	7.9	7.13	0.13	1.1	15.2	67.2	23.7	4.5	4.5	10.9	69.4	267	2047	438	15	157	0.5	4	234	64	20	3.8
HVOCHE2014-01	Sandy Clay	Slow	7.8	7.32	0.13	1.1	15.5	55.5	35.7	3.9	4.6	3.32	29.3	238	1723	672	32	166	0.5	1.7	141	47	6.8	3.4
HVOCHES2012-03	Sandy Loam	Rapid	8.2	7.63	0.12	1.7	15.5	73.5	19.4	3.4	3.7	3.99	117.1	203	2283	366	21	132	1.2	5.6	199	31	35	4.5
HVORIV201301	Clay Loam	Moderate	8.6	7.79	0.24	2.1	22.4	48.5	37.9	3.4	10	11.6	18.3	300	2177	1031	30	518	0.9	3	162	91	6.4	3.1
HVORIV201401	Clay Loam	Moderate	9	8.23	0.37	3.2	28.1	43.7	41.3	3.2	11.7	6.71	71.4	354	2463	1409	65	755	1.1	4.1	119	93	17	3.6
HVORIV201402	Clay Loam	Moderate	9.1	8.15	0.29	2.5	27.1	50.7	38.7	2.3	8.5	3.07	62.3	239	2752	1274	75	529	1	4.6	131	119	22	4.8
HVORIV201403	Clay Loam	Moderate	8.7	7.89	0.15	1.3	22.2	49.7	42	3	5.3	2.27	90.9	258	2212	1134	29	272	0.9	6.8	250	52	24	3.2
HVORIV201404	Clay Loam	Moderate	8.5	7.93	0.31	2.7	22.1	62.2	27.6	3.8	6.3	6.18	85.2	330	2754	740	112	321	1.2	5.9	210	51	25	5.8
HVORIV201405	Sandy Clay Loam	Moderate	8.4	7.65	0.11	1	13.4	70	19.7	6.6	3.7	4.01	123	346	1880	320	13	115	0.6	4.4	197	67	28	4.8
HVORIV201406	Clay Loam	Moderate	8.1	7.48	0.13	1.1	23.2	63.8	28.8	3.6	3.6	6.67	93.6	326	2966	812	22	194	0.8	4.5	262	57	33	7
HVOWES2008-01	Clay Loam	Moderate	7.2	6.72	0.08	0.7	12.3	55.4	38.1	5	1.1	4.46	2.9	237	1367	569	11	32.1	0.4	1.7	127	58	3.7	4.6
HVOWES2011-01	Light Clay	Slow	8.4	7.74	0.19	1.6	22.6	46.7	49.1	2.1	2.2	2.04	25.8	186	2115	1349	58	114	0.2	4	88.8	30	17	5.5
HVOWES2013-01	Clay Loam	Moderate	8.6	7.92	0.15	1.3	19	62.8	32	2.8	2.1	3.44	62.3	210	2391	739	22	92.9	0.5	4.8	116	45	20	2.1
HVOWES2013-02	Clay Loam	Moderate	8	7.45	0.15	1.3	13.6	61.8	32.1	4.2	2.2	2.07	23	222	1684	531	26	69.7	0.8	4	188	31	15	4.6

5. Discussion

5.1 Rehabilitation sites compared to Central Hunter Grey Box – Ironbark Woodland Reference Site Benchmarks

Rehabilitation sites have been compared to reference site benchmarks for Central Hunter Grey Box – Ironbark Woodland in Table 15.

The following conclusions can be made from comparing the reference site benchmarks for Central Hunter Grey Box-Ironbark Woodland against the rehabilitation sites:

- All sites are lower than benchmark for NPS.
- Sites HVO CAR200901, HVO WES200801 and MTWMTO200001 are within benchmark for NOS.
- MTWNPN200901 contains a high NOS (above benchmark). This is attributed to the close stands of eucalypts present at the site. Details are provided in Appendix 5.
- MTWCDC201101 did not have any NOS. This is likely due to juvenile trees not occurring in the canopy stratum.
- HVO CAR200902, HVO WES200801 and MTWNPN200502 are within benchmark for NMS, whilst HVO CAR200901 and MTWCDC201101 are above benchmark. It should be noted that the lower benchmark value for NMS is zero.
- HVO WES201101 and MTWMTO200001 are within benchmark for NGCG.
- HVO WES200801, MTWCDC201101, MTWNPN200501 and MTWNPN200901 were within benchmark for NGCS. It should be noted that the lower benchmark value for NGCS is zero, and thus any low shrub cover will put the site into benchmark for this attribute.
- HVO WES200801, HVO WES201101 and MTWCDC201101 are within benchmark for NGCO.
- All sites have a high percentage of weed cover.
- None of the sites contain evidence of native regeneration (e.g. young eucalypts regenerating naturally).
- All sites meet benchmark for NTH. However, this is due to the benchmark value being zero.
- Only site MTWMTO200503 is within benchmark for FL. Most sites did not contain any FL, although this is to be expected given the age of the canopy.
- It cannot be concluded that the older sites are trending closer to benchmark compared with younger sites, as there is a range of results for each of the attributes when comparing establishment years. For example, MTWNPN200901 has a high NOS (57.5 percent) compared to older years. This would largely be attributed to the management that has occurred at each rehabilitation area, including the seeding mix and seeding methods used.

Table 15. Rehabilitation sites compared to Central Hunter Grey Box – Ironbark Woodland benchmarks

Plot name	Soil treatment	NPS	NOS		NMS		NGCG		NGCS		NGCO		EPC	NTH	OR	FL
Central Hunter Grey Box-Ironbark Woodland benchmark	-	≥31	7.5	18.8	0	15.0	44.0	67.0	0	20.0	14.0	50.0	0	≥0	1	≥15
HVO CAR200901	Topsoil	9	12		23		0		0		2		38	0	0	1
HVO CAR200902	Topsoil	15	3		8		0		0		8		86	0	0	0
HVO WES200801	Topsoil	22	9		15		22		2		14		30	0	0	0
HVO WES201101	Topsoil	21	19		0		50		0		20		24	0	0	0
MTWCDC201101	Topsoil	20	0		18		26		18		22		34	0	0	0
MTWMTO200001	Topsoil	19	7.5		0		36		0		10		26	0	0	0
MTWMTO200503	Topsoil	21	5.5		0		10		0		6		14	0	0	28
MTWNPN200501	Topsoil	15	4		0		18		2		6		65	0	0	1.5
MTWNPN200502	Topsoil	15	8		9		4		0		0		36	0	0	1
MTWNPN200901	Topsoil	14	57.5		0		8		6		0		12	0	0	0

0-10% of reference site benchmark

10-50% of reference site benchmark

50-100% of reference site benchmark

within reference site benchmark

Include OEH Benchmark scores as well for reference. Leave colour-coding as a comparison with reference site benchmarks

5.2 Rehabilitation sites compared to Central Hunter Ironbark-Spotted Gum-Grey Box Forest Reference Site Benchmarks

Rehabilitation sites have been compared to reference site benchmarks for Central Hunter Ironbark-Spotted Gum-Grey Box in Table 16.

The following conclusions can be made from comparing the reference site benchmarks for Central Hunter Ironbark-Spotted Gum-Grey Box against the rehabilitation sites:

- All sites are lower than benchmark for NPS.
- Only HVO WES201101 is within benchmark for NOS.
- MTWNPN200901 contains a high NOS (above benchmark). This is attributed to the close stands of eucalypts present at the site. Details are provided in Appendix 5.
- MTWCDC201101 did not have any NOS. This is likely due to juvenile trees not occurring in the canopy stratum.
- HVO CAR200902 and MTWNPN200502 are within benchmark for NMS, whilst HVO CAR200901, HVO WES200801 and MTWCDC201101 are above benchmark. It should be noted that the lower benchmark value for NMS is zero.
- HVO WES201101 and MTWMTO200001 are within benchmark for NGCG.
- HVO WES200801, MTWNPN200501 and MTWNPN200901 were in benchmark for NGCS. MTWCDC201101 is above benchmark. It should be noted that the lower benchmark value for NGCS is zero, and thus any shrub cover will put the site into benchmark for this attribute.
- HVO WES200801, HVO WES201101 and MTWCDC201101 are within benchmark for NGCO.
- All sites have a high percentage of weed cover.

- None of the sites contain evidence of native regeneration (e.g. young eucalypts regenerating naturally).
- All sites meet benchmark for NTH. However, this is attributed to the benchmark value being zero.
- All sites are below benchmark for FL. Most sites did not contain any FL, although this is to be expected given the age of the canopy.
- It cannot be concluded that the older sites are trending closer to benchmark compared to younger sites, as there is a range of results for each attribute when comparing establishment years. For example, MTWNPN200901 has a high NOS (57.5 percent) compared to older years. This would largely be attributed to the management that has occurred at each rehabilitation area, including the seeding mix and seeding methods used.

Table 16. Rehabilitation sites compared to Central Hunter Ironbark-Spotted Gum-Grey Box Forest benchmarks

Plot name	Soil treat	NPS	NOS		NMS		NGCG		NGCS		NGCO		EPC	NTH	OR	FL
Central Hunter Ironbark-Spotted Gum-Grey Box Forest reference site benchmark	-	≥34	15.8	33.5	0.0	14.5	33.0	56.0	2.0	7.0	12.0	50.0	0	≥0	1	≥37
HVO CAR200901	Topsoil	9	12		23		0		0		2		38	0	0	1
HVO CAR200902	Topsoil	15	3		8		0		0		8		86	0	0	0
HVO WES200801	Topsoil	22	9		15		22		2		14		30	0	0	0
HVO WES201101	Topsoil	21	19		0		50		0		20		24	0	0	0
MTWCDC201101	Topsoil	20	0		18		26		18		22		34	0	0	0
MTWMTO200001	Topsoil	19	7.5		0		36		0		10		26	0	0	0
MTWMTO200503	Topsoil	21	5.5		0		10		0		6		14	0	0	28
MTWNPN200501	Topsoil	15	4		0		18		2		6		65	0	0	1.5
MTWNPN200502	Topsoil	15	8		9		4		0		0		36	0	0	1
MTWNPN200901	Topsoil	14	57.5		0		8		6		0		12	0	0	0

0-10% of reference site benchmark

10-50% of reference site benchmark

50-100% of reference site benchmark

within reference site benchmark

Include OEH Benchmark scores as well for reference. Leave colour-coding as a comparison with reference site benchmarks

5.3 Weed cover across rehabilitation sites

Based on the results of the BioBanking attribute data (Table 15 and Table 16), ground cover assessment and visual assessment (Appendix 5), weed cover was relatively high across all rehabilitation sites.

A high weed cover is expected given many of the sites were seeded with introduced cover crop species for initial stabilisation and the topsoil being used generally contains a high weed seed load.

A breakdown of the percentage of native vegetation cover compared to protective cover was not achievable, given such data collection was not specified in the AECOM (2012). A recommendation to include collection of this data in future survey has been provided in Section 6.

5.4 Comparison of ground cover assessment for compost and topsoil sites

A comparison of the ground cover assessment scores for four different soil treatment (Soil/Compost, Topsoil/Compost, Topsoil, Subsoil/Compost) at HVO North and MTW sites has been provided in Charts 1-3.

Significant findings include the following:

Protective Cover (%)

- Most of the sites had greater than 50 percent Protective Cover.
- Generally there was not a great deal of variation between different soil treatments.
- There were individual sites within each soil treatment which had high protective cover. For example, MTWCDD2013-01 (topsoil/Compost 98 percent), MTWNPN2014-02 (Spoil/Compost 97 percent), MTWNPN2011-01 (topsoil 84 percent) and MTWNPN2014-03 (subsoil/compost 93 percent).
- The site with the lowest Protective Cover was HVORIV2014-02.
- As mentioned above, a breakdown on the percentage of native vegetation cover compared to protective cover was not achievable, given such data collection was not specified in AECOM (2012). Furthermore, difference in scores may be attributed to weed management and seed establishment, but methodologies used at each site to enable these comparisons was not available.

Weed Cover (%) of Protective Cover

- High weed cover was present at all sites.
- The site with the lowest weed cover percentage was MTWCDD2015-01 and MTWTDI2015-01 however, this is likely due to the Protective Cover consisting more of rocks rather than vegetation cover.
- Generally there was not a great deal of variation between different soil treatments.

Number of native species

- The number of native species ranged from one to seven species.
- The site with the highest number of native species was MTWNPN2014-03 (seven species) and HVORIV2014-03 (six species).

Chart 1. Ground cover assessment – Protective Cover across rehabilitation sites

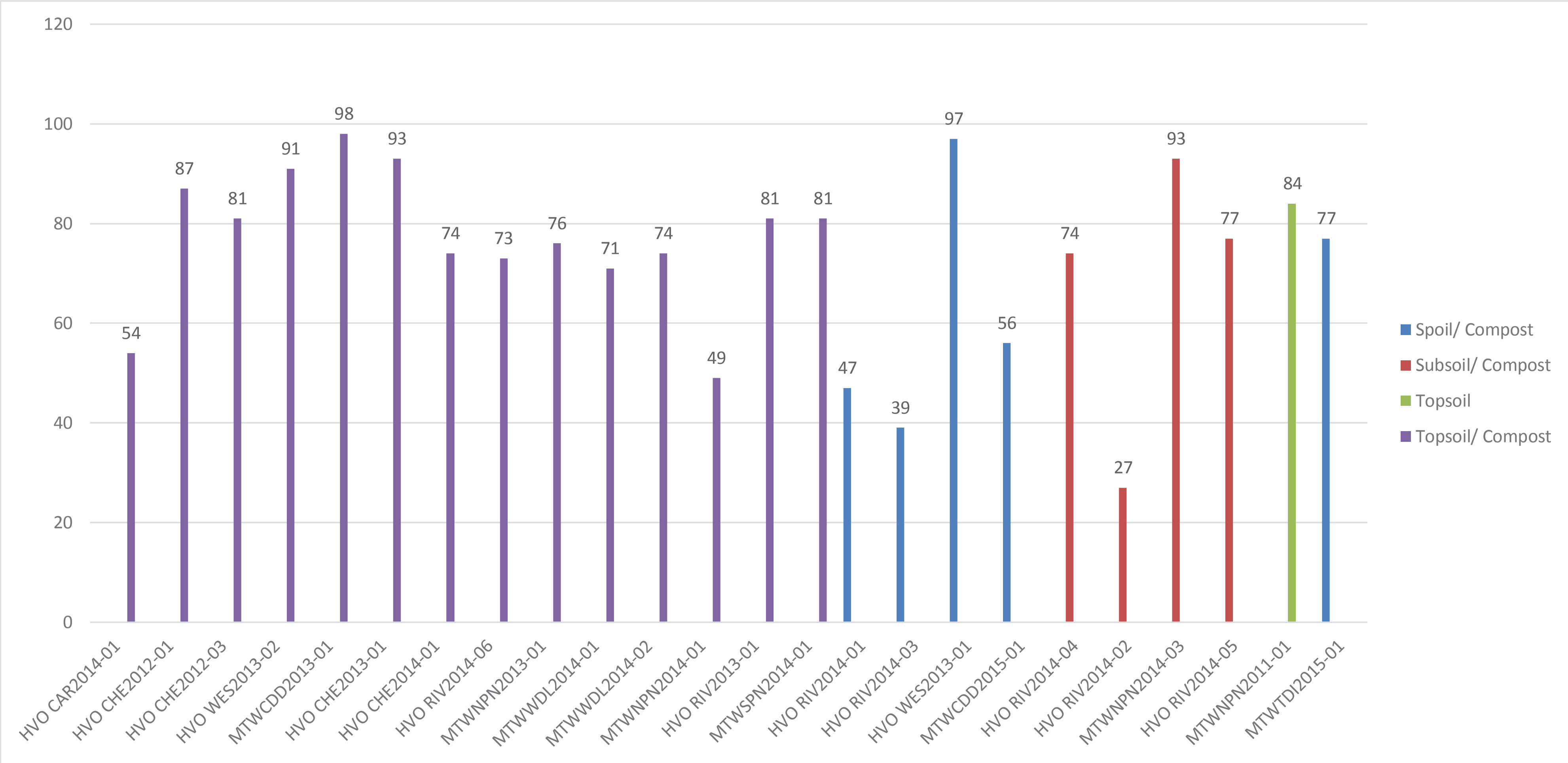


Chart 2. Weed cover percentage of the Protective Cover across rehabilitation sites.

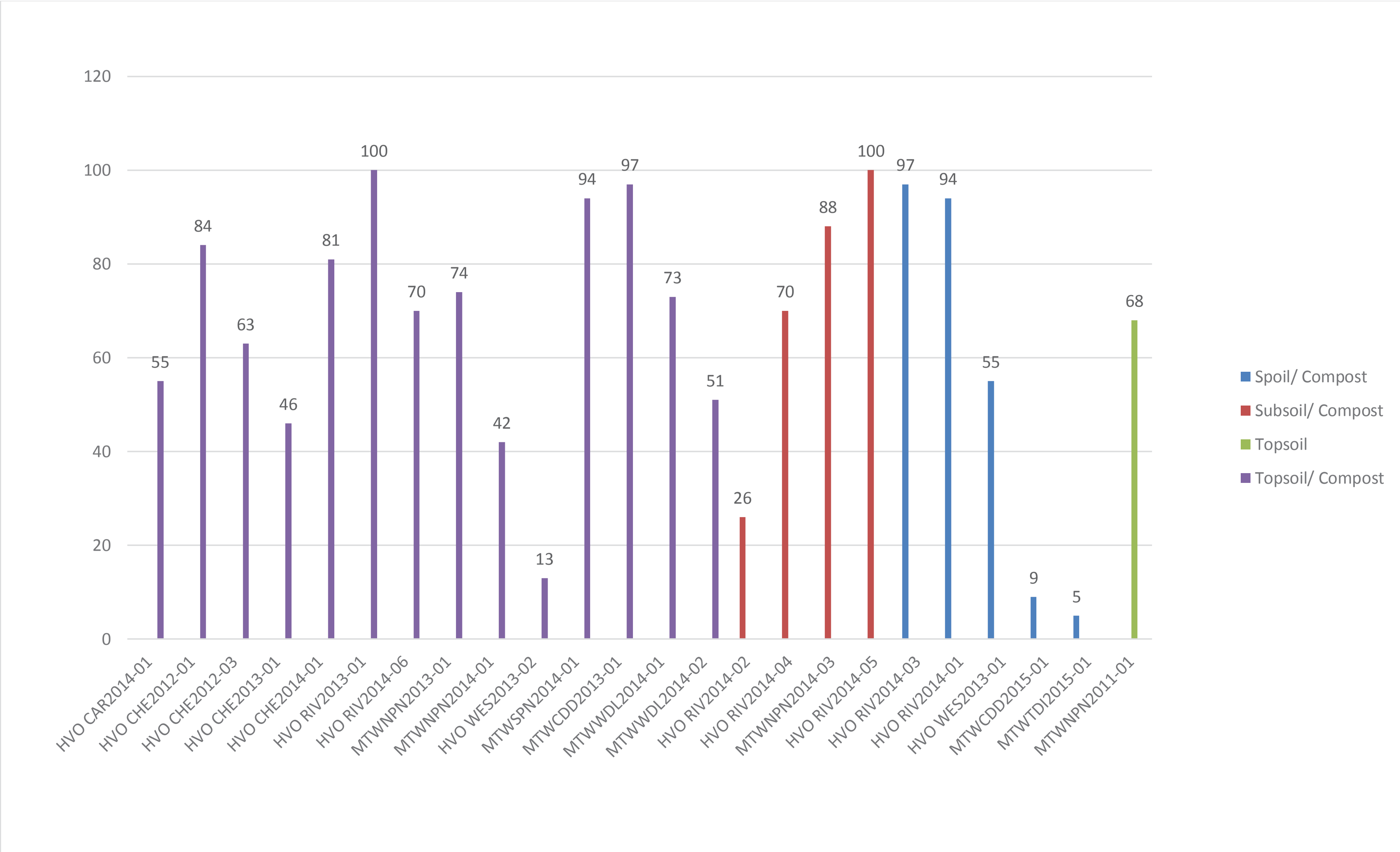
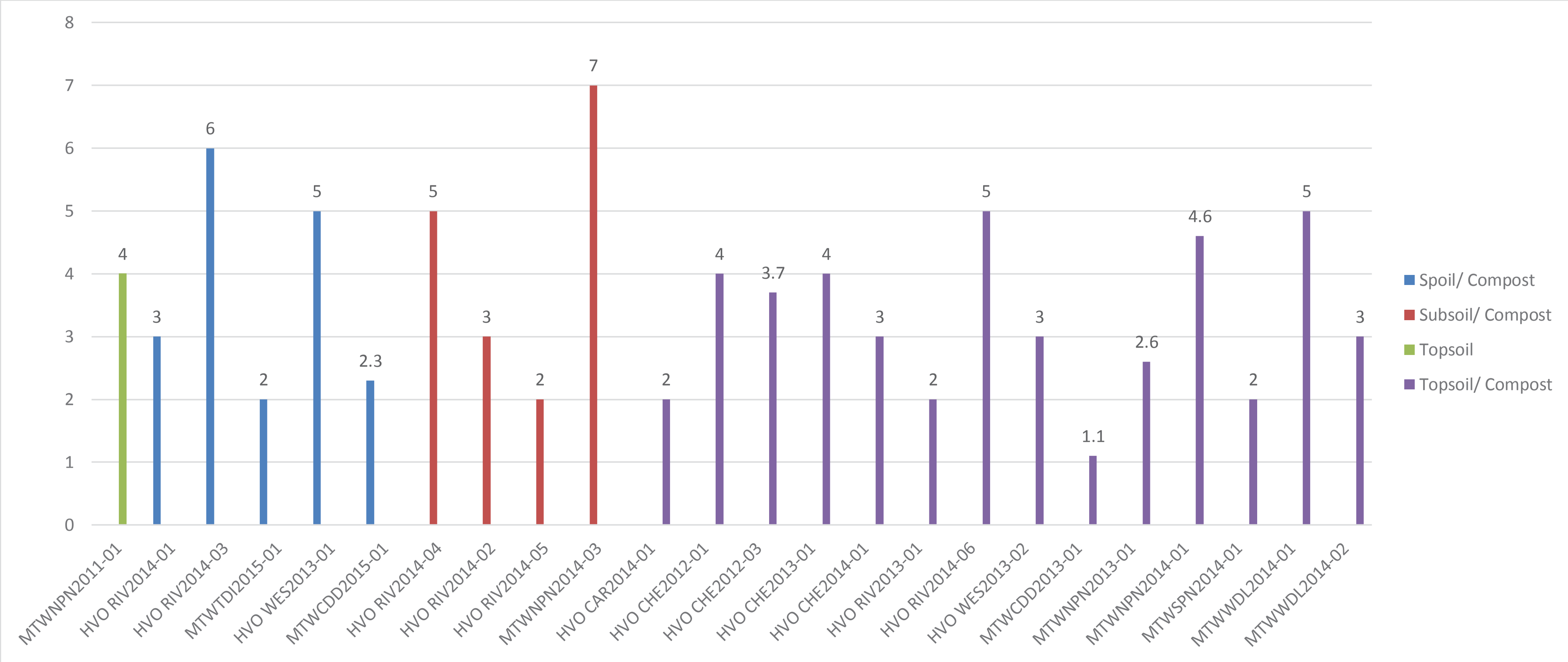


Chart 3. Number of native species across the rehabilitation sites



5.5 Landscape Function Analysis comparison to reference sites

5.5.1 Landscape Organisation Index (LOI)

In general the LOI at the reference and rehabilitation sites was high, with an average LOI of 0.98 for the reference sites and 0.87 for the rehabilitation sites (see Table 17). The variability in the range of scores however was greater at the rehabilitation sites than at the reference sites. The variability in values at the rehabilitation sites is likely to be influenced by the seed treatments applied to those sites and the age of the rehabilitation. For example, many of the rehabilitation sites with a LOI of 1 achieved this result due to the high density of grass species (whether native or exotic). Examples of these sites include HVORIV201405 and HVORIV201406. Conversely, sites that achieved relatively low LOI indices were typically spoil/compost sites that had only recently been established and exhibited little grass or plant cover (ie MTW CDD201501, MTW TD1201501 and HVO RIV201401).

Table 17. Provides the LOI and soil surface indicators for all sites.

Site name	Soil treatment	LOI	Stability	Infiltration	Nutrient Cycling
BELLSPOT1	Reference	1	66.7	51.6	43.6
BELLSPOT2	Reference	0.94	81.8	69.9	54.2
BELLSPOT3	Reference	1	63.9	65.3	54.9
WAMBOGB1	Reference	1	58.3	56.2	46.3
WAMBOGB2	Reference	1	72.5	48.4	48.4
WAMBOSPOT1	Reference	1	62.5	74	65.6
WAMBOSPOT2	Reference	0.96	72.7	64.2	62.1
WAMBOSPOT3	Reference	1	69.7	67.2	59.7
WARKGB01	Reference	1	69.8	49.7	43.2
WARKGB02	Reference	1	70	57.6	52.1
WARKGB03	Reference	0.84	57.9	49.8	38.7
WARKGB04	Reference	0.97	72.5	48.4	48.4
	Average	0.98	68.19	58.53	51.43
HVO RIV201401	Spoil/ Compost	0.69	49	33.2	22.6
HVO RIV201403	Spoil/ Compost	0.86	50.8	22	16
HVO WES201101	Spoil/ Compost	0.95	61.4	35.9	25.7
HVO WES201301	Spoil/ Compost	0.88	50.4	27	18.8
MTWCDD201501	Spoil/ Compost	0.14	47.8	10.3	10.3
MTWTDI201501	Spoil/ Compost	0.61	54.4	24	22
HVO RIV201402	Subsoil/ Compost	0.77	53.9	22.1	13.5
HVO RIV201404	Subsoil/ Compost	0.96	56	21.3	15.9
HVO RIV201405	Subsoil/ Compost	1	73.1	64.1	77.8
MTWNPN201403	Subsoil/ Compost	0.98	74.6	66.8	65.5
HVO CAR200901	Topsoil	0.83	66.5	47.4	44.2
HVO CAR200902	Topsoil	0.99	68	46.2	40.1
HVO WES200801	Topsoil	0.61	58.8	47.1	46
MTWCDD201101	Topsoil	0.98	85.4	65.2	72.1
MTWMTO200001	Topsoil	0.89	58.2	31.8	33.9
MTWNPN200501	Topsoil	0.92	63.3	43.3	39.9

Site name	Soil treatment	LOI	Stability	Infiltration	Nutrient Cycling
MTWNPN200502	Topsoil	0.95	61.3	37	32.4
MTWNPN200901	Topsoil	0.93	66.2	40.5	45.8
MTWNPN201101	Topsoil	1	58.7	57.1	53.5
MTWMTO200503	Topsoil	0.54	54	28.5	21.4
HVO CAR201401	Topsoil/ Compost	0.86	61.4	43.3	50.2
HVO CHE201201	Topsoil/ Compost	0.98	65.4	56.1	76.5
HVO CHE201203	Topsoil/ Compost	0.91	64.3	57.3	57.5
HVO CHE201301	Topsoil/ Compost	1	64.2	46.3	67
HVO CHE201401	Topsoil/ Compost	0.82	55.6	40.2	34.1
HVO RIV201301	Topsoil/ Compost	0.94	73.1	48.7	52.4
HVO RIV201406	Topsoil/ Compost	1	74.4	63.3	75.6
HVO WES201302	Topsoil/ Compost	0.93	55	33.8	25.5
MTWCDD201301	Topsoil/ Compost	1	78.7	77.8	64.6
MTWNPN201301	Topsoil/ Compost	1	63.5	57.1	53.3
MTWNPN201401	Topsoil/ Compost	0.67	61.9	32.8	21.4
MTWNPN201402	Topsoil/ Compost	0.96	59.8	39.5	47
MTWSPN201401	Topsoil/ Compost	1	73.7	40.7	37.2
MTWWDL201401	Topsoil/ Compost	0.97	63.7	40.6	36.8
MTWWDL201402	Topsoil/ Compost	0.98	66.5	71.4	67.2
	Average	0.87	62.66	43.42	42.39

5.5.2 Soil surface condition

Stability

There's some level of consistency between the average stability index for reference and rehabilitation sites, with the reference sites obtaining an average index of 68.7 and the rehabilitation sites obtaining an average score of 68.2. As with the results from the LOI (above), stability indicators across all the sites show greater consistency than the stability indicators for the rehabilitation sites. This is likely due to the variation in the age of the rehabilitation sites and the variation in the nature of the rehabilitation works undertaken at each site. The stability indicators for the rehabilitation scores had a range of 36.4, whilst the range of indices for the reference sites was 23.9.

Infiltration

There's a greater difference in the averages infiltration indices between reference and rehabilitation sites than for the soil surface condition indices (stability and nutrient cycling). The average value for the reference sites was 58.32, whilst the rehabilitation sites had an average of 43.42. The range of scores was greater for the rehabilitation scores than the reference sites. The range for the reference sites was 25.6, whilst the range value of the rehabilitation sites was 68.19.

Nutrient enrichment

The difference in the range of values for the nutrient enrichment is less than the average difference for the Infiltration indices. The average index for reference sites was 51.43, whilst the average index for rehabilitation sites was 42.39.

5.6 Landscape Function Analysis comparison to soil treatments

The results of the LFA showed a consistency across monitoring and rehabilitation sites, and between rehabilitation treatments. The LOI showed a large range (between 0.14 and 1), although the bulk of the sites exceeded 0.9.

Based on a preliminary evaluation of the data, sites have also been split for the purpose of this discussion into three broadly distinct categories of soil treatment:

1. Sites without treatment (reference/reference sites)
2. Spoil/ Compost
3. Subsoil/ Compost
4. Topsoil
5. Topsoil/ Compost

Sections 5.6.3 and 1.1.1 below provide a discussion of the LOI results and soil surface assessment indicators (stability, infiltration and nutrient cycling).

5.6.3 Landscape Organisation Index (LOI)

Whilst to a large extent the LOI scores were consistent across the sites and the relevant treatments, there is variation in the averages across the soil treatments. Table 18 shows the average LOI for the different soil treatments as well as the relevant range. Chart 4 provides the results of the LOI across all sites.

The averages show that the sites treated with Spoil/Compost have a lower average LOI, than the reference sites or other soil treatments. Topsoil/ Compost contained the greatest average LOI (0.93) which was close to Reference sites (0.97).

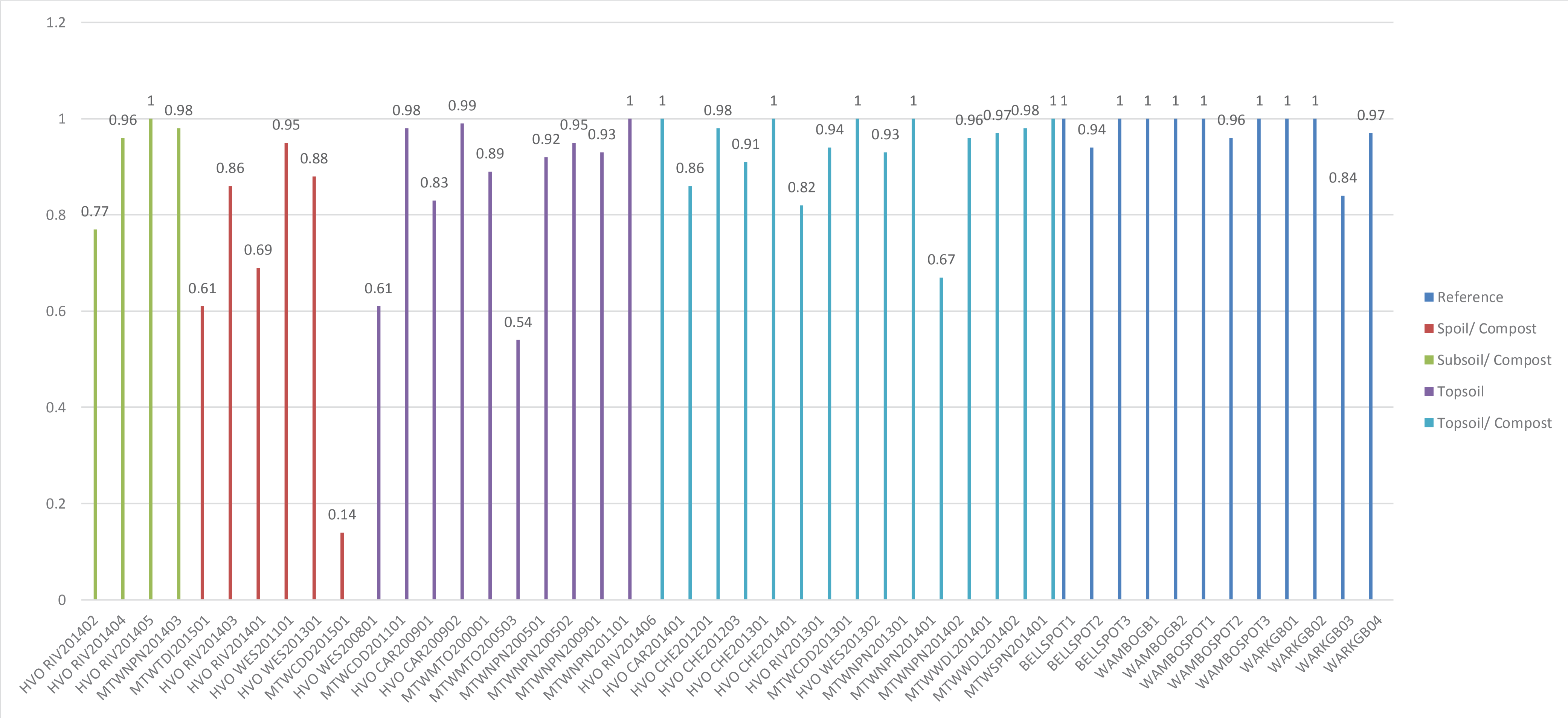
One outlier in the dataset is MTWCDD201501 which achieved a LOI of only 0. MTWDD201501 was a relatively new site, with a lack of plant cover and litter accumulation being the likely reason for the low LOI.

LOI is a measure of the total length of all measured 'patches' as a proportion of the length of the transect, which for this study was 50 m. A patch is a defined as a zone of resource accumulation and in the field was largely represented by vegetation and leaf litter. These parameters in a rehabilitation context would be expected to change with time, and are likely to be influenced by the revegetation techniques used. It is also valuable to note in this context that LOI is not a measure of native diversity, and in this regard successful rehabilitation. For example, WARKGB04 by comparison with other sites has a relatively low LOI, but still exhibits a high species richness score. By comparison, HVO RIV201301, with a LOI of 94, is comprised entirely of exotic vegetation.

Table 18. Average LOI scores across reference sites, and different soil treatment sites.

Treatment	Average scores across rehabilitation and reference sites
Reference site	0.97
Spoil/ Compost	0.69
Subsoil/ Compost	0.93
Topsoil	0.86
Topsoil/ Compost	0.94

Chart 4. Comparison of LOI across soil treatments



5.6.4 Soil surface condition

The ten soil surface indicators collected during LFA monitoring, feed into soil assessments; stability, infiltration and nutrient cycling. The results of these and some of the core outcomes of the results are provided below.

Stability

The averages for stability across all soil treatments are provided in Table 19. Chart 5 provide the results from all sites.

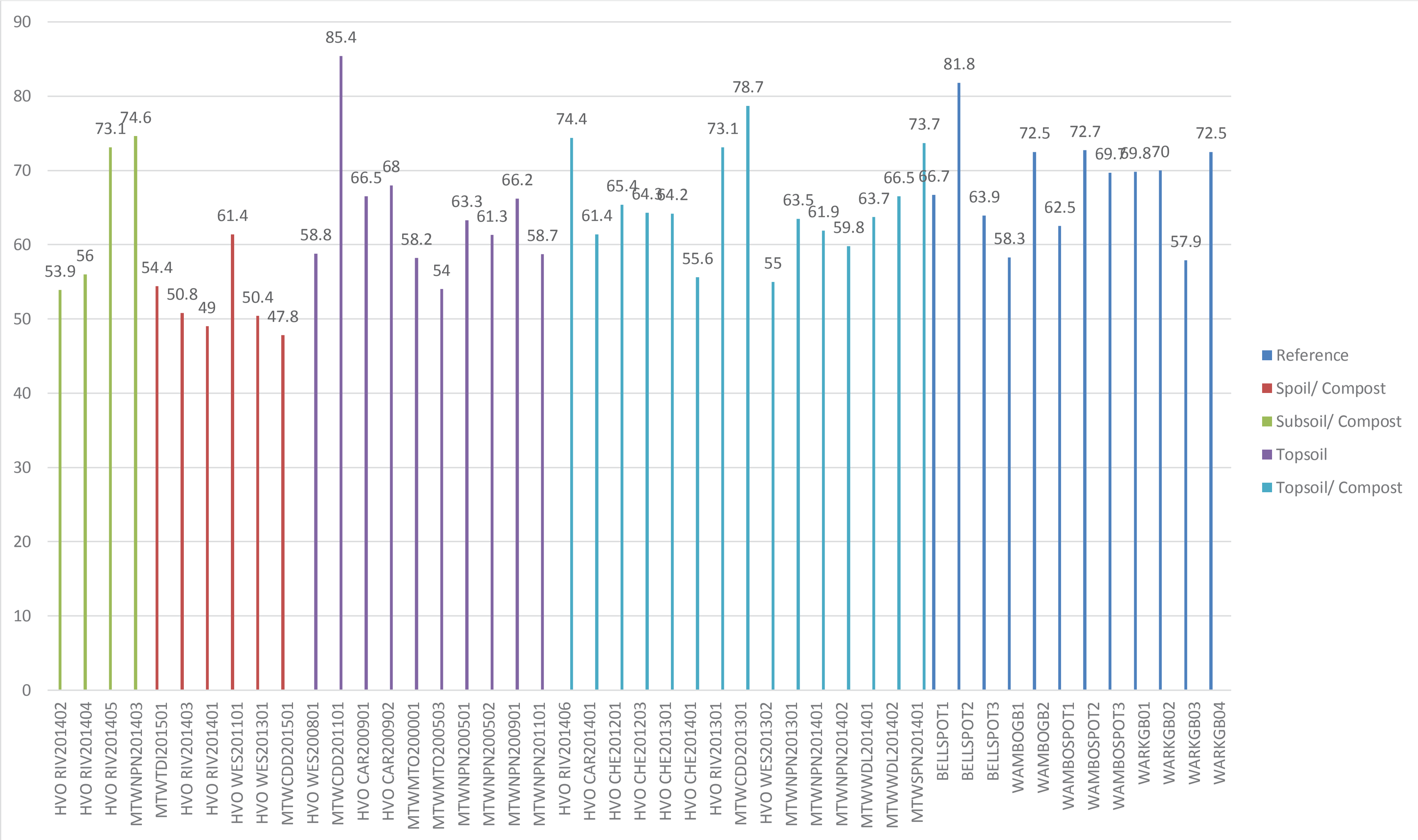
When the averages for each treatment are tabulated, the average of the reference sites have the highest stability score. The Spoil/Compost site contained the lowest average stability score, whilst the remaining soil treatments were similar.

Soil/plant cover is an indicator of stability, the variable cover at some of the compost sites may have influenced the lower average stability score at the compost sites. This parameter could be expected to increase with time, as the rehabilitation develops. It may also be the case, that the age of the rehabilitation and the rehabilitation technique has a greater influence on the stability value than the soil treatment. The range of values for the stability across the soil treatments can be seen in Chart 5.

Table 19. Averages of the stability values for the soil treatments.

Treatment	Average scores across rehabilitation and reference sites
Reference site	68.19
Spoil/ Compost	52.30
Subsoil/ Compost	64.40
Topsoil	64.04
Topsoil/ Compost	65.41

Chart 5. Comparison of the stability index against the soil treatments.



Infiltration

The average infiltration scores for the soil treatments are detailed in Table 20.

The Reference sites contained the highest average infiltration scores.

Both Subsoil/Compost and Topsoil treatments had similar results, with Topsoil/Compost being slightly higher. Spoil/Compost was quite low compared to the other soil treatments.

Whilst all rehabilitation sites scored lower than the reference site, this finding is consistent with Tongway and Hindley (2004) who found that whilst the stability index was consistent between rehabilitation areas and remnant woodland, infiltration index (and nutrient index) were lower in rehabilitation areas when compared with remnant woodland.

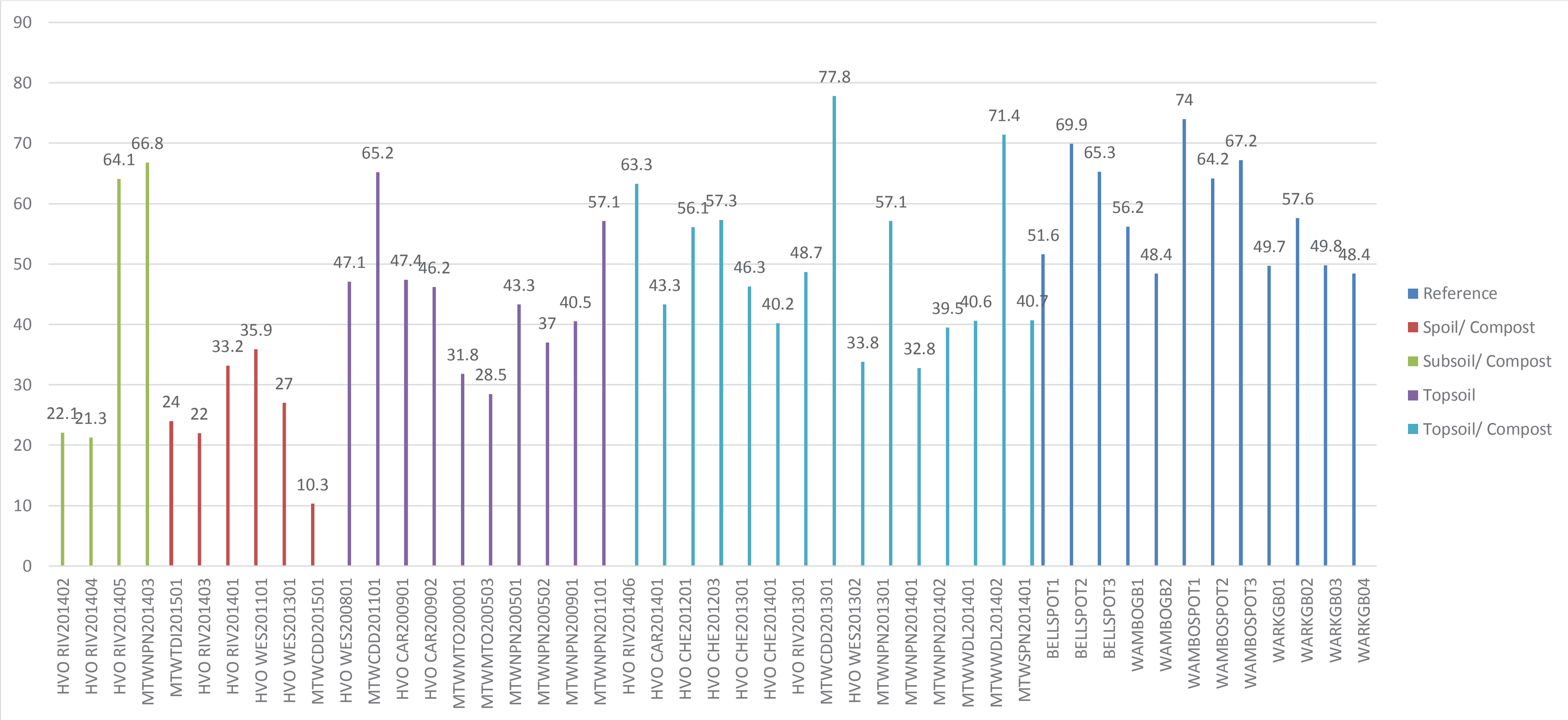
The range of infiltration values is presented in Chart 6.

The range of infiltration values were high, between 10.3 at MTWCDD201501 and 77.8 at MTWCDD201301. The infiltration index is driven by soil surface indicators, including leaf litter and surface roughness, which could be reasonably assumed to increase with the development of the rehabilitation.

Table 20. Average of the infiltration values for the Reference Sites and rehabilitation sites

Treatment	Average scores across rehabilitation and reference sites
Reference site	58.52
Spoil/ Compost	25.40
Subsoil/ Compost	43.58
Topsoil	44.41
Topsoil/ Compost	49.93

Chart 6. Comparison of the infiltration index against soil treatments.



Nutrient cycling

The average infiltration scores for the soil treatments are detailed in Table 21.

The Reference sites contained the greatest average score, with the average Topsoil/Compost score being a similar value.

Both Spoil/Compost and Subsoil/Compost treatment presented similar average results.

The Spoil/Compost treatment had the lowest average score.

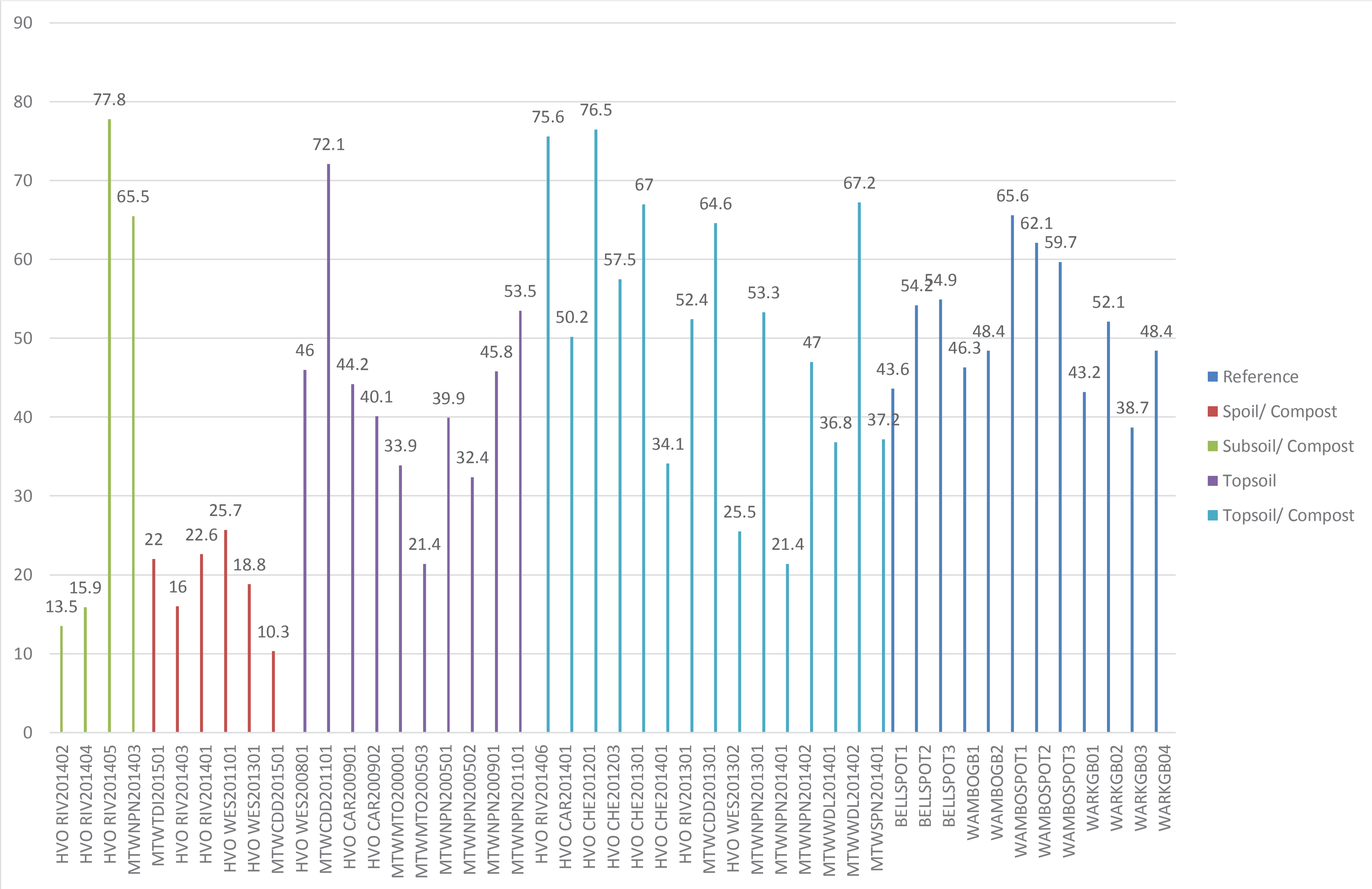
The range of values is presented in Chart 7.

The range of values was high, with the range of values being 10.3 for MTWCD201501 and 75.6 for HVRIV201406.

Table 21. Average values for the nutrient cycling index for Reference Sites and soil treatments.

Treatment	Average scores across rehabilitation and reference sites
Reference site	51.43
Spoil/ Compost	19.23
Subsoil/ Compost	43.18
Topsoil	42.93
Topsoil/ Compost	51.09

Chart 7. Comparison of the nutrient cycling index for each soil treatment.



6. Conclusions and recommendations

6.1 Conclusions

There is significant variation in the types and ages of the rehabilitation sites which were part of the monitoring project, thus there is a high degree of variability in monitoring results, this includes native plant species richness, exotic cover, percentage cover, LOI and projected cover of all strata. Provided below are some core outcomes of the monitoring undertaken. These outcomes have been provided below and summarised based on type of monitoring outcomes undertaken.

6.1.1 BioBanking assessment

Aspects of the BioBanking methodology have been used as part of this monitoring program to make comparisons with the target EECs, through the establishment of reference sites. A total of 12 reference sites were established, six representing the Central Hunter Ironbark-Spotted Gum-Grey Box EEC and six representing the Central Hunter Grey Box-Ironbark Woodland EEC. BioBanking plots were undertaken at a total of ten rehabilitation sites, enabling the comparison of 10 of 35 rehabilitation sites against the reference sites for the parameters collected. Results were generally positive, with some sites achieving the reference site benchmark for some of the ten attribute values. Some of the core outcomes included:

- All rehabilitation sites fall below benchmark in at least one attribute for both of the target communities. This means that management should aim to increase the number of native species present at the rehabilitation sites.
- Due to the density of regenerating shrub species, three sites are within benchmark for NMS (HVO CAR200902, HVO WES200801 and MTWNPN200502), whilst HVO CAR200901 and MTWCDC201101 are above benchmark. This is the case for benchmark data from both EECs.
- HVO WES200801, MTWNPN200501 and MTWNPN200901 were in benchmark for NGCS. MTWCDC201101 was above benchmark. It should be noted that the lower benchmark value for NGCS is zero, and thus any shrub cover would put the site into benchmark for this attribute.
- Three sites are within benchmark for NOS; HVO CAR200901, HVO WES200801 and MTWMTO200001 are within benchmark for NOS for Central Hunter Grey Box-Ironbark Woodland, and HVO WES200801 for Central Hunter Ironbark-Spotted Gum-Grey Box.

This report has noted differences between the published OEH benchmarks and the reference site benchmark data collected. Recommendations have been provided below where the lower benchmark values, obtained from reference site data, may not be suitable for setting performance criteria targets for rehabilitation areas.

6.1.2 Landscape function analysis

LFA was undertaken at all the sites surveyed, including the reference and rehabilitation sites. LFA scores (LOI and soil surface indicators) were high for reference sites, and variable for rehabilitation sites. It may be poignant to consider the efficacy of LFA assessment at all sites. A number of core outcomes of the LFA assessment include:

- LOI at the reference and rehabilitation sites was generally high, with an average LOI of .93 for the reference sites and .87 at the rehabilitation sites.
- The variability in the range of scores however was greater at the rehabilitation sites when compared with the reference sites. The variability in values at the rehabilitation sites is likely to be influenced by the seed treatments applied to sites and the age of the rehabilitation.

- Many of the rehabilitation sites with a LOI of 1 achieved this result due to the high density of grass species (whether native or exotic), including HVORIV201405 and HVORIV201406.
- Sites which achieved relatively low LOI indices (MTWCDD201501 and MTWTD201501) were sites that had only recently been established and exhibited little grass or plant cover. These sites were typically spoil/compost sites that had only recently been established and exhibited little grass or plant cover.
- It is also valuable to note in this context that LAI is not a measure of native diversity, and in this regard not a measure of successful rehabilitation of native vegetation. For example, WARKGB04 by comparison with other reference sites has a relatively low LOI, but still exhibits a high species richness score. By comparison, HVO RI201301, with a LOI of 94, is comprised entirely of exotic vegetation.
- Whilst to a large extent the LOI scores were consistent across the sites and the relevant treatments, there is variation in the averages across the soil treatments. The averages show that the sites treated with Spoil/ Compost have a lower average LOI than the reference sites or other soil treatments. Topsoil/ Compost contained the greatest average LOI (0.93), which was close to that of Reference sites (0.97).
- The Spoil/ Compost site contained the lowest average stability score, whilst the remaining soil treatments were quite similar.
- The Reference sites contained the highest average infiltration scores. Both Subsoil/ Compost and Topsoil treatments had similar infiltration scores, with Topsoil/ Compost being slightly higher. Infiltration for Spoil/ Compost sites was relatively low when compared to the other soil treatments.

6.1.3 Groundcover assessment

The groundcover assessment was limited to rehabilitation sites and thus there is no reference data available for comparison. A comparison with soil treatments was undertake, with the key outcomes of the groundcover assessment being:

- Generally there was little variation in the ground cover assessment scores between different soil treatments.
- High weed cover was present at all sites.
- Most sites had greater than 50 percent Protective Cover.
- There were individual sites within each soil treatment which had high protective cover. For example, MTWCDD2013-01 (topsoil/ Compost 98 percent), MTWNPN2014-02 (Spoil/ Compost 97 percent), MTWNPN2011-01 (topsoil 84 percent) and MTWNPN2014-03 (subsoil/ compost 93 percent).
- The site with the lowest Protective Cover was HVORIV2014-02.
- The number of native species ranged from one to seven species.
- The site with the highest number of native species was MTWNPN2014-03 (seven species) and HVORIV2014-03 (six species).

6.2 Recommendations

Based on the results and conclusions above, and implementation of the monitoring protocols, a number of recommendations have been developed pertaining to site results and the monitoring protocols (Table 22). The following recommendations are proposed:

Table 22. Recommendations for improving monitoring protocols

Component	Issue	Recommendation
Ground cover assessment	The ground cover assessment does not capture a comprehensive list of the regenerating species. The assessment is part of the visual	Replace the groundcover assessment with a nested 20 x 20 m floristic plot. Record all species (native and exotic) and record cover abundance scores for each. This is the same process as that undertaken at sites where

Component	Issue	Recommendation
	assessment, which only requires recording of dominant species.	BioBanking plots are conducted. The traditional groundcover assessment may have more utility if used by C&A staff (or other field staff) to measure the efficacy of targeted weed treatment, in areas where herbaceous weeds are abundant. Utilising this process before, and a number of times after, treatments may improve the efficacy of measuring the actions undertaken.
Ground cover assessment	The assessment records information which is substantially covered by the LFA assessment. This includes plant cover, litter cover, rock and bare ground. The assessment adds field time and data management time to the process.	Cease the use of the groundcover assessment. Rely on LFA for information on surface cover (plants, rocks and litter) and use the cover abundance scores (recommended above) to provide information on the proportion of weed and native cover.
Visual Assessment - Species composition	The species composition assessment requires the dominant species in each strata to be recorded. This information is recorded automatically at sites where biometric plots are undertaken via cover abundance scores – and thus is a duplication. It is also difficult to quantify within the reporting.	Cease using the species conservation assessment and rely on a 20 x 20 m floristic plot instead. This would provide a more robust list of species present (i.e. every species in the plot). Dominant species could be discerned via the cover abundance scores. Eliminating the Visual Assessment at BioBanking sites would reduce field and data management time by reducing duplication.
Visual Assessment - Species composition	The capture of information regarding tree maturity (height and DBH) is not undertaken in a qualitative sense (i.e. the methodology does not stipulate a sample size or how the information should be reflected in the report).	Stipulate in the methodology that DBH and tree height is recorded for 10 canopy tree at each sample site. Replicate this process at reference sites. Tree maturity is not reflected in BioBanking data or benchmarks.
Monitoring timing	Species identification is always assisted by the presence of flowers or fruit, and undertaking monitoring when these features are not present may inhibit data collection.	Undertake monitoring during spring and/or autumn to increase opportunities for more thorough identification. Identification at rehabilitation sites will be limited by the maturity of the plants present.
Local Benchmark data - Central Hunter Grey Box-Ironbark Woodland	Lower benchmark for NGCS is zero. A midstorey of zero for this community may not provide a suitable performance criteria.	Consideration to use the OEH benchmark for NGCS (Lower = five percent, Upper = 10 percent) as the lower benchmark more likely reflects the BVT.
Local Benchmark data - Central Hunter Grey Box-Ironbark Woodland	NTH is zero, which may not reflect a true benchmark for this attribute.	Consideration to use the OEH benchmark for NTH (three) as this benchmark more likely reflects the BVT.

Component	Issue	Recommendation
Local Benchmark data - Central Hunter Ironbark-Spotted Gum-Grey Box Forest	Lower benchmark for NMS is zero. A midstorey of zero for this community and may not provide a suitable performance criteria.	Consideration to use the OEH benchmark for NMS (Lower = 10 percent, Upper = 60 percent) as the lower benchmark more likely reflects the BVT.
Local Benchmark data - Central Hunter Ironbark-Spotted Gum-Grey Box Forest	NTH is zero, which may not reflect a true benchmark for this attribute.	Consideration to use the OEH benchmark for NTH (one) as this benchmark more likely reflects the BVT.
Scope of the analysis	It is noted that without more accurate data on the rehabilitation measures implemented (seed mixes used and yield), it is difficult to discern accurate information regarding the efficacy of particular rehabilitation techniques.	Compile data on the particular rehabilitation techniques implemented and target aspect of the monitoring program to establish the efficacy of rehabilitation outcomes.

7. References

AECOM (2012) Monitoring Methodology - Post-mined Lands MTW and HVO North Mine Sites, Prepared for Coal and Allied.

Coal and Allied (2015a) Mining Operations Plan – HVO North – Draft edition.

Coal and Allied (2015b) Mining Operations Plan - Mount Thorley Warkworth - Draft edition.

OEH (2014) BioBanking Assessment Methodology, Prepared by Office of Environment and Heritage for the NSW Government

Tongway, D. and Hindley, N. (2004) Landscape Function Analysis: Procedures for Monitoring and Assessing Landscapes with Special References to Mine sites and Rangelands. CSIRO Sustainable Ecosystems, Canberra.

Figures

Drawn by: RJ   Project Manager: VH   Project Number: 2766   Date: 08/03/2016

Project location

Coal and Allied Rehabilitation Monitoring

FIGURE 1

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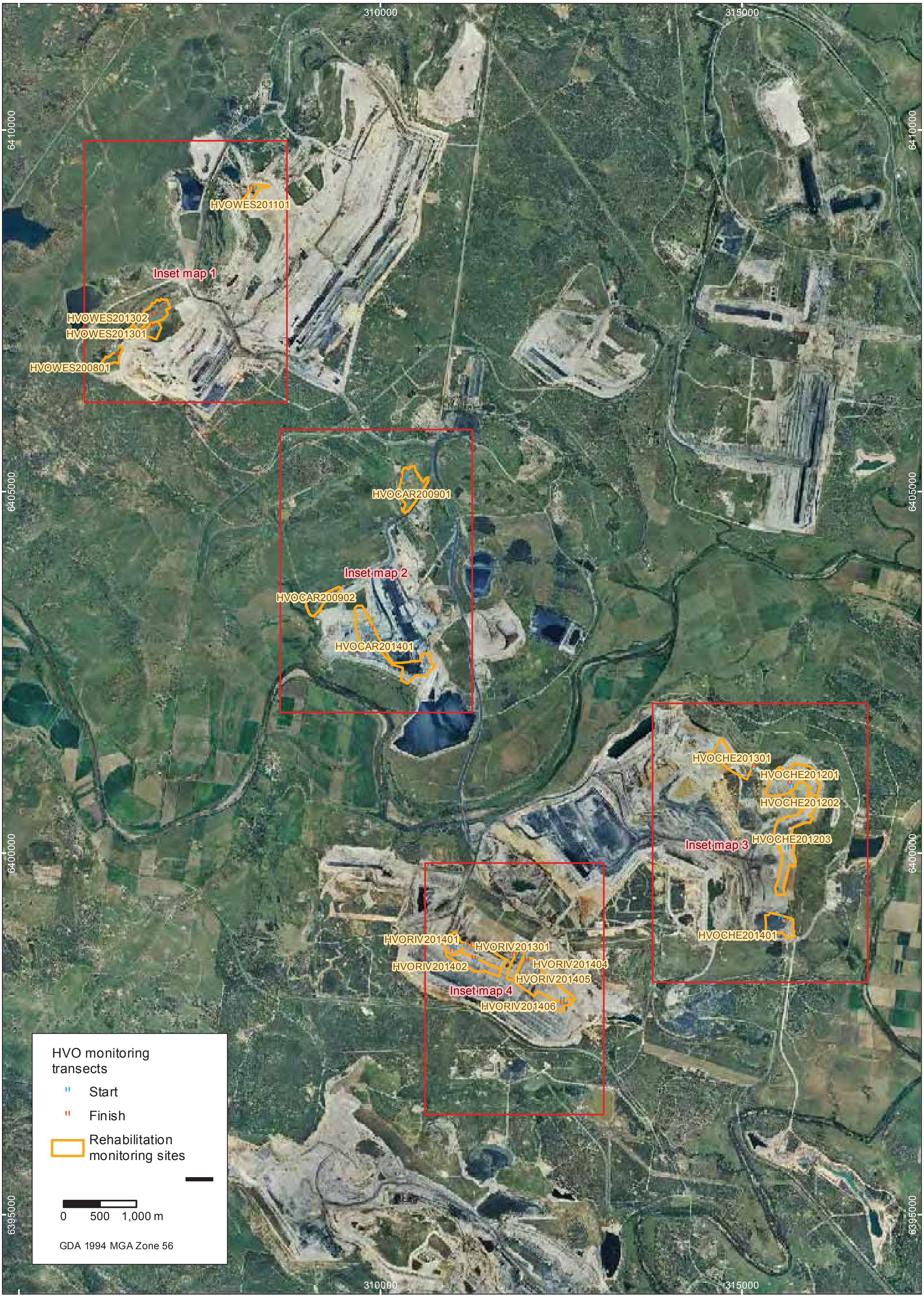
Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_1_StudyArea.mxd

Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016



HVO survey locations overview

Coal and Allied Rehabilitation Monitoring

FIGURE 2

Imagery: (c) RTCA 2010-12-31

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_2_HVO.mxd

Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

HVO survey locations - Inset map 1

Coal and Allied Rehabilitation Monitoring

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FIGURE 3

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_3_HVO.mxd

Imagery: (c) RTCA 2010-12-31

Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

HVO survey locations - Inset map 2

Coal and Allied Rehabilitation Monitoring

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FIGURE 4

Imagery: (c) RTCA 2010-12-31

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_4_HVO.mxd

Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

HVO survey locations - Inset map 3

Coal and Allied Rehabilitation Monitoring

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FIGURE 5

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_5_HVO.mxd

Imagery: (c) RTCA 2010-12-31

Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

HVO survey locations - Inset map 4

Coal and Allied Rehabilitation Monitoring

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FIGURE 6

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_6_HVO.mxd

Imagery: (c) RTCA 2010-12-31

Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

MTW survey locations overview

Coal and Allied Rehabilitation Monitoring

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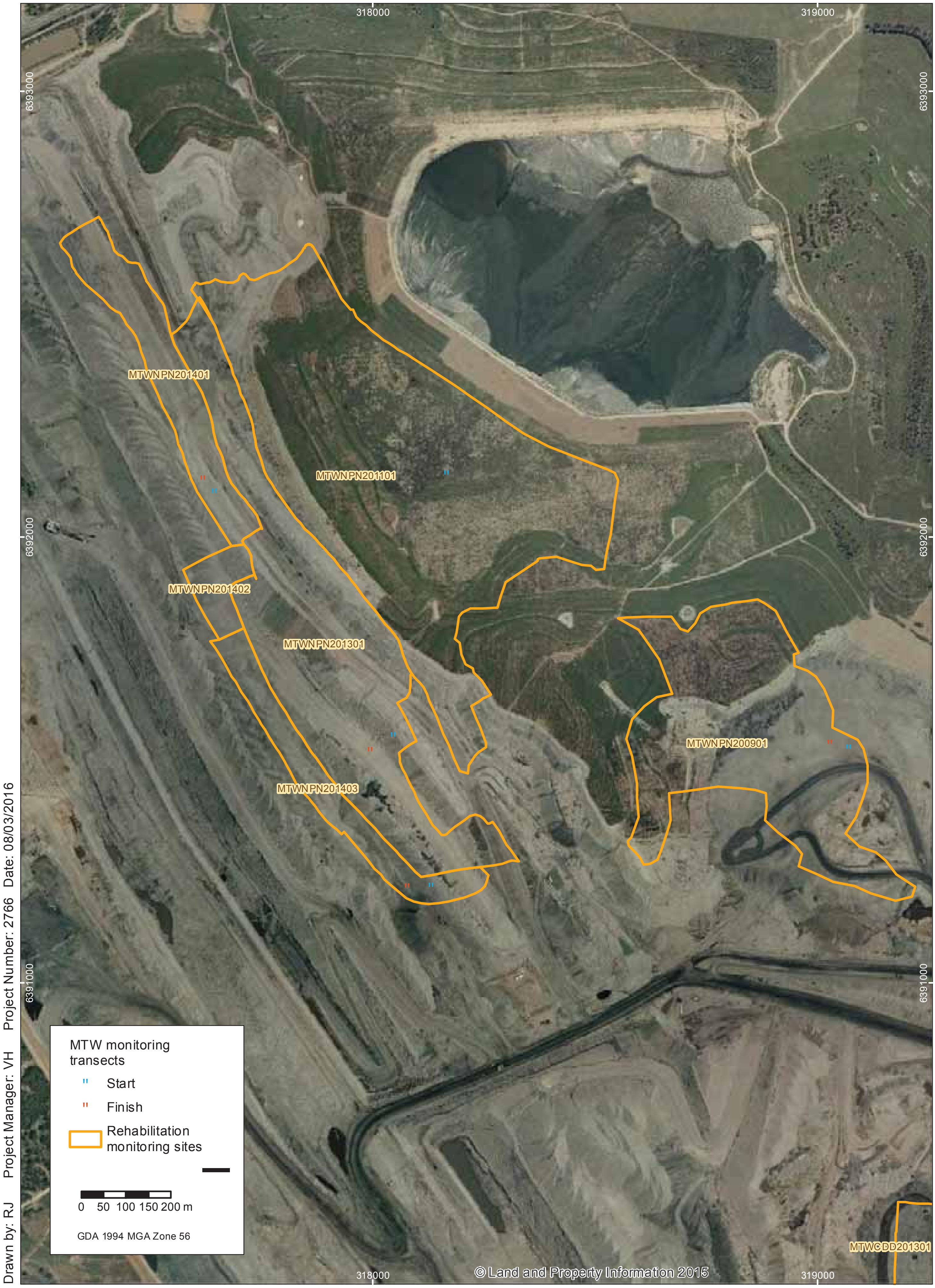
FIGURE 7

Imagery: (c) LPI 2008-12-17

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_7_MTW.mxd



MTW survey locations overview - Inset map 1

Coal and Allied Rehabilitation Monitoring

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FIGURE 8

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_8_MTW.mxd

Imagery: (c) LPI 2008-12-17

Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

MTW survey locations overview - Inset map 2

Coal and Allied Rehabilitation Monitoring

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FIGURE 9

Imagery: (c) LPI 2008-12-17

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_9_MTW.mxd

Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

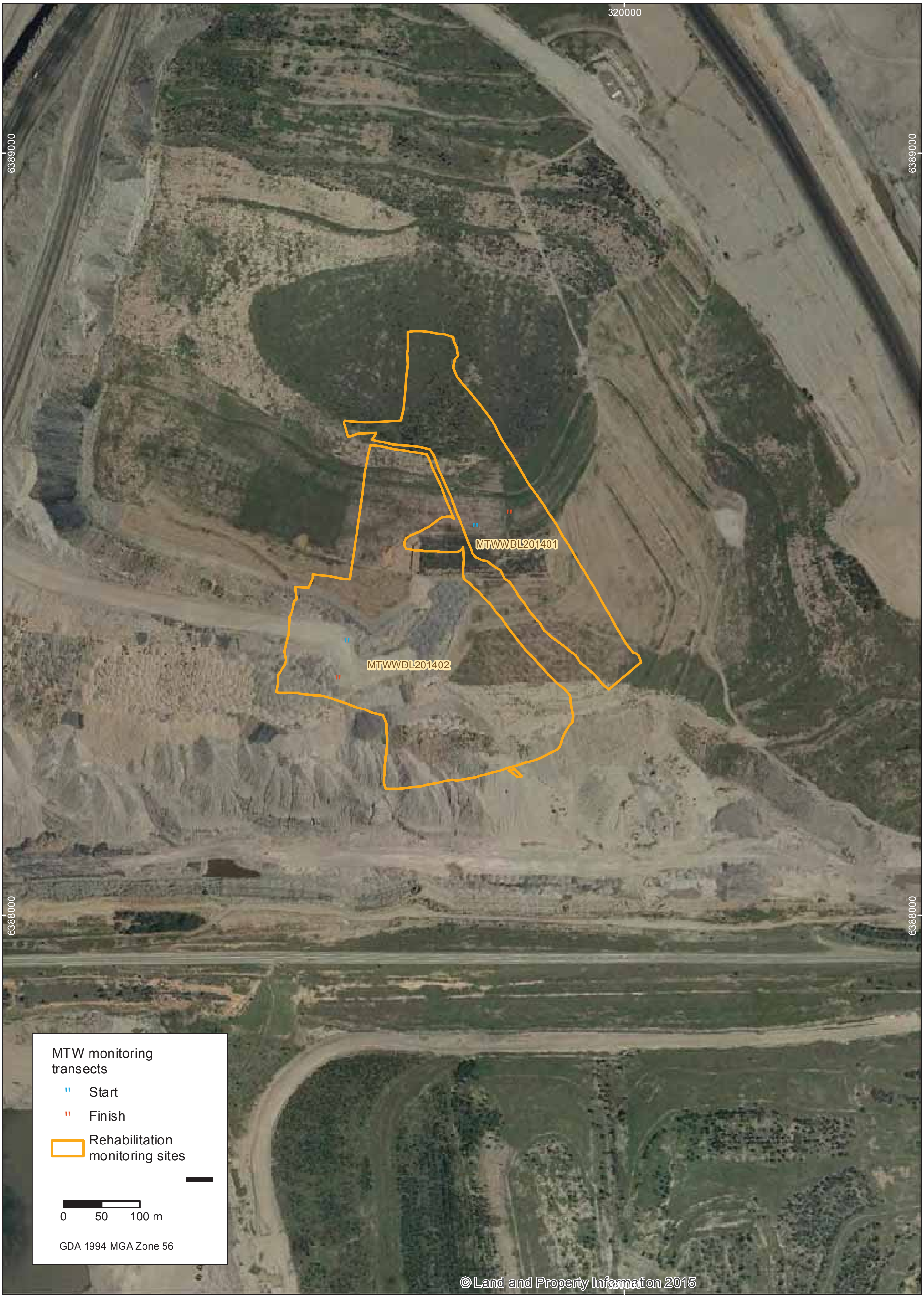
MTW survey locations overview - Inset map 3

Coal and Allied Rehabilitation Monitoring

FIGURE 10

Imagery: (c) LPI 2008-12-17

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_10_MTW.mxd



Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

MTW survey locations overview - Inset map 4

Coal and Allied Rehabilitation Monitoring

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FIGURE 11

Imagery: (c) LPI 2008-12-17

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_11_MTW.mxd

Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

MTW survey locations overview - Inset map 5

Coal and Allied Rehabilitation Monitoring

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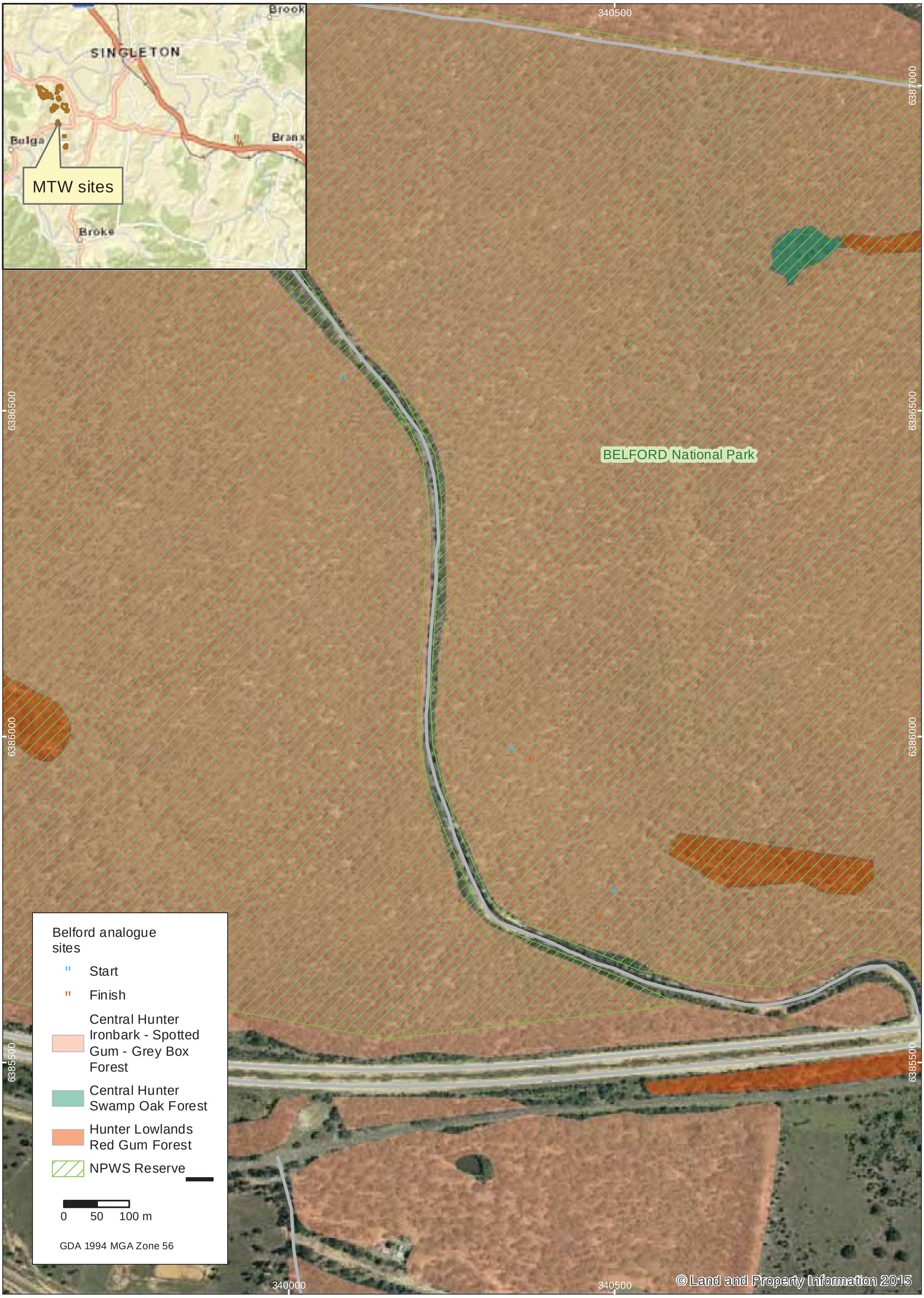
FIGURE 12

Imagery: (c) LPI 2008-12-17

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_12_MTW.mxd



Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

Analogue sites – Belford National Park

Coal and Allied Rehabilitation Monitoring

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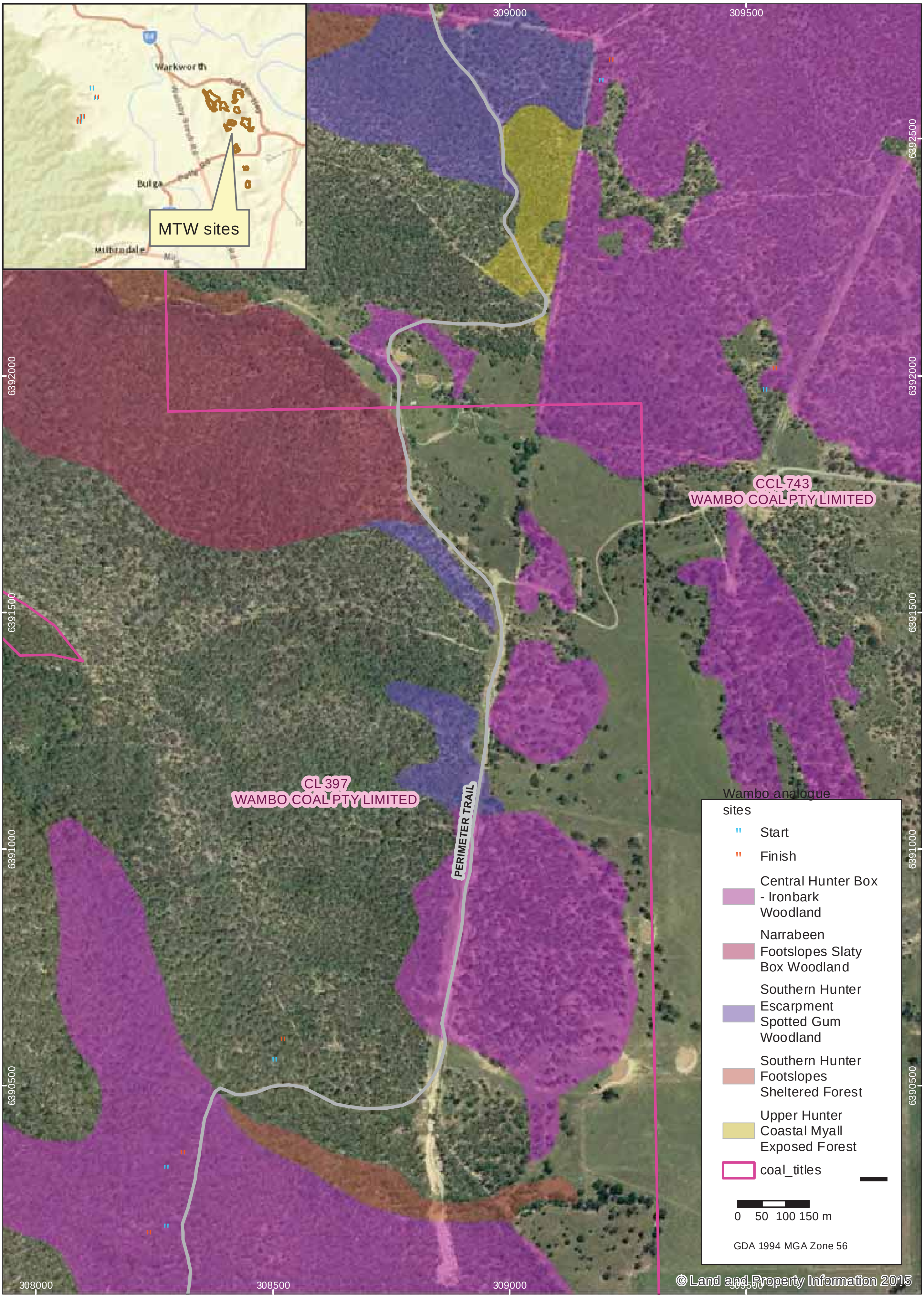
FIGURE 13

Imagery: (c) LPI 2008-12-17

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_13_AnalogBELL.mxd



Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

Analogue sites – Wambo Colliery Land

Coal and Allied Rehabilitation Monitoring

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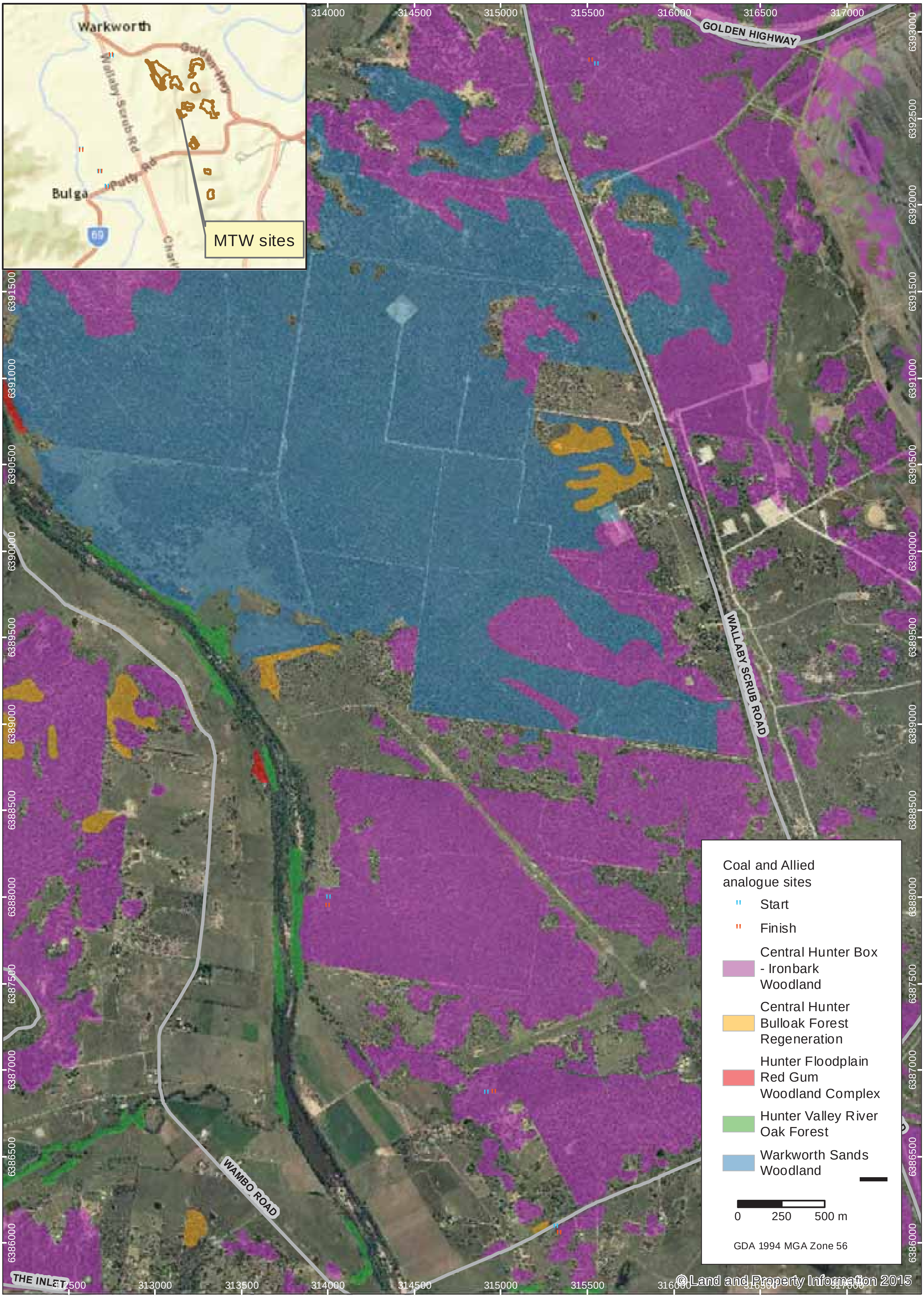
FIGURE 14

Imagery: (c) LPI 2008-12-17

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_14_AnalogWAMBO.mxd



Drawn by: RJ Project Manager: VH Project Number: 2766 Date: 08/03/2016

Analogue sites – Coal and Allied managed land

Coal and Allied Rehabilitation Monitoring

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FIGURE 15

Imagery: (c) LPI 2008-12-17

Path: T:\spatial\projects\a2700\a2766_MTW_HVO\Maps\report\2766_Figure_15_AnalogCNA.mxd

Appendix 1 – Monitoring dates

Location	Survey personnel	Date	BioBanking completed
BELLSPOT1	Luke Baker and Vivien Howard	01/02/2016	Completed
HVO RIV201406	Luke Baker, Vivien Howard and Robert Carter	02/02/2016	Not required
HVO RIV201405	Luke Baker, Vivien Howard and Robert Carter	02/02/2016	Not required
HVO RIV201404	Luke Baker, Vivien Howard and Robert Carter	02/02/2016	Not required
HVO RIV201403	Luke Baker, Vivien Howard and Robert Carter	02/02/2016	Not required
BELSPOT2	Luke Baker and Vivien Howard	02/02/2016	Completed
MTWWDL201401	Luke Baker, Vivien Howard and Robert Carter	03/02/2016	Not required
MTWWDL201402	Luke Baker, Vivien Howard and Robert Carter	03/02/2016	Not required
HVO RIV201402	Luke Baker, Vivien Howard and Bill Baxter	03/02/2016	Not required
HVO RIV201401	Luke Baker, Vivien Howard and Bill Baxter	03/02/2016	Not required
HVO RIV201301	Luke Baker, Vivien Howard and Bill Baxter	03/02/2016	Not required
HVO CHE201201	Luke Baker, Vivien Howard and Bill Baxter	03/02/2016	Not required
HVO CHE201202	Luke Baker, Vivien Howard and Bill Baxter	03/02/2016	Not required
HVO CHE201301	Luke Baker, Vivien Howard and Bill Baxter	03/02/2016	Not required
MTWNPN200901	Luke Baker, Vivien Howard and Robert Carter	04/02/2016	Completed
MTWCDD201101	Luke Baker, Vivien Howard and Jess Blair	04/02/2016	Not required
MTWCDD201301	Luke Baker, Vivien Howard and Jess Blair	04/02/2016	Not required
MTWCDD201501	Luke Baker, Vivien Howard and Jess Blair	04/02/2016	Not required
MTWSPN201401	Luke Baker, Vivien Howard and Robert Carter	04/02/2016	Not required
MTWNPN200502	Luke Baker, Vivien Howard and Robert Carter	04/02/2016	Completed
MTWNPN201301	Luke Baker, Vivien Howard and Jess Blair	05/02/2016	Not required
MTWNPN201402	Luke Baker, Vivien Howard and Jess Blair	05/02/2016	Not required
MTWNPN201401	Luke Baker, Vivien Howard and Jess Blair	05/02/2016	Not required
MTWNPN201403	Luke Baker, Vivien Howard and Jess Blair	05/02/2016	Not required
MTWNPN201101	Luke Baker, Vivien Howard and Robert Carter	05/02/2016	Not required
MTWTD1201501	Luke Baker, Vivien Howard and Bill Baxter	05/02/2016	Not required
MTWNPN200501	Luke Baker, Vivien Howard and Bill Baxter	05/02/2016	Completed
MTWMTO200001	Luke Baker, Vivien Howard and Bill Baxter	08/02/2016	Completed
MTWMTO200503	Luke Baker, Vivien Howard and Bill Baxter	08/02/2016	Completed
HVO CAR200901	Luke Baker, Vivien Howard and Robert Carter	08/02/2016	Completed
HVO CAR200902	Luke Baker, Vivien Howard and Robert Carter	08/02/2016	Completed
HVO CAR201401	Luke Baker, Vivien Howard and Robert Carter	08/02/2016	Not required
HVO WES200801	Luke Baker, Vivien Howard and Bill Baxter	09/02/2016	Completed
HVO WES201101	Luke Baker, Vivien Howard and Bill Baxter	09/02/2016	Completed
HVO WES201301	Luke Baker, Vivien Howard and Bill Baxter	09/02/2016	Not required
HVO WES201302	Luke Baker, Vivien Howard and Bill Baxter	09/02/2016	Not required
HVO CHE201203	Luke Baker, Vivien Howard and Robert Carter	09/02/2016	Not required

Location	Survey personnel	Date	BioBanking completed
HVO CHE201401	Luke Baker, Vivien Howard and Robert Carter	09/02/2016	Not required
BELSPOT3	Luke Baker and Vivien Howard	09/02/2016	Completed
SBOAGB1	Luke Baker and Vivien Howard	10/02/2016	Completed
WAMBOSPOT1	Luke Baker and Vivien Howard	11/02/2016	Completed
WAMBOSPOT2	Luke Baker and Vivien Howard	12/02/2016	Completed
SBOAGB2	Luke Baker and Vivien Howard	12/02/2016	Completed
WAMBOSPOT3	Luke Baker and Vivien Howard	13/02/2016	Completed
SBOAGB3	Luke Baker and Vivien Howard	13/02/2016	Completed
WAMBOGB1	Luke Baker and Vivien Howard	14/02/2016	Completed
SBOAGB4	Luke Baker and Vivien Howard	14/02/2016	Completed
WAMBOGB2	Luke Baker and Vivien Howard	15/02/2016	Completed

Appendix 2 – Monitoring locations

Monitoring site	Position on transection	GDA94 MGA Zone 56	
		Northing	Easting
HVO North rehabilitation monitoring sites			
HVO CAR200901	Start	6405168	310358
HVO CAR200901	Finish	6405171	310311
HVO CAR200902	Start	6403453	309114
HVO CAR200902	Finish	6403430	309076
HVO CAR201401	Start	6403057	309832
HVO CAR201401	Finish	6403083	309872
HVO CHE201201	Start	6400898	315694
HVO CHE201201	Finish	6400937	315660
HVO CHE201203	Start	6400040	315617
HVO CHE201203	Finish	6400044	315667
HVO CHE201301	Start	6401135	315159
HVO CHE201301	Finish	6401172	315170
HVO CHE201401	Start	6399065	315541
HVO CHE201401	Finish	6399040	315582
HVO RIV201301	Start	6398690	311184
HVO RIV201301	Finish	6398695	311233
HVO RIV201401	Start	6398663	311033
HVO RIV201401	Finish	6398633	310994
HVO RIV201402	Start	6398476	311320
HVO RIV201402	Finish	6398516	311293
HVO RIV201403	Start	6398539	311901
HVO RIV201403	Finish	6398558	311854
HVO RIV201404	Start	6398524	312023
HVO RIV201404	Finish	6398476	312029
HVO RIV201405	Start	6398089	312243
HVO RIV201405	Finish	6398114	312269
HVO RIV201406	Start	6397946	312522
HVO RIV201406	Finish	6397895	312522
HVO WES200801	Start	6406920	306340
HVO WES200801	Finish	6406877	306364
HVO WES201101	Start	6409164	308265
HVO WES201101	Finish	6409172	308223
HVO WES201301	Start	6407223	306899
HVO WES201301	Finish	6407251	306859
HVO WES201302	Start	6407365	306889
HVO WES201302	Finish	6407409	306878
MTW Rehabilitation monitoring sites			

Monitoring site	Position on transection	GDA94 MGA Zone 56	
		Northing	Easting
MTWCDC201101	Start	6390304	319599
MTWCDC201101	Finish	6390312	319552
MTWCDD201301	Start	6390165	319516
MTWCDD201301	Finish	6390212	319535
MTWCDD201501	Start	6390074	319049
MTWCDD201501	Finish	6390034	319081
MTWMPN201401	Start	6392128	317619
MTWMPN201401	Finish	6392128	317619
MTWMTO200001	Start	6386940	320551
MTWMTO200001	Finish	6386982	320531
MTWMTO200503	Start	6385782	320678
MTWMTO200503	Finish	6385756	320640
MTWNPN200501	Start	6391225	319816
MTWNPN200501	Finish	6391183	319842
MTWNPN200502	Start	6391981	319682
MTWNPN200502	Finish	6391981	319682
MTWNPN200901	Start	6391524	319069
MTWNPN200901	Finish	6391535	319027
MTWNPN201101	Start	6392138	318166
MTWNPN201301	Finish	6391519	317995
MTWNPN201301	Start	6391551	318047
MTWNPN201401	Start	6392098	317646
MTWNPN201401	Finish	6392098	317646
MTWNPN201403	Start	6391212	318079
MTWNPN201403	Finish	6391213	318131
MTWSPN201401	Start	6390161	320170
MTWSPN201401	Finish	6390304	319574
MTWTDI201501	Start	6392186	319688
MTWTDI201501	Finish	6392236	319692
MTWWDL201401	Start	6388508	319805
MTWWDL201401	Finish	6388526	319849
MTWWDL201402	Start	6388357	319636
MTWWDL201402	Finish	6388309	319624
Reference sites			
BEL1	Start	6386547	340083
BEL1	Finish	6386546	340033
BEL2	Start	6386551	340072
BEL2	Finish	6385962	340373
BEL3	Start	6385760	340498
BEL3	Finish	6385719	340474

Monitoring site	Position on transection	GDA94 MGA Zone 56	
		Northing	Easting
WamboGB01	Start	6392661	309215
WamboGB01	Finish	6392618	309194
WamboGB02	Start	6391965	309539
WamboGB02	Finish	6392010	309561
WamboSpot1	Start	6390324	308275
WamboSpot1	Finish	6390355	308311
WamboSpot2	Start	6390550	308504
WamboSpot2	Finish	6390593	308522
WamboSpot3	Start	6390200	308276
WamboSpot3	Finish	6390185	308238
WARKGB01	Start	6392801	315553
WARKGB01	Finish	6392824	315517
WARKGB02	Start	6387985	314002
WARKGB02	Finish	6387939	313998
WARKGB03	Start	6386859	314917
WARKGB03	Finish	6386864	314960
WARKGB04	Start	6386046	315336
WARKGB04	Finish	6386087	315316

Appendix 3 – Flora species list

Flora two-way table: Rehabilitation sites

Family	Species	Common Name	Exotic *	HVOCAR 200901	HVOCAR 200902	HVOWES 200801	HVOWES 201101	MTWCDC 201101	MTWMTO 200001	MTWMTO 200503	MTWNPN 200501	MTWNPN 200502	MTWNPN 200901	Wambo GB01
Acanthaceae	Brunoniella australis	Blue Trumpet												4
Adiantaceae	Cheilanthes sieberi	Rock Fern							2			3		2
Aizoaceae	Galenia pubescens	Galenia	*	3		3	2	2	3	3	3	2		
Anthericaceae	Tricoryne spp.													1
Apocynaceae	Gomphocarpus fruticosus	Narrow-leaved Cotton Bush	*	3				4	2		3	2	2	
Asteraceae	Bidens pilosa	Cobbler's Pegs	*		3	3	2	3		2	3	3		1
Asteraceae	Calotis lappulacea	Yellow Burr-daisy							2	2				
Asteraceae	Chrysocephalum apiculatum	Common Everlasting									3			2
Asteraceae	Cirsium vulgare	Spear Thistle	*	3				3						
Asteraceae	Conyza bonariensis	Flaxleaf Fleabane	*	3			3	4	4	3	3	2		
Asteraceae	Lactuca serriola	Prickly Lettuce	*					3						
Asteraceae	Olearia elliptica	Sticky Daisy-bush												5
Asteraceae	Senecio madagascariensis	Fireweed	*	3			2	3	3	3	3	2		1
Asteraceae	Sonchus oleraceus	Common Sowthistle	*									1		
Asteraceae	Vittadinia cuneata	A Fuzzweed								1	2	2		2
Asteraceae	Vittadinia sulcata					2			2					
Boraginaceae	Heliotropium amplexicaule	Blue Heliotrope	*			3								
Brassicaceae	Brassica spp.	Brassica	*				3							
Brassicaceae	Lepidium campestre	Field Cress	*						2					
Cactaceae	Opuntia aurantiaca	Tiger Pear	*						2	2				1

Family	Species	Common Name	Exotic *	HVOCAR 200901	HVOCAR 200902	HVOWES 200801	HVOWES 201101	MTWCDC 201101	MTWMTO 200001	MTWMTO 200503	MTWNPN 200501	MTWNPN 200502	MTWNPN 200901	Wambo GB01
Campanulaceae	Wahlenbergia gracilis	Sprawling Bluebell								2				2
Campanulaceae	Wahlenbergia stricta	Tall Bluebell			1						2			
Casuarinaceae	Allocasuarina littoralis	Black She-Oak					1							
Casuarinaceae	Casuarina cunninghamiana	River Oak												6
Chenopodiaceae	Einadia nutans	Climbing Saltbush							2	2	1			3
Chenopodiaceae	Einadia trigonos	Fishweed						2						
Chenopodiaceae	Enchylaena tomentosa	Ruby Saltbush				2	3		2	3				
Convolvulaceae	Convolvulus arvensis	Field Bindweed	*					1						
Convolvulaceae	Dichondra repens	Kidney Weed		3	2	2	2	2			3		2	3
Cyperaceae	Carex inversa	Knob Sedge						1						
Cyperaceae	Cyperus gracilis	Slender Flat-sedge			1					2			1	3
Cyperaceae	Fimbristylis dichotoma	Common Fringe-sedge						2						
Ericaceae	Lissanthe strigosa	Peach Heath												2
Fabaceae (Faboideae)	Desmodium brachypodum	Large Tick-trefoil												2
Fabaceae (Faboideae)	Glycine tabacina	Variable Glycine			2	2		3		2	2	1		2
Fabaceae (Faboideae)	Hardenbergia violacea	False Sarsaparilla					2	2						
Fabaceae (Faboideae)	Indigofera australis	Australian Indigo					2	2						
Fabaceae (Faboideae)	Medicago arabica	Spotted Burr Medic	*		2	2								
Fabaceae (Faboideae)	Swainsona galegifolia	Smooth Darling Pea					2							
Fabaceae (Mimosoideae)	Acacia amblygona	Fan Wattle		3		4		5			3	2	3	
Fabaceae (Mimosoideae)	Acacia binervata	Two-veined Hickory					1							
Fabaceae (Mimosoideae)	Acacia cultriformis	Knife-leaved Wattle						3						

Family	Species	Common Name	Exotic *	HVOCAR 200901	HVOCAR 200902	HVOWES 200801	HVOWES 201101	MTWCDC 201101	MTWMTO 200001	MTWMTO 200503	MTWNPN 200501	MTWNPN 200502	MTWNPN 200901	Wambo GB01
Fabaceae (Mimosoideae)	Acacia dealbata	Silver Wattle			2	4		1	2				2	
Fabaceae (Mimosoideae)	Acacia falcata			3			2						2	
Fabaceae (Mimosoideae)	Acacia longifolia			3	3		3							
Fabaceae (Mimosoideae)	Acacia mearnsii	Black Wattle		4	2									
Fabaceae (Mimosoideae)	Acacia paradoxa	Kangaroo Thorn				2								
Fabaceae (Mimosoideae)	Acacia parvipinnula	Silver-stemmed Wattle				4								
Fabaceae (Mimosoideae)	Acacia saligna	Golden Wreath Wattle	*	5		3		2		1	5	3		
Fabaceae (Mimosoideae)	Acacia spp.	Wattle			3	1			1					1
Fabaceae (Mimosoideae)	Mimosa pudica	Common Sensitive Plant	*		2					1				
Gentianaceae	Centaurium spicatum	Spike Centaury									2			
Lomandraceae	Lomandra filiformis	Wattle Matt-rush				1								
Lomandraceae	Lomandra multiflora	Many-flowered Mat-rush				1								2
Malvaceae	Malvastrum americanum	Spiked Malvastrum	*			2								
Malvaceae	Sida corrugata	Corrugated Sida		3	2			2	3				2	2
Malvaceae	Sida rhombifolia	Paddy's Lucerne	*	3		3	1	4	3	3		2	3	
Myoporaceae	Eremophila debilis	Amulla				3			2	2	1	2		
Myoporaceae	Myoporum montanum	Western Boobialla					2							
Myrsinaceae	Anagallis arvensis	Scarlet Pimpernel	*								1	1		
Myrtaceae	Corymbia citriodora	Lemon-scented Gum	*									2		
Myrtaceae	Corymbia maculata	Spotted Gum			3	6	4	3			3	4	6	
Myrtaceae	Eucalyptus crebra	Narrow-leaved Ironbark			2		3					3	3	5
Myrtaceae	Eucalyptus maculata	Spotted Gum		5										

Family	Species	Common Name	Exotic *	HVOCAR 200901	HVOCAR 200902	HVOWES 200801	HVOWES 201101	MTWCDC 201101	MTWMTO 200001	MTWMTO 200503	MTWNPN 200501	MTWNPN 200502	MTWNPN 200901	Wambo GB01
Myrtaceae	Eucalyptus punctata	Grey Gum				6	2		2	5	4	3		
Myrtaceae	Eucalyptus spp.								1					
Oleaceae	Notelaea longifolia	Large Mock-olive												1
Orchidaceae	Acianthus spp.	Mosquito Orchid												1
Oxalidaceae	Oxalis perennans				2	2			2	2	2	2	2	2
Phormiaceae	Dianella revoluta	Blueberry Lily												2
Phyllanthaceae	Breynia oblongifolia	Coffee Bush											2	
Phyllanthaceae	Phyllanthus gunnii													2
Phyllanthaceae	Phyllanthus spp.		*						1	1				
Pittosporaceae	Bursaria spinosa	Native Blackthorn											1	
Plantaginaceae	Plantago debilis	Shade Plantain				1								
Plantaginaceae	Plantago lanceolata	Lamb's Tongues	*		2	3		3		2	3	2		
Poaceae	Aristida ramosa	Purple Wiregrass								2		2		3
Poaceae	Aristida vagans	Threeawn Speargrass												2
Poaceae	Austrodanthonia racemosa	Wallaby Grass				4								5
Poaceae	Austrostipa scabra	Speargrass					2			2				3
Poaceae	Bothriochloa decipiens	Red Grass						3						
Poaceae	Bothriochloa macra	Red Grass		3	2	3	3			2		2	3	3
Poaceae	Capillipedium spicigerum	Scented-top Grass					3	6						
Poaceae	Chloris gayana	Rhodes Grass	*	6	6		3	3			3	4	3	
Poaceae	Chloris truncata	Windmill Grass			2		2		2	3	3			
Poaceae	Chloris ventricosa	Tall Chloris				3				3				3
Poaceae	Cymbopogon refractus	Barbed Wire Grass									3			6
Poaceae	Cynodon dactylon	Common Couch		3		3		3		2		3		

Family	Species	Common Name	Exotic *	HVOCAR 200901	HVOCAR 200902	HVOWES 200801	HVOWES 201101	MTWCDC 201101	MTWMTO 200001	MTWMTO 200503	MTWNPN 200501	MTWNPN 200502	MTWNPN 200901	Wambo GB01
Poaceae	Echinochloa crusgalli	Barnyard Grass	*										3	
Poaceae	Echinopogon caespitosus	Bushy Hedgehog-grass						3						
Poaceae	Ehrharta erecta	Panic Veldtgrass	*									2		
Poaceae	Eragrostis curvula	African Lovegrass	*							2	4		2	
Poaceae	Eriochloa pseudoacrotricha	Early Spring Grass						3	4	4			2	
Poaceae	Melinis repens	Red Natal Grass	*									2		
Poaceae	Microlaena stipoides	Weeping Grass					2							
Poaceae	Panicum effusum	Hairy Panic			3					3		2		2
Poaceae	Panicum maximum	Guinea Grass	*	4	6	3					3			
Poaceae	Panicum spp.	Panicum				1								
Poaceae	Paspalidium spp.								3					
Poaceae	Paspalum dilatatum	Paspalum	*	3				5						
Poaceae	Pennisetum clandestinum	Kikuyu Grass	*			3	2							
Poaceae	Poa annua	Winter Grass	*					2				2		
Poaceae	Setaria gracilis	Slender Pigeon Grass	*							3	4			
Poaceae	Setaria parviflora		*				3							
Poaceae	Sporobolus creber	Slender Rat's Tail Grass				2		3	3	2	3	4		3
Poaceae	Sporobolus fertilis	Giant Parramatta Grass	*									3		
Poaceae	Themeda australis	Kangaroo Grass					1		3	2		1		
Poaceae	Themeda avenacea	Native Oatgrass					1							
Poaceae	Themeda triandra							2						
Polygonaceae	Polygonum aviculare	Wireweed	*				3			2				
Portulacaceae	Portulaca oleracea	Pigweed						2	3	2			2	

Family	Species	Common Name	Exotic *	HVOCAR 200901	HVOCAR 200902	HVOWES 200801	HVOWES 201101	MTWCDC 201101	MTWMTO 200001	MTWMTO 200503	MTWNPN 200501	MTWNPN 200502	MTWNPN 200901	Wambo GB01
Proteaceae	Hakea sericea	Needlebush					1							
Rubiaceae	Asperula conferta	Common Woodruff												2
Solanaceae	Solanum nigrum	Black-berry Nightshade	*					3						
Solanaceae	Solanum prinophyllum	Forest Nightshade							2					
Sterculiaceae	Lasiopetalum spp.													3
Verbenaceae	Verbena bonariensis	Purpletop	*			3		4			4	2	3	

Flora two-way table: Reference sites

Family	Species	Common Name	Exotic *	BEL 1	BEL 2	BEL 3	Wambo GB01	Wambo GB02	Wambo Spot1	Wambo Spot2	Wambo Spot3	WARK GB01	WARK GB02	Wark GB03	Wark GB04
Acanthaceae	Brunoniella australis	Blue Trumpet			2		4	3	3	2					
Acanthaceae	Pseuderanthemum variabile	Pastel Flower		3	2	2		2		2	2	2			
Adiantaceae	Cheilanthes sieberi	Rock Fern		3	4	2	2	2	3	2	3	2	3	2	3
Aizoaceae	Galenia pubescens	Galenia	*												2
Amaranthaceae	Alternanthera spp.	Joyweed												1	
Anthericaceae	Dichopogon spp.	Chocolate Lily				1							2		
Anthericaceae	Laxmannia gracilis	Slender Wire Lily		3	2									4	
Anthericaceae	Thysanotus tuberosus	Common Fringe-lily			2	2									
Anthericaceae	Tricoryne spp.						1								
Asteraceae	Bidens pilosa	Cobbler's Pegs	*		2		1	1	2				1	2	
Asteraceae	Calotis lappulacea	Yellow Burr-daisy		1	2			2							2
Asteraceae	Chrysocephalum apiculatum	Common Everlasting					2	2						2	
Asteraceae	Conyza bonariensis	Flaxleaf Fleabane	*					1							
Asteraceae	Crassocephalum spp.												1		
Asteraceae	Hypochaeris radicata	Catsear	*		1									2	
Asteraceae	Olearia elliptica	Sticky Daisy-bush		3			5		4	4	5		2		
Asteraceae	Senecio linearifolius	Fireweed Groundsel		1	1				1	2			2		
Asteraceae	Senecio madagascariensis	Fireweed	*				1	1						2	
Asteraceae	Vittadinia cuneata	A Fuzzweed		2	2	2	2					2	3		
Asteraceae	Vittadinia sulcata			1											
Brassicaceae	Lepidium spp.	A Peppercress	*												2
Cactaceae	Opuntia aurantiaca	Tiger Pear	*				1	1	1	2		2	2	2	2
Campanulaceae	Wahlenbergia gracilis	Sprawling Bluebell				2	2	2							2
Campanulaceae	Wahlenbergia stricta	Tall Bluebell												2	
Casuarinaceae	Allocasuarina luehmannii	Bulloak										5	5	4	4

Family	Species	Common Name	Exotic *	BEL 1	BEL 2	BEL 3	Wambo GB01	Wambo GB02	Wambo Spot1	Wambo Spot2	Wambo Spot3	WARK GB01	WARK GB02	Wark GB03	Wark GB04
Casuarinaceae	Allocasuarina torulosa	Forest Oak				1									
Casuarinaceae	Casuarina cunninghamiana	River Oak					6	2							
Chenopodiaceae	Einadia hastata	Berry Saltbush										1			
Chenopodiaceae	Einadia nutans	Climbing Saltbush					3								
Chenopodiaceae	Enchylaena tomentosa	Ruby Saltbush											2		
Commelinaceae	Commelina cyanea	Native Wandering Jew						4		2	3	3	4	4	3
Convolvulaceae	Dichondra repens	Kidney Weed		2	3	2	3	3		1		3	3		2
Cyperaceae	Cyperus gracilis	Slender Flat-sedge					3	2			2		2	2	2
Cyperaceae	Fimbristylis ferruginea							2							
Cyperaceae	Fimbristylis tristachya												2	2	2
Cyperaceae	Gahnia aspera	Rough Saw-sedge			2	2		2			2		3		
Cyperaceae	Lepidosperma latens														
Cyperaceae	Lepidosperma laterale	Variable Sword-sedge		3	6										
Dilleniaceae	Hibbertia spp.				3					3	2				
Ericaceae	Lissanthe strigosa	Peach Heath		2	3		2	3							
Fabaceae (Faboideae)	Daviesia ulicifolia	Gorse Bitter Pea										2			2
Fabaceae (Faboideae)	Desmodium brachypodum	Large Tick-trefoil				2	2	4	3				3		
Fabaceae (Faboideae)	Desmodium gunnii	Slender Tick-trefoil							2	2	2	2			
Fabaceae (Faboideae)	Desmodium varians	Slender Tick-trefoil		2	2	2			2				3	2	
Fabaceae (Faboideae)	Glycine clandestina	Twining glycine							2						
Fabaceae (Faboideae)	Glycine microphylla	Small-leaf Glycine		1				2							
Fabaceae (Faboideae)	Glycine tabacina	Variable Glycine		3	3	3	2	3		2	2	1		2	3
Fabaceae (Faboideae)	Hardenbergia violacea	False Sarsaparilla		2							2				2
Fabaceae (Faboideae)	Hovea linearis								3						

Family	Species	Common Name	Exotic *	BEL 1	BEL 2	BEL 3	Wambo GB01	Wambo GB02	Wambo Spot1	Wambo Spot2	Wambo Spot3	WARK GB01	WARK GB02	Wark GB03	Wark GB04
Fabaceae (Faboideae)	Pultenaea spinosa	A Bush Pea		4	3										
Fabaceae (Faboideae)	Viminaria juncea	Native Broom								1					
Fabaceae (Mimosoideae)	Acacia amblygona	Fan Wattle						3		3				2	3
Fabaceae (Mimosoideae)	Acacia binervata	Two-veined Hickory							1						
Fabaceae (Mimosoideae)	Acacia bulgaensis	Bulga Wattle							5						
Fabaceae (Mimosoideae)	Acacia dealbata	Silver Wattle						2							
Fabaceae (Mimosoideae)	Acacia decurrens	Black Wattle											3		
Fabaceae (Mimosoideae)	Acacia falcata			3	3			2				2			3
Fabaceae (Mimosoideae)	Acacia longifolia								2		3				
Fabaceae (Mimosoideae)	Acacia mearnsii	Black Wattle		4	3	2									
Fabaceae (Mimosoideae)	Acacia spp.	Wattle					1								
Goodeniaceae	Goodenia hederacea	Ivy Goodenia												3	
Goodeniaceae	Goodenia rotundifolia			2					3				2		2
Goodeniaceae	Goodenia spp.								1						
Lobeliaceae	Pratia purpurascens	Whiteroot		3	4	3					3				
Lomandraceae	Lomandra filiformis	Wattle Matt-rush						2			2				
Lomandraceae	Lomandra longifolia	Spiny-headed Mat-rush		2	2										
Lomandraceae	Lomandra multiflora	Many-flowered Mat-rush		2	3	3	2				2			2	
Luzuriagaceae	Geitonoplesium cymosum	Scrambling Lily							2	2					
Malvaceae	Hibiscus heterophyllus										2				
Malvaceae	Sida corrugata	Corrugated Sida					2						1		
Malvaceae	Sida rhombifolia	Paddy's Lucerne	*												2
Myoporaceae	Eremophila debilis	Amulla				2		3		2		2		2	2
Myrsinaceae	Rapanea howittiana	Brush Muttonwood									2				

Family	Species	Common Name	Exotic *	BEL 1	BEL 2	BEL 3	Wambo GB01	Wambo GB02	Wambo Spot1	Wambo Spot2	Wambo Spot3	WARK GB01	WARK GB02	Wark GB03	Wark GB04
Myrtaceae	Corymbia maculata	Spotted Gum		6	4	3			5	5	5				
Myrtaceae	Eucalyptus crebra	Narrow-leaved Ironbark		3			5		1		5	5	5	5	5
Myrtaceae	Eucalyptus fibrosa	Red Ironbark				3									
Myrtaceae	Eucalyptus moluccana	Grey Box			3	3		5		5		2			
Myrtaceae	Eucalyptus punctata	Grey Gum							5		5				
Myrtaceae	Eucalyptus tereticornis	Forest Red Gum												3	
Myrtaceae	Melaleuca decora													3	
Oleaceae	Notelaea longifolia	Large Mock-olive					1			2		2			
Oleaceae	Notelaea microcarpa	Native Olive						2					3		
Orchidaceae	Acianthus spp.	Mosquito Orchid					1								
Oxalidaceae	Oxalis perennans					3	2					2		2	2
Phormiaceae	Dianella caerulea	Blue Flax-lily				2								3	
Phormiaceae	Dianella revoluta	Blueberry Lily		3		3	2		2						
Phyllanthaceae	Breynia oblongifolia	Coffee Bush		2	5	2			3	2	2	3	3	3	
Phyllanthaceae	Phyllanthus gunnii						2	2			2	3			
Phyllanthaceae	Phyllanthus hirtellus	Thyme Spurge				2									
Pittosporaceae	Billardiera scandens	Hairy Apple Berry		2											
Pittosporaceae	Bursaria spinosa	Native Blackthorn		3		2				3	5		4	4	
Plantaginaceae	Plantago debilis	Shade Plantain						2							
Poaceae	Aristida ramosa	Purple Wiregrass			3	3	3					3			2
Poaceae	Aristida vagans	Threeawn Speargrass		5	2		2						2		
Poaceae	Austrodanthonia racemosa	Wallaby Grass		4			5							5	
Poaceae	Austrostipa scabra	Speargrass					3	3						4	3
Poaceae	Bothriochloa macra	Red Grass					3	4				4			3
Poaceae	Chloris truncata	Windmill Grass													3
Poaceae	Chloris ventricosa	Tall Chloris				1	3	3					3		2
Poaceae	Cymbopogon refractus	Barbed Wire Grass		4	3	2	6	6	4	3	2	3	4	5	3

Family	Species	Common Name	Exotic *	BEL 1	BEL 2	BEL 3	Wambo GB01	Wambo GB02	Wambo Spot1	Wambo Spot2	Wambo Spot3	WARK GB01	WARK GB02	Wark GB03	Wark GB04
Poaceae	Cynodon dactylon	Common Couch												4	2
Poaceae	Dichelachne micrantha	Shorthair Plumegrass			2			2				3	3		
Poaceae	Digitaria spp.	A Finger Grass	*	2											
Poaceae	Echinopogon caespitosus	Bushy Hedgehog-grass				3						2	2		
Poaceae	Entolasia marginata	Bordered Panic		4											
Poaceae	Entolasia stricta	Wiry Panic			5				3	2					
Poaceae	Eragrostis brownii	Brown's Lovegrass												2	3
Poaceae	Eragrostis curvula	African Lovegrass	*												2
Poaceae	Eragrostis elongata	Clustered Lovegrass												2	
Poaceae	Eriochloa pseudoacrotricha	Early Spring Grass						3							
Poaceae	Melinis repens	Red Natal Grass	*											2	2
Poaceae	Microlaena stipoides	Weeping Grass		4	5	3			2		2	3	3	3	
Poaceae	Oplismenus aemulus										3				
Poaceae	Panicum effusum	Hairy Panic			3		2	4		3	3	1			3
Poaceae	Paspalidium spp.								2	1	2		3		2
Poaceae	Pennisetum clandestinum	Kikuyu Grass	*											2	
Poaceae	Poa sieberiana	Snowgrass												3	
Poaceae	Setaria gracilis	Slender Pigeon Grass	*					1	1						
Poaceae	Sporobolus creber	Slender Rat's Tail Grass			5	3	3	4					3		
Poaceae	Themeda australis	Kangaroo Grass			3	2			3	3		3		4	3
Proteaceae	Persoonia linearis	Narrow-leaved Geebung							2		2				
Ranunculaceae	Clematis aristata	Old Man's Beard									1				
Rhamnaceae	Pomaderris ferruginea								2						
Rubiaceae	Asperula conferta	Common Woodruff					2	2							
Rubiaceae	Pomax umbellata	Pomax			3	2					2				

Family	Species	Common Name	Exotic *	BEL 1	BEL 2	BEL 3	Wambo GB01	Wambo GB02	Wambo Spot1	Wambo Spot2	Wambo Spot3	WARK GB01	WARK GB02	Wark GB03	Wark GB04
Santalaceae	Exocarpos cupressiformis	Cherry Ballart							2		3	3			
Sapindaceae	Dodonaea pinnata									3					
Sapindaceae	Dodonaea viscosa	Sticky Hop-bush						2		4	5				
Solanaceae	Lycium ferocissimum	African Boxthorn	*		2										
Solanaceae	Solanum prinophyllum	Forest Nightshade		2					2			3	2		3
Solanaceae	Solanum spp.		*					1							
Sterculiaceae	Brachychiton populneus	Kurrajong							1		1				
Sterculiaceae	Lasiopetalum spp.						3								
Thymelaeaceae	Pimelea neo-anglica	Poison Pimelea							3						
Verbenaceae	Lantana camara	Lantana	*									2			
Zamiaceae	Macrozamia flexuosa								3	2	2				

Appendix 4 –Visual and Photo Monitoring

Belford Site 01 (Bell1)

Bellford Site 01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	340083	6386547
End transect	340031	6386548

Description: The Belford Site 01 occurs in Belford National Park. The site was established in an area that aligns to the native vegetation community Central Hunter Ironbark – Spotted Gum – Grey Box Forest, which is listed as an EEC under the NSW TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 28 cm.

Disturbance:

Disturbance present at the site consisted of few weed species, evidence of foot traffic and bike use. Feral animals including the dog (*Canis familiaris familiaris*), European red fox (*Vulpes vulpes*), rabbit (*Oryctolagus cuniculus*), cat (*Felis catus*), black rat (*Rattus rattus*) and Indian mynah (*Acridotheres tristis*) are considered to be impacting the Reserve (DECCW 2010).

Historically the site has been logged, with the majority of trees within the reserve being regrowth from past logging (DECCW 2010).

The following weed species have been identified in DECCW (2010) as a threat to the native vegetation of the reserve; African olive (*Olea europaea subsp. cuspidata*), Prickly Pear and Tiger Pear (*Opuntia* spp.) and Mother of Millions (*Brophyllum* sp.). The Analogue site was set up where little disturbance from these weeds occurred.

Table. Dominant species and structure at Belford Site 01

Stratum	Height (m)	% cover*	Dominant native species
Tree layer	15 - 30	40	*Eucalyptus moluccana* and *Corymbia maculata*
Midstorey layer	6 - 13	30 - 40	*Acacia falcate* and *Acacia mearnsii*
Shrub layer	2	35 - 40	*Breynia oblongifolia, Bursaria spinosa, Lissanthe strigosa* and *Pultenaea spinosa.*
Ground layer	1	20 - 30	*Aristida vagans, Austrodanthonia racemosa, Billardiera scandens, Bursaria spinosa, Calotis lappulacea, Cheilanthes sieberi, Cymbopogon refractus, Desmodium varians, Dianella revoluta, Dichondra repens, Entolasia marginata, Glycine tabacina, Hardenbergia violacea, Laxmannia gracilis, Lepidosperma laterale* and *Pratia purpurascens.*

*Projected foliage cover

Site photographs at Belford Site 01 (left to right)

Start position

End position

Belford Site 02 (Bell2)

Belford Site 02	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	340332	6385942
End transect	340373	6385962

Description: Belford Site 02 occurs in Belford National Park. The site was established in an area that aligns to the native vegetation community Central Hunter Ironbark – Spotted Gum – Grey Box Forest, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 30 cm.

Disturbance:

Disturbance present at the site consisted of a few weed species, evidence of foot traffic and bike use.

Historically the site has been logged, with the majority of trees within the reserve consisting of regrowth from past logging (DECCW 2010).

The following weed species have been identified in DECCW (2010) as a threat to the native vegetation of the reserve; African olive (*Olea europaea subsp. cuspidata*), Prickly Pear and Tiger Pear (*Opuntia* spp.) and Mother of Millions (*Brophyllum* sp.). The analogue site was set up where little disturbance from these weeds occurred, however few indivuals of *Olea europaea* subsp*. cuspidata* and *Opuntia* spp. were recorded in at the site.

Table. Dominant species and structure at Belford Site 02

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 30	40	*Eucalyptus moluccana* and *Corymbia maculata*
Midstorey layer	6 - 13	30 - 40	*Acacia falcata*
Shrub layer	2	35 - 40	*Breynia oblongifolia, Bursaria spinosa, Lissanthe strigosa* and *Pultenaea spinosa.*
Ground layer	1	20 - 30	*Aristida vagans, Austrodanthonia racemosa, Billardiera scandens, Bursaria spinosa, Calotis lappulacea, Cheilanthes sieberi, Cymbopogon refractus, Desmodium varians, Dianella revoluta, Dichondra repens, Entolasia marginata, Glycine tabacina, Hardenbergia violacea, Laxmannia gracilis, Lepidosperma laterale* and *Pratia purpurascens.*

*Projected foliage cover

Site photographs at Belford Site 02 (left to right)

Start position

End position

Bellford Site 03 (Bell03)

Bellford Site 03	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	340498	6385760
End transect	340474	6385719

Description: Belford Site 03 occurs in Belford National Park. The site was established in an area that aligns to the native vegetation community Central Hunter Ironbark – Spotted Gum – Grey Box Forest, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 29 cm.

Disturbance:

Disturbance present at the site consisted of few weed species, evidence of foot traffic and bike use.

Historically the site has been logged, with the majority of trees within the reserve consisting of regrowth from past logging (DECCW 2010).

The following weed species have been identified in DECCW (2010) as a threat to the native vegetation of the reserve; African olive (*Olea europaea subsp. cuspidata*), Prickly Pear and Tiger Pear (*Opuntia* spp.) and Mother of Millions (*Brophyllum* sp.). The analogue site was set up where little disturbance from these weeds occurred, however few indivuals of *Olea europaea* subsp. *cuspidata* and *Opuntia* spp. were recorded in at the site.

Table. Dominant species and structure at Belford Site 03

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	40	*Eucalyptus crebra, Eucalyptus moluccana* and *Corymbia maculata*
Midstorey layer	6 - 13	30 - 40	*Acacia mearnsii* and *Acacia falcata*
Shrub layer	2	35 - 40	*Breynia oblongifolia, Bursaria spinosa, Lissanthe strigosa and Pultenaea spinosa.*
Ground layer	1	20 - 30	*Aristida vagans, Austrodanthonia racemosa, Billardiera scandens, Bursaria spinosa, Calotis lappulacea, Cheilanthes sieberi, Cymbopogon refractus, Desmodium varians, Dianella revoluta, Dichondra repens, Entolasia marginata, Glycine tabacina, Hardenbergia violacea, Laxmannia gracilis, Lepidosperma laterale* and *Pratia purpurascens.*

*Projected foliage cover

Site photographs at Belford Site 03 (left to right)

Start position



End position



WAMBOSPOT1

WamboSpottedGum 01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	308275	6390324
End transect	308311	6390355

Description: WAMBOSPOT1 occurs in land currently managed by Wambo Coal. The site was established in an area that has been previously mapped as a native vegetation community, consistent with Central Hunter Ironbark – Spotted Gum – Grey Box Forest, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 34 cm.

Disturbance:

Disturbance present at the site consisted of few weed species. Weeds recorded include *Opuntia* spp and *Bidens pilosa.*

No damage from fire activity was observed at the site.

No access tracks, or evidence of trail bikes or foot traffic was observed at the site.

Table. Dominant species and structure at Wambo Spotted Gum 01

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	40-50	*Eucalyptus crebra, Eucalyptus punctate* and *Corymbia maculata*
Midstorey layer	6 - 13	50-60	*Acacia binervata, Acacia bulgaensis,* and *Acacia longifolia*
Shrub layer	2	30-50	*Breynia oblongifolia, Exocarpos cupressiformis, Pimelea neo-angelica* and *Macrozamia flexuosa.*
Ground layer	1	20 - 30	*Brunoniella australis, Cheilanthes sieberi, Cymbopogon refractus, Desmodium brachypodum, Dianella revoluta, Entolasia stricta, Geitonoplesium cymosum, Glycine clandestina, Goodenia rotundifolia, Hovea linearis, Microlaena stipoides, Olearia elliptica, Solanum prinophyllum,* and *Themeda australis.*

*Projected foliage cover

Site photographs Wambo Spotted Gum 01 (left to right)

Start position

End position

WAMBOSPOT2

WAMBOSPOT2	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	308504	6390550
End transect	308522	6390593

Description: WAMBOSPOT2 occurs in land currently managed by Wambo Coal. The site was established in an area that has been previously mapped as a native vegetation community consistent with Central Hunter Ironbark – Spotted Gum – Grey Box Forest, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 34 cm.

Disturbance:

Disturbance present at the site consisted of few weed species. Weeds recorded include *Opuntia* spp., *Bidens pilosa* and *Senecio madagascariensis.*

No damage from fire activity was observed at the site.

No access tracks, or evidence of trail bikes or foot traffic was observed at the site.

Table. Dominant species and structure at Wambo Spotted Gum 02

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	40-50	*Eucalyptus moluccana* and *Corymbia maculata*
Midstorey layer	5-10	50-60	*Acacia mearnsii*
Shrub layer	2	40-60	*Bursaria spinosa, Dodonaea viscosa, Breynia oblongifolia, Pimelea neo-angelica* and *Macrozamia flexuosa.*
Ground layer	1	20 - 30	*Austrodanthonia racemosa, Brunoniella australis, Cheilanthes sieberi, Cymbopogon refractus, Desmodium brachypodum, Desmodium gunnii, Desmodium varians, Dianella revoluta, Entolasia stricta, Geitonoplesium cymosum, Glycine clandestina, Hovea linearis, Microlaena stipoides, Solanum prinophyllum* and *Themeda australis.*

*Projected foliage cover

Site photographs at Wambo Spotted Gum 02 (left to right)

Start position



End position



WAMBOSPOT3

WAMBOSPOT3	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	308276	6390200
End transect	308238	6390185

Description: WAMBOSPOT3 occurs in land currently managed by Wambo Coal. The site was established in an area that has been previously mapped as a native vegetation community consistent with Central Hunter Ironbark – Spotted Gum – Grey Box Forest, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 40 cm.

Disturbance:

Disturbance present at the site consisted of few weed species. Weeds recorded include *Opuntia* spp., *Bidens pilosa* and *Senecio madagascariensis.*

No damage from fire activity was observed at the site.

No access tracks, or evidence of trail bikes or foot traffic was observed at the site.

Table. Dominant species and structure at Wambo Spotted Gum 03

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	40-50	*Eucalyptus crebra, Eucalyptus punctate* and *Corymbia maculata*
Midstorey layer	5-10	50-60	*Acacia longifolia*
Shrub layer	2	30-50	*Bursaria spinosa, Dodonaea viscosa, Olearia elliptica,* and *Exocarpous cupressiformis*
Ground layer	1	20 - 30	*Austrodanthonia racemosa, Brunoniella australis, Cheilanthes sieberi, Cymbopogon refractus, Desmodium brachypodum, Desmodium gunnii, Desmodium varians, Dianella revoluta, Entolasia stricta, Geitonoplesium cymosum, Glycine clandestina, Hovea linearis, Microlaena stipoides, Solanum prinophyllum* and *Themeda australis.*

*Projected foliage cover

Site photographs at Wambo Spotted Gum 03 (left to right)

Start position

End position

WAMBOGB01

WAMBOGB01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	309194	6392618
End transect	309215	6392661

Description: WAMBOGB01 occurs in land currently managed by Wambo Coal. The site was established in an area that has been previously mapped as a native vegetation community consistent with Central Hunter Grey-Box – Ironbark Woodland, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 30 cm.

Disturbance:

Disturbance present at the site consisted of few weed species. Weeds recorded include *Opuntia* spp., *Bidens pilosa* and *Senecio madagascariensis.*

No damage from fire activity was observed at the site.

No access tracks, or evidence of trail bikes or foot traffic was observed at the site.

The site has been historically cleared in areas. The site generally lacks mature trees.

Table. Dominant species and structure at Wambo Grey Box 01

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	30-40	*Eucalyptus crebra* and *Eucalyptus moluccana*
Midstorey layer	5-10	10-20	*Casuarina cunninghamiana*
Shrub layer	2	10-20	*Olearia elliptica* and *Lissanthe strigosa*
Ground layer	1	30-40	*Brunoniella australis, Cheilanthes sieberi, Chrysocephalum apiculatum, Vittadinia cuneata, Wahlenbergia gracilis, Einadia nutans, Dichondra repens, Cyperus gracilis, Desmodium brachypodum, Glycine tabacina, Lomandra multiflora, Sida corrugata, Notelaea longifolia, Acianthus spp. Oxalis perennans, Dianella revoluta, Phyllanthus gunnii, Aristida ramosa Aristida vagans, Austrodanthonia racemosa, Austrostipa scabra Bothriochloa macra, Chloris ventricosa, Cymbopogon refractus, Panicum effusum, Sporobolus creber* and *Asperula conferta.*

*Projected foliage cover

Site photographs at Wambo Grey Box 01 (left to right)

Start position



End position



WAMBOGB02

WAMBOGB02	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	309539	6391965
End transect	309561	6392010

Description: WAMBOGB02 occurs in land currently managed by Wambo Coal. The site was established in an area that has been previously mapped as a native vegetation community consistent with Central Hunter Grey-Box – Ironbark Woodland, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 30 cm.

Disturbance:

Disturbance present at the site consisted of few weed species. Weeds recorded include *Opuntia* spp., *Bidens pilosa* and *Senecio madagascariensis.*

No damage from fire activity was observed at the site.

No access tracks, or evidence of trail bikes or foot traffic was observed at the site.

The site has been historically cleared in areas. The site generally lacks mature trees.

Table. Dominant species and structure at Wambo Grey Box 02

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	10-20	*Eucalyptus moluccana*
Midstorey layer	5-10	10-20	*Acacia amblygona, Acacia dealbata* and *Acacia falcata.*
Shrub layer	2	10-20	*Olearia elliptica and Lissanthe strigosa*
Ground layer	1	30-40	*Brunoniella australis, Cheilanthes sieberi, Chrysocephalum apiculatum, Vittadinia cuneata, Wahlenbergia gracilis, Einadia nutans, Dichondra repens, Cyperus gracilis, Desmodium brachypodum, Glycine tabacina, Lomandra multiflora, Sida corrugata, Notelaea longifolia, Acianthus spp. Oxalis perennans, Dianella revoluta, Phyllanthus gunnii, Aristida ramosa Aristida vagans, Austrodanthonia racemosa, Austrostipa scabra Bothriochloa macra, Chloris ventricosa, Cymbopogon refractus, Panicum effusum, Sporobolus creber* and *Asperula conferta.*

*Projected foliage cover

Site photographs at Wambo Grey Box 02 (left to right)

Start position



End position



WARKGB01

WARKGB01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	315553	6392801
End transect	315517	6392823

Description: WarkGB01 occurs in land currently managed by Coal and Allied. The site was established in an area that has been previously mapped (Niche 2015a) as a native vegetation community consistent with Central Hunter Grey-Box – Ironbark Woodland, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 29 cm.

Disturbance:

Disturbance present at the site consisted of few weed species. Weeds recorded include *Opuntia* spp., *Bidens pilosa* and *Senecio madagascariensis.*

No damage from fire activity was observed at the site.

No access tracks, or evidence of trail bikes or foot traffic was observed at the site.

The site has been historically cleared in areas. The site generally lacks mature trees.

Table. Dominant species and structure at Warkworth Grey Box 01

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	10-20	*Eucalyptus crebra* and *Eucalyptus moluccana*,
Midstorey layer	5-10	10-20	*Acacia falcata, Allocasuarina luehmannii* and *Exocarpos cupressiformis*,
Shrub layer	2	10-20	*Breynia oblongifolia, Daviesia ulicifolia, Notelaea longifolia*
Ground layer	1	30-40	*Aristida ramosa, Bothriochloa macra, Cheilanthes sieberi, Commelina cyanea, Cymbopogon refractus, Desmodium gunnii, Dichelachne micrantha, Dichondra repens, Echinopogon caespitosus, Einadia hastata, Eremophila debilis, Glycine tabacina, Lantana camara* *Microlaena stipoides, Oxalis perennans, Panicum effusum, Phyllanthus gunnii, Pseuderanthemum variabile, Solanum prinophyllum, Themeda australis* and *Vittadinia cuneata.*

*Projected foliage cover

Site photographs at Warkworth Grey Box 01 (left to right)

Start position



End position



WARKGB02

WARKGB02	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	314003	6387985
End transect	313998	6387939

Description: WarkGB02 occurs in land currently managed by Coal and Allied. The site was established in an area that has been previously mapped as the native vegetation community Central Hunter Grey-Box – Ironbark Woodland, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 26 cm.

Disturbance:

Disturbance present at the site consisted of few weed species. Weeds recorded include *Opuntia* spp., *Bidens pilosa* and *Senecio madagascariensis.*

No damage from fire activity was observed at the site.

No access tracks, or evidence of trail bikes or foot traffic was observed at the site.

The site has been historically cleared in areas. The site generally lacks mature trees.

Table. Dominant species and structure at Warkworth Grey Box 02

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	10-20	*Eucalyptus crebra,*
Midstorey layer	5-10	10-20	*Acacia decurrens* and *Allocasuarina luehmannii,*
Shrub layer	2	10-20	*Breynia oblongifolia, Bursaria spinosa, Notelaea microcarpa,* and *Olearia elliptica,*
Ground layer	1	30-40	*Aristida vagans, Cheilanthes sieberi, Chloris ventricosa, Commelina cyanea, Crassocephalum spp., Cymbopogon refractus, Cyperus gracilis, Desmodium brachypodum, Desmodium varians, Dichelachne micrantha, Dichondra repens, Dichopogon spp., Echinopogon caespitosus, Enchylaena tomentosa, Fimbristylis tristachya, Gahnia aspera, Goodenia rotundifolia, Microlaena stipoides, Sida corrugata, Solanum prinophyllum, Sporobolus creber* and *Vittadinia cuneata.*

*Projected foliage cover

Site photographs at Warkworth Grey Box 02 (left to right)

Start position



End position



WARKGB03

WARKGB03	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	314917	6386859
End transect:	314960	6386864

Description: WARKGB03 occurs in land currently managed by Coal and Allied. The site was established in an area that has been previously mapped as a native vegetation community constituting Central Hunter Grey-Box – Ironbark Woodland, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 28 cm.

Disturbance:

Disturbance present at the site consisted of few weed species. Weeds recorded include *Opuntia* spp., *Bidens pilosa* and *Senecio madagascariensis.*

No damage from fire activity was observed at the site.

No access tracks, or evidence of trail bikes or foot traffic was observed at the site.

The site has been historically cleared in areas. The site generally lacks mature trees.

Table. Dominant species and structure at Warkworth Grey Box 03

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	10-20	*Eucalyptus tereticornis* and *Eucalyptus crebra,*
Midstorey layer	5-10	10-20	*Allocasuarina luehmannii*
Shrub layer	2	10-20	*Acacia amblygona Breynia oblongifolia* and *Bursaria spinosa,*
Ground layer	1	30-40	*Alternanthera spp., Austrodanthonia racemosa, Austrostipa scabra, Cheilanthes sieberi, Chrysocephalum apiculatum, Commelina cyanea, Cymbopogon refractus, Cynodon dactylon, Cyperus gracilis, Desmodium varians, Dianella caerulea, Eragrostis brownii, Eragrostis elongata, Eremophila debilis, Fimbristylis tristachya, Glycine tabacina, Goodenia hederacea, Hypochaeris radicata, Laxmannia gracilis, Lomandra multiflora, Melaleuca decora, Melinis repens, Microlaena stipoides, Oxalis perennans, Pennisetum clandestinum, Poa sieberiana, Themeda australis* and *Wahlenbergia stricta.*

*Projected foliage cover

Site photographs at Warkworth Grey Box 03 (left to right)

Start position



End position



WARKGB04

WARKGB04	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	315316	6386087
End transect:	315336	6386046

Description: WarkGB04 occurs in land currently managed by Coal and Allied. The site was established in an area that has been previously mapped as a native vegetation community constituting Central Hunter Grey-Box – Ironbark Woodland, which is listed as an EEC under the TSC Act.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 30 cm.

Disturbance:

Disturbance present at the site consisted of few weed species. Weeds recorded include *Melinus repens, Eragrostis curvula, Opuntia* spp., *Bidens pilosa* and *Senecio madagascariensis.*

No damage from fire activity was observed at the site.

No access tracks, or evidence of trail bikes or foot traffic was observed at the site.

The site has been historically cleared in areas. The site generally lacks mature trees.

Table. Dominant species and structure at Warkworth Grey Box 04

Stratum	Height(m)	% cover*	Dominant native species
Tree layer	15 - 25	10-20	*Eucalyptus crebra,*
Midstorey layer	5-10	10-20	*Acacia amblygona, Acacia falcate* and *Allocasuarina luehmannii,*
Shrub layer	2	10-20	*Daviesia ulicifolia,*
Ground layer	1	30-40	*Aristida ramosa, Austrostipa scabra, Bothriochloa macra, Calotis lappulacea, Cheilanthes sieberi, Chloris truncata, Chloris ventricosa, Commelina cyanea, Cymbopogon refractus, Cynodon dactylon, Cyperus gracilis, Dichondra repens, Eragrostis brownii, Eremophila debilis, Fimbristylis tristachya, Galenia pubescens, Glycine tabacina, Goodenia rotundifolia, Hardenbergia violacea, Oxalis perennans, Panicum effusum, Paspalidium spp., Sida rhombifolia, Solanum prinophyllum, Themeda australis* and *Wahlenbergia gracilis.*

*Projected foliage cover

Site photographs at Warkworth Grey Box 04 (left to right)

Start position



End position



HVOCAR2009-01

HVOCAR2009-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	310310	6405170
End transect	310358	6405167

Description:

The HVOCAR2009-01 rehabilitation area occurs on imported topsoil.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 14 cm.

Disturbance:

Disturbance present at the rehabilitation site consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Common weeds recorded at the site included *Galea pubescens, Plantago lanceolata*, *Conyza bonariensis*, *Chloris gayana*, *Sida rhombifolia*, and *Verbena bonariensis.*

Table. Dominant species and structure at HVOCAR2009-01

Stratum	Height	% cover*	Dominant native species
Tree layer	15 - 30	15	*Eucalyptus moluccana*
Midstorey layer	6 - 13	25	*Acacia longifolia*, *Acacia falcata*, and *Acacia mearnsii*
Shrub layer	2	5	*Acacia amblygona.*
Ground layer	1	40	*Cynodon dactylon*, *Dichondra repens*, *Sida corrugata*, and *Bothriochloa macra.*

*Projected foliage cover

Site photographs at HVOCAR2009-01 (left to right)

Start position

End position

HVOCAR2009-02

HVOCAR2009-02	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	309114	6403453
End transect	309076	6403430

Description:

HVOCAR2009-02 rehabilitation area occurs on imported topsoil.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 10 cm.

Disturbance:

Disturbance present at the rehabilitation site consists mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Common weeds recorded at the site included *Galea pubescens, Plantago lanceolata, Conyza bonariensis, Chloris gayana, Sida rhombifolia* and *Verbena bonariensis*.

Table. Dominant species and structure at HVOCAR2009-02

Stratum	Height (m)	% cover*	Dominant native species
Tree layer	-	-	-
Midstorey layer	6	10	*Eucalyptus crebra, Corymbia maculata, Acacia mearnsii,* and *Acacia longifolia,*
Shrub layer	-	-	-
Ground layer	1	50	*Bothriochloa macra, Dichondra repens, Panicum effusum, Oxalis perennans,* and *Wahlenbergia gracilis,*

*Projected foliage cover

Site photographs at HVOCAR2009-02 (left to right)

Start position



End position



HVOWES2008-01

HVOWES2008-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	306340	6406920
End transect	306364	6406877

Description:

The HVOWES2008-01 rehabilitation area occurs on imported topsoil.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 15 cm.

Disturbance:

Disturbance present at the rehabilitation site consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Common weeds recorded at the site included *Heliotronium amplexicaule, Malvastrum americanum, Galea pubescens, Plantago lanceolata, Chloris gayana, Cymbopogon refractus, Sida rhombifolia* and *Verbena bonariensis*.

Table. Dominant species and structure at HVOWES2008-01

Stratum	Height (m)	% cover*	Dominant native species
Tree layer	5	20	*Eucalyptus punctate* and *Corymbia maculata*
Midstorey layer	2 – 4	30	*Acacia parvipula, Acacia mearnsii, Acacia dealbata* and *Acacia amblygona,*
Shrub layer	2	25	*Acacia paradoxa, Acacia mearnsii, Acacia dealbata* and *Acacia amblygona*
Ground layer	1	40	*Austrostipa ramossisima, Bothriochloa macra, Plantago debilis, Dichondra repens, Sporobolous creber, Chloris ventricosa, Enchylaena tomentose* and *Glycine tabacina.*

*Projected foliage cover

Site photographs at HVOWES2008-01 (left to right)

Start position



End position



HVOWES2011-01

HVOWES2011-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	308265	6409164
End transect	308223	6409171

Description:

The HVOWES2011-01 rehabilitation area occurs on spoil with compost. Native seed has been hydroseeded in the rehabilitation area.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 13 cm.

Disturbance:

Disturbance present at the site consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Pig scats were recorded at the site during the monitoring.

Common weeds recorded at the site included *Galea pubescens, Plantago lanceolata, Conyza bonariensis, Chloris gayana, Sida rhombifolia* and *Verbena bonariensis.*

Table. Dominant species and structure at HVOWES2011-01

Stratum	Height	% cover*	Dominant native species
Tree layer	-	-	-
Midstorey layer	5-6	50	*Eucalyptus crebra, Eucalyptus punctata, Corymbia maculata, Acacia longifolia, Allocasuarina littoralis, Acacia implexa, Acacia binervata,* and *Acacia falcata.*
Shrub layer	2	5	*Indigofera australis* and *Hakea sericea.*
Ground layer	1	60	*Austrostipa ramossisima, Bothriochloa macra, Dichondra repens, Sporobolous creber, Chloris truncata, Hardenbergia violacea, Microlaeana stipoides, Enchylaena tomentosa, Glycine tabacina* and *Themeda australis.*

*Projected foliage cover

Site photographs at HVOWES2011-01 (left to right)

Start position



End position



MTWNPN2005-01

MTWNPN2005-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	319816	6391225
End transect	319842	6391183

Description:

The MTWNPN2005-01 rehabilitation area occurs on imported topsoil.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 22 cm.

Disturbance:

Disturbance present at the rehabilitation site consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Common weeds recorded at the site included *Acacia saligna, Plantago lanceolata, Conyza bonariensis, Chloris gayana, Sida rhombifolia* and *Verbena bonariensis.*

Table. Dominant species and structure at MTWNPN2005-01

Stratum	Height (m)	% cover*	Dominant native species
Tree layer	10	5	*Corymbia maculata* and *Eucalyptus punctata*
Midstorey layer	4	20	Dominanted by *Acacia saligna*
Shrub layer	2	5	*Acacia amblygona,*
Ground layer	1	40	*Bothriochloa macra, Dichondra repens, Hardenbergia violacea, Oxalis perennans, Enchylaena tomentosa, Sporobolus creber, Wahlenbergia stricta* and *Eremophila debilis*

*Projected foliage cover

Site photographs at MTWNPN2005-01 (left to right)

Start position



End position



MTWNPN2005-02

MTWNPN2005-02	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	319682	6391980
End transect	319682	6391980

Description:

The MTWNPN2005-01 rehabilitation area occurs on imported topsoil.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 18 cm.

Disturbance:

Disturbance present at the rehabilitation site consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Common weeds recorded at the site included *Acacia saligna, Plantago lanceolata, Conyza bonariensis, Chloris gayana, Sida rhombifolia* and *Verbena bonariensis.*

Table. Dominant species and structure at MTWNPN2005-02

Stratum	Height (m)	% cover*	Dominant native species
Tree layer	10	10	*Corymbia maculata, Corymbia citriodora, Eucalyptus crebra,* and *Eucalyptus punctata*
Midstorey layer	5	20	Acacia spp (no flowers or seed pods to assist in identification).
Shrub layer	2	5	*Acacia amblygona,*
Ground layer	1	40	*Bothriochloa macra, Dichondra repens, Oxalis perennans, Enchylaena tomentosa, Sporobolus creber, Vittadinia cuneata, Eremophila debilis, Themeda australis,* and *Panicum effusum.*

*Projected foliage cover

Site photographs at MTWNPN2005-02 (left to right)

Start position



End position



MTWNPN2009-01

MTWNPN2009-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	319069	6391524
End transect	319027	6391535

Description:

The MTWNPN2009-01 rehabilitation area occurs on imported topsoil.

The dominant species, including the structure of the site is provided in the table below.

The spacing between the eucalypts were noticeable densely compact compared to the other sites.

The average DBH of the trees is approximately 16 cm.

Disturbance:

Disturbance present at the site consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Common weeds recorded at the site included *Galea pubescens, Plantago lanceolata, Conyza bonariensis, Chloris gayana, Sida rhombifolia* and *Verbena bonariensis.*

Pig scats were found at the site during the monitoring.

Table. Dominant species and structure at MTWNPN2009-01

Stratum	Height	% cover*	Dominant native species
Tree layer	7-8	60	*Corymbia maculata* and *Eucalyptus crebra*
Midstorey layer	3	10	*Acacia amblygona* and *Acacia falciformis*
Shrub layer	2	10	Small acacias, *Bursaria spinulosa* and *Breynia oblongifolia.*
Ground layer	1	20	*Bothriochloa macra, Dichondra repens, Hardenbergia violacea,* and *Oxalis perennans.*

*Projected foliage cover

Site photographs at MTWNPN2009-01 (left to right)

Start position



End position



MTWCDD2011-01

MTWCDC2011-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	319599	6390304
End transect	319552	6390312

Description:

The MTWCDD2011-01 rehabilitation area occurs on imported topsoil with native seeds hydroseeded into the soil.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 13 cm.

Disturbance:

Disturbance present at the site consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Common weeds recorded at the site included *Acacia saligna, Bidens pilosa, Solanum nigrum, Galea pubescens, Plantago lanceolata, Chloris gayana, Cymbopogon refractus, Sida rhombifolia* and *Verbena bonariensis.*

Table. Dominant species and structure at MTWCDC2011-01

Stratum	Height (m)	% cover*	Dominant native species
Tree layer	-	-	-
Midstorey layer	4	10	*Corymbia maculata, Acacia cultriformis, Acacia amblygona,* and *Acacia falcata,*
Shrub layer	1	10	*Indigofera australis,*
Ground layer	0.5	40	*Dichondra repens, Cynodon dactylon, Bothriochloa macra, Einadia nutans, Echinopogon caespiotsis, Themeda australis, Fimbristylis dicholoma* and *Capillipedium spicigerum*

*Projected foliage cover

Site photographs at MTWCDC2011-01 (left to right)

Start position

MTWMTO2005-03

MTWMTO2005-03	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	320678	6385782
End transect	320640	6385756

Description:

The MTWMTO2005-03 rehabilitation area occurs on imported topsoil.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the average trees is approximately 17 cm.

Disturbance:

Disturbance present at the rehabilitation site consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Common weeds recorded at the site included *Acacia saligna, Eragrostis curvula, Bidens pilosa, Plantago lanceolata, Conyza bonariensis, Chloris gayana, Sida rhombifolia, Verbena bonariensis.*

Table. Dominant species and structure at MTWMTO2005-03

Stratum	Height	% cover*	Dominant native species
Tree layer	10	10	*Eucalyptus punctata*
Midstorey layer	-	-	-
Shrub layer	-	-	-
Ground layer	1	20	*Einadia nutans, Sporobolus creber, Chloris truncata, Chloris ventricosa, Calotis lappulacea, Bothriochloa macra, Dichondra repens, Oxalis perennans, Enchylaena tomentosa, Cyperus gracilis, Eremophila debilis,* and *Aristida vagans.*

*Projected foliage cover

MTWMTO2000-01

MTWMTO2000-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	320551	6386940
End transect	320531	6386982

Description:

The MTWMTO2000-01 rehabilitation area occurs on imported topsoil.

The dominant species, including the structure of the site is provided in the table below.

The average DBH of the trees is approximately 23 cm.

Disturbance:

Disturbance present at the site consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Common weeds recorded at the site included *Opuntia stricta, Senecio madagascariensis, Bidens pilosa, Plantago lanceolata, Conyza bonariensis, Chloris gayana, Sida rhombifolia* and *Verbena bonariensis.*

Table. Dominant species and structure at MTWMTO2000-01

Stratum	Height	% cover*	Dominant native species
Tree layer	10	10	*Eucalyptus punctata* and *E. moluccana*
Midstorey layer	-	-	-
Shrub layer	2	20	*Acacia* spp.,
Ground layer	1	20	*Solanum prinophyllum, Einadia nutans, Cheilanthes sieberi, Themeda australis, Chloris truncata, Dichondra repens, Oxalis perennans, Enchylaena tomentosa,* and *Eremophila debilis.*

*Projected foliage cover

Site photographs at MTWMTO2000-01 (left to right)

Start position



End position



HVORIV2013-01

HVORIV2013-01	MGA 84 Zone 56	
Position	Easting	Northing
Start transect:	311184	6398689
End transect	311232	6398695

Description:

HVORIV2013-01 rehabilitation area occurs on a combination of topsoil and compost at HVO West. The rehabilitation site is dominated by the following species; *Chloris gayana, Bidens pilosa, Echinochloa crus-galli, Galenia pubescens, Plantago lanceolata, Senecio mada gascariensis, Gomphocarpous fruiticosis, Panicum maximum, Plantago lanceolata, Portulacca olearea, Sida rhombifolia* and *Solanum nigrum.*

Disturbance:

Disturbance present at rehabilitation site HVORIV2013-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVORIV2013-01 has an average 81 percent Protective cover. The percentage of weeds occupy an average of 100 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from one to three species. The average number of species per 1 x 1 metre plot is two species.

Table. Ground cover assessment percentage cover at HVORIV2013-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	100	0	100	3
10m	100	0	100	2
15m	100	0	100	3
20m	90	10	100	3
25m	90	10	100	2
30m	80	20	100	2
35m	100	0	100	3
40m	80	20	100	1
45m	60	40	100	3
50m	10	90	100	1
Average	81	19	100	2

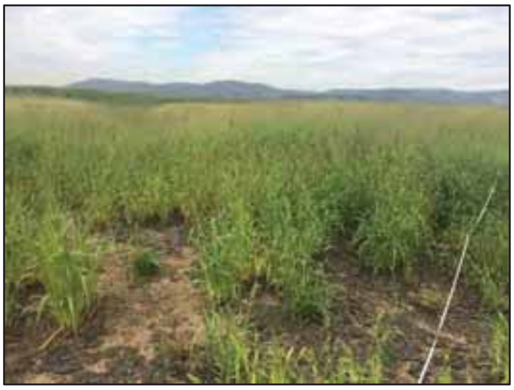
*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVORIV2013-01 (left to right)

Start position



End position



HVORIV2014-01

HVORIV2014-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	311033	6398662
End transect	310993	6398633

Description:

HVORIV2014-01 rehabilitation area occurs on a comination of spoil and compost at HVO West. The rehabilitation site is dominated by *Conyza bonariensis.* Other species include *Chloris gayana, Bidens pilosa, Bothriochloa macra, Galenia pubescens, Plantago lanceolata, Senecio mada gascariensis, Gomphocarpous fruiticosis, Panicum maximum, Plantago lanceolata, Nicotiana glauca* and *Solanum nigrum.* It should be noted that a number of regenerating eucalypts (thin leaves – likely *E. crebra*), and small acacias and *Enchylaena tomentosa* were also recorded regenerating in the plot.

Disturbance:

Disturbance present at rehabilitation site HVORIV2014-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVORIV2014-01 has an average 47 percent Protective cover. The percentage of weeds occupy an average of 94 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from one to six species. The average number of species per 1 x 1 metre plot is three species.

Table. Ground cover assessment percentage cover at HVORIV2014-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	20	80	100	3
10m	70	30	90	6
15m	30	70	100	1
20m	10	90	70	3
25m	20	80	100	2
30m	30	70	100	1
35m	70	30	80	4
40m	70	30	100	3
45m	80	20	100	3
50m	70	30	100	3
Average	47	53	94	3

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVORIV2014-01 (left to right)

Start position



End position



HVORIV2014-02

HVORIV2014-02	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	311293	6398516
End transect	311320	6398476

Description:

HVORIV2014-02 rehabilitation area occurs on a comination of subsoil and compost at HVO West. The rehabilitation site is dominated by *Conyza bonariensis.* Other species include *Chloris gayana, Chloris truncata, Bidens pilosa, Bothriochloa macra, Galenia pubescens, Hypochaeria radicata, Plantago lanceolata, Senecio mada gascariensis, Gomphocarpous fruiticosis, Panicum maximum, Plantago lanceolata, Sida rhombifolia, Solanum nigrum* and *Polymeiria aviculare.* It should be noted that a number of regenerating eucalypts (thin leaves – likely *E. crebra*), small acacias (*Acacia decora, Acacia implexa), Salsola tragus* and *Enchylaena tomentosa* were also recorded regenerating in the plot.

Disturbance:

Disturbance present at rehabilitation site HVORIV2014-02 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVORIV2014-02 has an average 27 percent Protective cover. The percentage of weeds occupy an average of 26 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from one to four species. The average number of species per 1 x 1 metre plot is three species.

Table. Ground cover assessment percentage cover at HVORIV2014-02

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	20	80	20	3
10m	30	70	30	2
15m	40	60	20	4
20m	30	70	30	2
25m	30	70	30	1
30m	10	90	10	3
35m	40	60	30	4
40m	30	70	20	2
45m	30	70	60	2
50m	10	90	10	2
Average	27	73	26	3

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVORIV2014-02 (left to right)

Start position



End position



HVORIV2014-03

HVORIV2014-03	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	311900	6398539
End transect	311853	6398557

Description:

HVORIV2014-03 rehabilitation area occurs on a comination of spoil and compost at HVO West. The rehabilitation site consisted predominantly of the following introduced species; *Bidens pilosa, Panicum maximum, Echinochloa crus-gali, Chloris gayana,* and *Conyza bonariensis.* Native species included *Chloris truncata, Austrodanthonia spp.*, and *Persicaria decipiens.*

Disturbance:

Disturbance present at rehabilitation site HVORIV2014-03 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVORIV2014-03 has an average 39 percent Protective cover. The percentage of weeds occupy an average of 97 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from four to eight species. The average number of species per 1 x 1 metre plot is 6 species.

Table. Ground cover assessment percentage cover at HVORIV2014-03

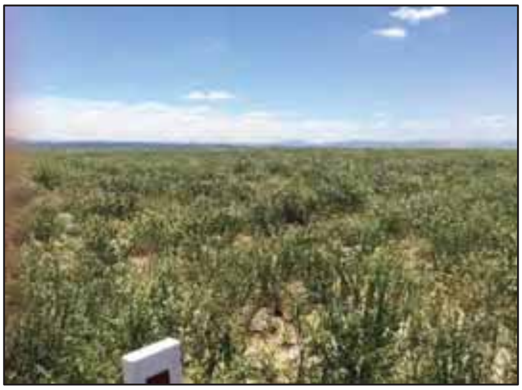
Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	20	80	100	8
10m	10	90	100	7
15m	30	70	100	9
20m	20	80	100	5
25m	20	80	100	4
30m	30	70	80	6
35m	30	70	100	5
40m	30	70	100	5
45m	100	0	90	7
50m	100	0	100	4
Average	39	61	97	6

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVORIV2014-03 (left to right)

Start position





End position



HVORIV2014-04

HVORIV2014-04	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	311900	6398539
End transect	311853	6398557

Description:

HVORIV2014-04 rehabilitation area occurs on a comination of subsoil and compost at HVO West. The rehabilitation site consisted predominantly of the following introduced species: *Panicum maximum, Echinochloa crus-gali, Cynodon dactylon, Eriochloa pseudoastrotrica, Chloris gayana, Solanum nigrum* and *Conyza bonariensis.*

Disturbance:

Disturbance present at rehabilitation site HVORIV2014-04 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVORIV2014-04 has an average 74 percent Protective cover. The percentage of weeds occupy an average of 70 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from one to six species. The average number of species per 1 x 1 metre plot is 5 species.

Table. Ground cover assessment percentage cover at HVORIV2014-04

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	80	20	10	4
10m	10	90	40	9
15m	80	20	20	6
20m	40	60	100	6
25m	80	20	100	6
30m	90	10	80	4
35m	100	0	100	1
40m	80	20	80	6
45m	90	10	80	5
50m	90	10	90	4
Average	74	26	70	5

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVORIV2014-04 (left to right)

Start position



End position



HVORIV2014-05

HVORIV2014-05	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	312242	6398088
End transect	312268	6398113

Description:

HVORIV2014-05 is rehabilitation area occurs on a comination of subsoil and compost at HVO West. The rehabilitation site consisted predominantly of the following introduced species: *Panicum maximum, Echinochloa crus-gali, Chloris gayana, Solanum nigrum* and *Conyza bonariensis.*

Disturbance:

Disturbance present at rehabilitation site HVORIV2014-05 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVORIV2014-05 has an average 77 percent Protective cover. The percentage of weeds occupy an average of 100 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from one to three species. The average number of species per 1 x 1 metre plot is 2 species.

Table. Ground cover assessment percentage cover at HVORIV2014-05

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	90	10	100	2
10m	90	10	100	1
15m	80	20	100	1
20m	70	30	100	1
25m	80	20	100	3
30m	70	30	100	2
35m	60	40	100	1
40m	60	40	100	2
45m	90	10	100	2
50m	80	20	100	2
Average	77	23	100	2

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVORIV2014-05 (left to right)

Start position



End position



HVORIV2014-06

HVORIV2014-06	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	312521	6397946
End transect	312521	6397895

Description:

HVORIV2014-06 rehabilitation area occurs on a comination of topsoil and compost at HVO West. The rehabilitation site consisted predominantly of the following introduced species: *Chloris gayana, Bidens pilosa, Bothriochloa macra, Galenia pubescens, , Plantago lanceolata, Senecio madagascariensis, Panicum maximum, Solanum nigrum* and *Conyza bonariensis. Solanum prinophyllum* and *Enchylaena tomentosa* were also recorded regenerating in the plot.

Disturbance:

Disturbance present at rehabilitation site HVORIV2014-06 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVORIV2014-06 has an average 73 percent Protective cover. The percentage of weeds occupy an average of 70 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from four to seven species. The average number of species per 1 x 1 metre plot is five species.

Table. Ground cover assessment percentage cover at HVORIV2014-06

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	90	10	30	6
10m	70	30	40	6
15m	70	30	60	5
20m	60	40	100	6
25m	90	10	60	4
30m	90	10	60	5
35m	90	10	70	7
40m	50	50	80	5
45m	90	10	100	4
50m	30	70	100	6
Average	73	27	70	5

*Protective cover includes dead and live vegetation, rocks, litter and logs

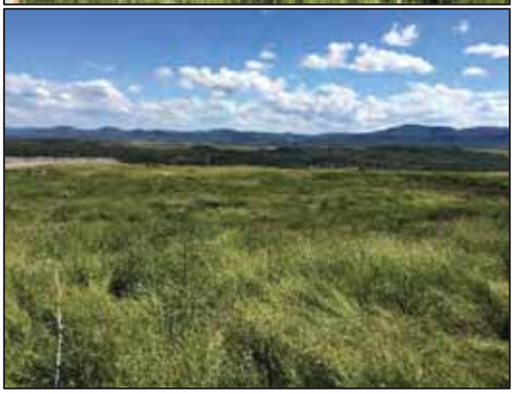
Site photographs at HVORIV2014-06 (left to right)

Start position



End position





HVOWES2013-01

HVOWES2013-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	306899	6407222
End transect	306858	6407251

Description:

HVOWES2013-01 rehabilitation area occurs on a comination of spoil and compost at HVO West. The rehabilitation site includes the following grasses: Bothriochloa macra, Austrodanthonia spp. (lack of seed head), *Eragstristis curvula, Chloris gayana* and *Chloris truncata.*

A number of eucalypts were observed within the rehabilitation area. It is likely that the eucalypts regenerating included *Eucalyptus crebra* and *Corymbia maculata.*

Disturbance:

Disturbance present at rehabilitation site HVOWES2013-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

Rehabilitation site HVOWES2013-01 has a high percentage of Protective cover (97 percent). Weed occupied 55 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots was relatively high compared to other sites, ranging from three to eight species, with an average of five species.

Table. Ground cover assessment percentage cover at HVOWES2013-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	100	0	50	6
10m	100	0	50	8
15m	90	10	80	5
20m	90	10	100	5
25m	90	10	70	7
30m	100	0	50	4
35m	100	0	50	3
40m	100	0	50	4
45m	100	0	20	4
50m	100	0	30	4
Average	97	3	55	5

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVOWES2013-01 (left to right)

Start position



End position



HVOWES2013-02

HVOWES2013-02	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	306889	6407365
End transect	306879	6407409

Description:

HVOWES2013-02 rehabilitation area occurs on a comination of topsoil and compost at HVO West. The rehabilitation site includes the following grasses: *Eriochloa pseudoastritrica, Panicum maximum, Chloris gayana* and *Sporobolus creber.* Herbaceous weeds including *Verbena bonariensis, Conyza bonariensis* and *Brassica* spp. were recorded in the monitoring plot. All three of these herbaceous weeds were flowering at the time of the survey.

Disturbance:

Disturbance present at rehabilitation site HVOWES2013-02 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVOWES2013-02 has a high percentage of Protective cover (91 percent). Weed occupied 13 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots was low, ranging from one to three species, with an average of three species.

Table. Ground cover assessment percentage cover at HVOWES2013-02

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	100	0	10	3
10m	90	10	10	3
15m	90	10	10	3
20m	80	20	20	3
25m	70	30	10	2
30m	90	10	0	1
35m	100	0	10	3
40m	100	0	20	3
45m	90	10	40	3
50m	100	0	0	2
Average	91	9	13	3

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVOWES2013-02 (left to right)

Start position

End position

HVOCAR2014-01

HVOCAR2014-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	6403083	309872
End transect	6403057	309832

Description:

HVOCAR2014-01 rehabilitation area occurs on a comination of topsoil and compost at HVO West. Rehabilitation site includes the following grasses: *Panicum maximum, Echinochloa crus-galli* and *Chloris gayana.* Herbaceous weeds including *Verbena bonariensis, Solanum nigrum, Senecio madagascariensis, Conyza bonariensis* and *Brassica* spp. were recorded in the monitoring plot.

Disturbance:

Disturbance present at rehabilitation site HVOCAR2014-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVOCAR2014-01 just a relatively higher percentage of Protective cover (54 percent) compared to Bare earth cover (45 percent). Weed dominanted the cover occupying an average of 55 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots was low, and ranged from one to six species, with an average of two species.

Table. Ground cover assessment percentage cover at HVOCAR2014-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	40	60	40	6
10m	50	50	40	3
15m	80	20	80	3
20m	50	50	50	3
25m	40	60	40	2
30m	50	60	50	1
35m	60	40	60	2
40m	80	20	80	1
45m	30	50	50	1
50m	60	40	60	1
Average	54	45	55	2

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVOCAR2014-01 (left to right)

Start position



End position



HVOCHE2012-01

HVOCHE2012-01	MGA 84 Zone 56

Position	Easting	Northing
Start transect:	315694	6400898
End transect	315660	6400932

Description:

HVOCHE2012-01 rehabilitation area occurs on a comination of topsoil and compost at HVO West. The rehabilitation site is dominated by the following species: *Chloris gayana, Chloris truncata, Conyza bonariensis, Echinochloa crus-galli, Eriochloa pseudoastrotricha, Hypochaeria radicata, Plantago lanceolata, Senecio madagascariensis, Panicum maximum, Plantago lanceolata, Sida rhombifolia,* and *Solanum nigrum.*

Disturbance:

Disturbance present at rehabilitation site HVOCHE2012-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVOCHE2012-01 has an average 87 percent Protective cover. The percentage of weeds occupy an average of 84 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from two to seven species. The average number of species per 1 x 1 metre plot is four species.

Table. Ground cover assessment percentage cover at HVOCHE2012-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	90	10	100	4
10m	50	50	80	5
15m	100	0	100	2
20m	80	20	60	4
25m	60	40	80	7
30m	100	0	80	6
35m	100	0	100	4
40m	90	10	40	4
45m	100	0	100	3
50m	100	0	100	3
Average	87	13	84	4

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVOCHE2012-01 (left to right)

Start position



End position



HVOCHE2013-01

HVOCHE2013-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	315159	6401135
End transect	315170	6401172

Description:

HVOCHE2013-01 rehabilitation area occurs on a comination of topsoil and compost at HVO West. The rehabilitation site is dominated by the following species: Chloris *gayana, Chloris truncata, Conyza bonariensis, Echinochloa crus-galli, Eriochloa pseudoastrotricha, Hypochaeria radicata, Plantago lanceolata, Senecio mada gascariensis, Gomphocarpous fruiticosis, Panicum maximum, Plantago lanceolata, Sida rhombifolia* and *Solanum nigrum.*

Disturbance:

Disturbance present at rehabilitation site HVOCHE2013-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVOCHE2013-01 has an average 93 percent Protective cover. The percentage of weeds occupy an average of 46 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from two to five species. The average number of species per 1 x 1 metre plot is four species.

Table. Ground cover assessment percentage cover at HVOCHE2013-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	70	30	40	5
10m	100	0	40	5
15m	100	0	40	4
20m	100	0	90	3
25m	100	0	30	4
30m	80	20	60	3
35m	100	0	80	4
40m	100	0	20	3
45m	100	0	30	2
50m	80	20	30	3
Average	93	7	46	4

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVOCHE2013-01 (left to right)

Start position



End position



HVOCHE2014-01

HVOCHE2014-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	315581	6399040
End transect	315541	6399065

Description:

HVOCHE2014-01 rehabilitation area occurs on a comination of topsoil and compost at HVO West. The rehabilitation site includes the following grasses: *Echinochloa crus-gali, Panicum maximum, Eriochloa pseudoastritrica* and *Sporobolus creber.* Herbaceous weeds including *Verbena bonariensis, Conyza bonariensis* and *Brassica* spp. were recorded in the monitoring plot. All three of these herbaceous weeds were flowering at the time of the survey.

Disturbance:

Disturbance present at rehabilitation site HVOCHE2014-01consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVOCHE2014-01 has a high percentage of Protective cover (91 percent). The percentage of weed occupied 81 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots was relatively low, ranging from two to five species, with an average of three species.

Table. Ground cover assessment percentage cover at HVOCHE2014-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	50	50	40	2
10m	80	20	30	5
15m	80	20	60	3
20m	70	30	100	3
25m	80	20	100	3
30m	70	30	100	2
35m	80	20	100	4
40m	80	20	80	3
45m	70	30	100	2
50m	80	20	100	3
Average	74	26	81	3

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVOCHE2014-01 (left to right)

Start position



End position



HVOCHE2012-03

HVOCHE2012-03	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	315667	6400043
End transect	315617	6400040

Description:

HVOCHE2012-03 rehabilitation area occurs on a comination of topsoil and compost at HVO West. The rehabilitation site includes the following grasses: *Eriochloa pseudoastritrica, Panicum maximum* and Chloris gayana. Herbaceous weeds including *Conyza bonariensis, Brassica* spp., *Lepidium spp.* and *Portulaca oleracea* were recorded in the monitoring plot. All three of these herbaceous weeds were flowering at the time of the survey.

Disturbance:

Disturbance present at rehabilitation site HVOCHE2012-03 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

HVOCHE2012-03 has a high percentage of Protective cover (81 percent). The percentage of weed occupied 63 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from three to five species, with an average of three species.

Table. Ground cover assessment percentage cover at HVOCHE2012-03

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	70	30	50	4
10m	80	20	70	4
15m	70	30	60	4
20m	90	10	70	3
25m	90	10	90	3
30m	50	50	50	3
35m	100	0	50	4
40m	90	10	50	3
45m	80	20	60	5
50m	90	10	80	4
Average	81	19	63	3.7

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at HVOCHE2012-03 (left to right)

Start position



End position



MTWNPN2011-01

MTWNPN2011-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	318166	6392138
End transect	318115	6392138

Description:

MTWNPN2011-01 rehabilitation area occurs on a comination of topsoil and compost at Mount Thorley-Warkworth. The rehabilitation site includes the following regenerating native species: *Acacia amblygona, A. longifolia, A, decora, A. cultriformis* and *Themeda australis.* Introduced species included: *Acacia saligna, Eriochloa pseudoastritrica, Panicum maximum* and Chloris gayana*.* Herbaceous weeds including *Conyza bonariensis, Brassica* spp., *Gomphocarpus fruiticosis* and *Sida rhombifolia* were recorded in the monitoring plot. All three of these herbaceous weeds were flowering at the time of the survey.

Disturbance:

Disturbance present at rehabilitation site MTWNPN2011-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWNPN2011-01 has a high percentage of Protective cover (84 percent). The percentage of weed occupied 68 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from two to five species, with an average of four species.

Table. Ground cover assessment percentage cover at MTWNPN2011-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	100	0	100	2
10m	90	10	90	4
15m	80	20	70	5
20m	80	20	70	4
25m	90	10	90	5
30m	50	50	50	3
35m	100	0	90	2
40m	90	10	60	4
45m	60	40	20	5
50m	100	0	40	4
Average	84	16	68	4

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWNPN2011-01 (left to right)

Start position



MTWTDI2015-01

MTWTD12015-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	319687	6392186
End transect	319691	6392236

Description:

MTWTDI2015-01 rehabilitation area occurs on a comination of spoil and compost at Mount Thorley-Warkworth. The rehabilitation site includes the following grasses: Chloris truncata, Digitaria sanguinalis, Panicum effusum, Setaria gracilis, *Eriochloa pseudoastritrica, Echinochloa crus-gali* and Chloris gayana. Herbaceous weeds including *Conyza bonariensis* and *Portulaca oleracea* were recorded in the monitoring plot. *Enchylaena tomentosa* and *Einadia hastata* were also recorded in the monitoring plot.

Disturbance:

Disturbance present at rehabilitation site MTWTDI2015-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWTD12015-01 has 77 percent Protective cover, of which most is attributed due to rock and stone throughout the site. The percentage of weed occupied 5 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from one to five species, with an average of two species.

Table. Ground cover assessment percentage cover at MTWTDI2015-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	70	30	10	2
10m	90	10	0	1
15m	90	10	10	5
20m	60	40	0	0
25m	90	10	0	1
30m	90	10	0	1
35m	80	20	0	3
40m	80	20	10	2
45m	60	40	10	1
50m	60	40	10	2
Average	77	23	5	2

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWTDI2015-01 (left to right)

Start position



End position



MTWSPN2014-01

MTWSPN2014-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	320170	6390161
End transect	320186	6390201

Description:

MTWSPN2014-01 rehabilitation area occurs on a comination of topsoil and compost at Mount Thorley-Warkworth. The rehabilitation site was dominanted by the following species: *Conyza bonariensis, Chloris gayana, Eriochloa pseudoastritrica, Echinochloa crus-gali* and *Panicum maximum.*

Disturbance:

Disturbance present at rehabilitation site MTWSPN2014-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWSPN2014-01 has an average of 81 percent Protective cover. The percentage of weed occupied an average of 94 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from one to four species. The average number of species within a 1 x 1 plot is 2 species.

Table. Ground cover assessment percentage cover at MTWSPN2014-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	60	40	100	3
10m	70	30	100	2
15m	70	30	100	2
20m	90	10	100	2
25m	90	10	100	3
30m	90	10	100	2
35m	80	20	50	4
40m	80	20	90	1
45m	90	10	100	1
50m	90	10	100	2
Average	81	19	94	2

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWSPN2014-01 (left to right)

Start position



End position



MTWNPN2014-01

MTWNPN2014-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	317645	6392097
End transect	317618	6392128

Description:

MTWNPN2014-01 rehabilitation area occurs on a comination of topsoil and compost at Mount Thorley-Warkworth. The rehabilitation site includes the following native species: Bothriochloa macra, *Chloris truncata, Cynodon dactylon, Dichondra repens, Hardenbergia violacea,* and *Acacia amblygona.* Weeds included: *Bidens pilosa, Conyza bonariensis, Lepidium spp. Pennisetum cladenstina, Senecio madagascariensis, Solanum nigrum,* and *Verbena bonariensis*.

Disturbance:

Disturbance present at rehabilitation site MTWNPN2014-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWNPN2014-01 has an average 49 percent Protective cover. The percentage of weeds occupy an average of 42 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from three to eight species. The average number of species per 1 x 1 metre plot is 5 specis.

Table. Ground cover assessment percentage cover at MTWNPN2014-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	30	70	30	5
10m	30	70	20	8
15m	50	50	40	4
20m	60	40	30	4
25m	60	40	60	4
30m	60	40	60	4
35m	30	70	40	4
40m	40	60	40	5
45m	40	60	40	3
50m	90	10	60	5
Average	49	51	42	4.6

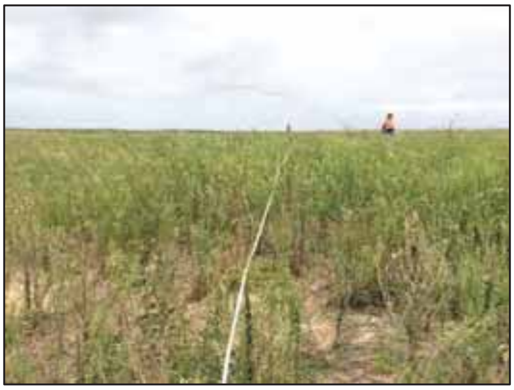
*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWNPN2014-01 (left to right)

Start position



End position


MTWNPN2014-03

MTWNPN2014-03	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	318131	6391213
End transect	318131	6391213

Description:

MTWNPN2014-03 rehabilitation area occurs on a comination of subsoil and compost at Mount Thorley-Warkworth. The rehabilitation site includes the following grasses: Austrodanthonia spp., Chloris truncata, *Eriochloa pseudoastritrica* and *Pennisetum cladenstina.* Herbaceous weeds including *Bidens pilosa, Conyza bonariensis, Chenopodium spp.* and *Trifolium repens,* were recorded in the monitoring plot. *Acacia saligna* was recorded in the plot.

Disturbance:

Disturbance present at rehabilitation site MTWNPN2014-03 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWNPN2014-03 has 93 percent Protective cover. The percentage of weeds occupy an average of 88 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from two to eight species, with an average of 7 species.

Table. Ground cover assessment percentage cover at MTWNPN2014-0

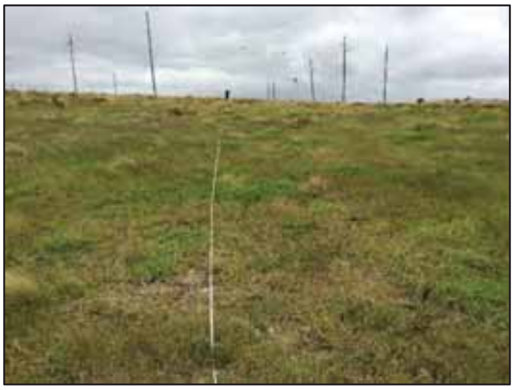
Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	90	10	80	9
10m	80	20	30	11
15m	100	0	90	8
20m	100	0	100	7
25m	100	0	100	7
30m	90	10	100	8
35m	100	0	100	4
40m	100	0	100	5
45m	80	20	80	2
50m	90	10	100	4
Average	93	7	88	7

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWNPN2014-0 (left to right)

Start position

End position



MTWNPN2013-01

MTWNPN2013-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	318046	6391550
End transect	317995	6391518

Description:

MTWNPN2013-01 rehabilitation area occurs on a comination of topsoil and compost at Mount Thorley-Warkworth. The rehabilitation site includes the following native species: *Chloris truncata, Chloris ventricosa, Cynodon dactylon, Acacia amblygona, Acacia decora* and *Wahlenbergia stricta.* Herbaceous weeds including *Bidens pilosa, Conyza bonariensis, Lepidium spp. Solanum nigrum* and *Verbena bonariensis* were recorded in the monitoring plot.

Disturbance:

Disturbance present at rehabilitation site MTWNPN2013-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWNPN2013-01 has an average 76 percent Protective cover. The percentage of weeds occupy an average of 74 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from two to four species. The average number of species per 1 x 1 metre plot is three species.

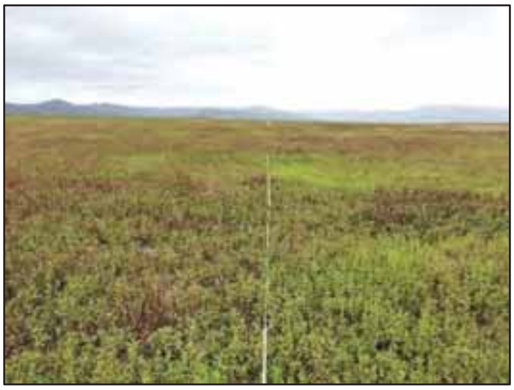
Table. Ground cover assessment percentage cover at MTWNPN2013-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	70	30	80	4
10m	60	40	80	2
15m	100	0	80	2
20m	80	20	80	2
25m	90	10	90	3
30m	50	50	50	3
35m	50	50	50	4
40m	80	20	70	2
45m	90	10	70	2
50m	90	10	90	2
Average	76	24	74	2.6

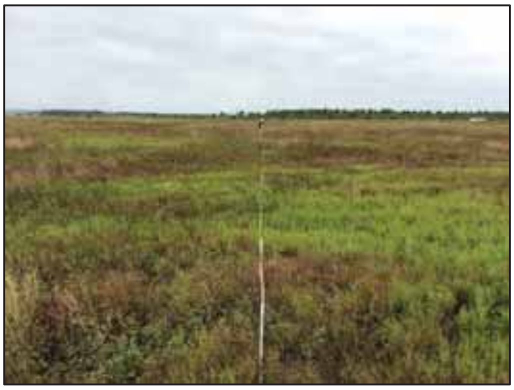
*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWNPN2013-01 (left to right)

Start position


End position


MTWWDL2014-01

MTWWDL2014-01	**MGA 84 Zone 56**	
Position	**Easting**	**Northing**
Start transect:	319804	6388507
End transect	319849	6388525

Description:

MTWWDL2014-01 rehabilitation area occurs on a comination of topsoil and compost at Mount Thorley-Warkworth. The rehabilitation site included a number of regenerating species such as *Acacia amblygona, A. falciformis, Acacia (bipinate), Enchaleana tomentosa, Hardenbergia violacea, Indigofera australis*, *Chloris truncata* and *Bothriochloa macra*. Introduced species included *Conyza bonariensis, Digitaria sanguinalis*, *Eriochloa pseudoastritrica, Echinochloa crus-gali* and *Chloris gayana.*

Disturbance:

Disturbance present at rehabilitation site MTWWDL2014-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWWDL2014-01 has 71 percent Protective cover, of which most can be attributed to rock and stone throughout the site. The percentage of weed occupied 73 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from four to seven species, with an average of five species.

Table. Ground cover assessment percentage cover at MTWWDL2014-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	70	30	100	4
10m	60	40	100	4
15m	100	0	50	6
20m	50	50	40	4
25m	80	20	70	5
30m	90	10	90	5
35m	70	30	80	7
40m	70	30	40	8
45m	30	70	90	5
50m	90	10	70	5
Average	71	29	73	5

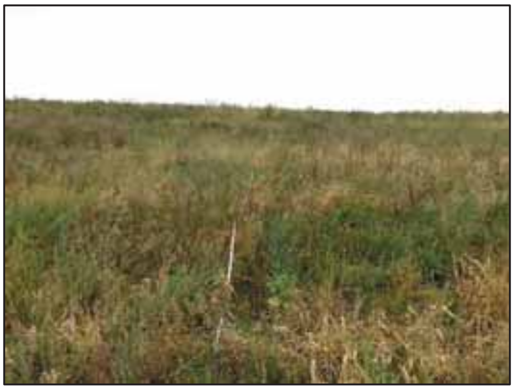
*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWWDL2014-01 (left to right)

Start position



End position


MTWWDL2014-02

MTWWDL2014-02	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	319636	6388357
End transect	319624	6388309

Description:

MTWWDL2014-02 rehabilitation area occurs on a comination of topsoil and compost at Mount Thorley-Warkworth. The rehabilitation site includes the following introduced species: Chloris gayana, Panicum maximum, *Eriochloa pseudoastritrica* and *Echinochloa crus-galli.* Herbaceous weeds including *Conyza bonariensis* and *Portulaca oleracea* were recorded in the monitoring plot.

Disturbance:

Disturbance present at rehabilitation site MTWWDL2014-02 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWWDL2014-02 has an average 74 percent Protective cover. The percentage of weeds occupy an average of 51 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from two to five species. The average number of species per 1 x 1 metre plot is three species.

Table. Ground cover assessment percentage cover at MTWWDL2014-02

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	70	30	40	3
10m	80	20	20	3
15m	80	20	30	3
20m	70	30	40	2
25m	60	40	50	4
30m	70	30	80	3
35m	70	30	80	2
40m	80	20	70	5
45m	80	20	60	4
50m	80	20	40	3
Average	74	26	51	3

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWWDL2014-02 (left to right)

Start position



End position



MTWCDD2015-01

MTWCDD2015-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	319049	6390074
End transect	319081	6390034

Description:

MTWCDD2015-01 rehabilitation area occurs on a comination of spoil and compost at Mount Thorley-Warkworth. The rehabilitation site was dominanted by the following introduced species: *Conyza bonariensis*, *Chloris gayana*, *Echinochloa crus-gali*, *Senecio madagascariensis*, *Solanum nigrum* and *Panicum maximum.* Native species included *Eriochloa pseudoastritrica*, *Austrodanthonia spp.*, *Einadia nutans*, *Austrostipa scabra*, *Bothriochloa macra* and *Chloris truncata.*

It should be noted that a number of Eucalypts were regenerating in the area. Most of these are likely *Eucalyptus crebra* due to their narrow leaves.

Disturbance:

Disturbance present at rehabilitation site MTWCDD2015-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWCDD2015-01 has an average of 56 percent Protective cover. The percentage of weed occupied an average of 9 percent of the Protective cover. The remainder of the Protective cover generally consists of rocks. The number of species recorded in each of the 1 x 1 metre plots ranged from one to four species. The average number of species within a 1 x 1 plot is 2 species.

Table. Ground cover assessment percentage cover at MTWCDD2015-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	40	60	0	2
10m	60	40	10	3
15m	60	40	10	1
20m	60	40	10	4
25m	60	40	10	2
30m	60	40	10	2
35m	40	60	10	3
40m	60	40	10	3
45m	60	40	10	1
50m	60	40	10	2
Average	56	44	9	2.3

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWCDD2015-01 (left to right)

Start position



End position



MTWCDD2013-01

MTWCDD2013-01	MGA 84 Zone 56	
Position	**Easting**	**Northing**
Start transect:	319516	6390165
End transect	319535	6390212

Description:

MTWCDD2013-01 rehabilitation area occurs on topsoil at Mount Thorley-Warkworth. The rehabilitation site was dominanted by the following introduced species: *Chloris gayana, Echinochloa crus-gali, Senecio madagascariensis* and *Panicum maximum.*

Disturbance:

Disturbance present at rehabilitation site MTWCDD2013-01 consisted mainly of weeds, and grazing by macropods. No evidence of fire was observed in the rehabilitation area. No areas containing rubbish were observed.

Ground cover assessment:

MTWCDD2013-01 has an average of 98 percent Protective cover. The percentage of weed occupied an average of 97 percent of the Protective cover. The number of species recorded in each of the 1 x 1 metre plots ranged from one to two species. The average number of species within a 1 x 1 plot is one species.

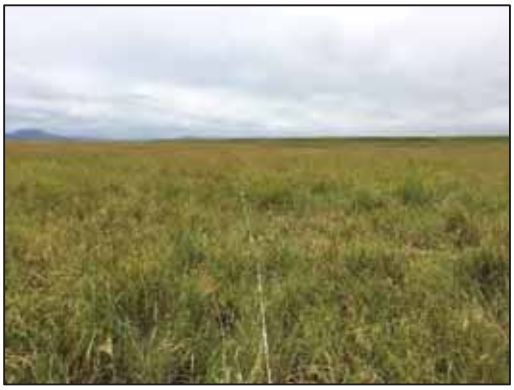
Table. Ground cover assessment percentage cover at MTWCDD2013-01

Transect	% Protective cover*	% Bare	% Weeds	Number of species
5m	90	10	100	1
10m	90	10	100	1
15m	100	0	70	1
20m	100	0	100	1
25m	100	0	100	2
30m	100	0	100	1
35m	100	0	100	1
40m	100	0	100	1
45m	100	0	100	1
50m	100	0	100	1
Average	98	2	97	1.1

*Protective cover includes dead and live vegetation, rocks, litter and logs

Site photographs at MTWCDD2013-01 (left to right)

Start position


End position



Appendix 5 –SESL report

SESL AUSTRALIA
Environment & Soil Sciences

Mount Thorley Warkworth & Hunter Valley Operations

Rehabilitation sites soil analysis and interpretation

Prepared for:

Niche Environment and Heritage

March 2016

(Report: C8738.B38017.Q5236 FA)

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APPENDICES

INTRODUCTION

SESL Australia (SESL) was engaged by Niche Environment and Heritage (the client) to provide soil analysis and interpretation services for the Mount Thorley Warkworth (MTW) and Hunter Valley Operations (HVO) mine sites. The project involves revegetation by recreating woodland community and native pasture ecosystems.

The site has established 12 reference sites which are native vegetation communities and relatively undisturbed. The other sites are on mined land, which have been rehabilitated using one of the five different soil treatments listed below:

1. Subsoil / compost
2. Topsoil / compost
3. Topsoil
4. Spoil / compost
5. Fresh sand topsoil / compost

Table 1 below provides a summary of sample names, numbers, treatment and revegetation goals.

Samples were collected by the client and delivered to the SESL laboratory in February 2016. All samples were analysed for pH, salinity, cations, plant available nutrients, organic matter, and texture. Thirty-one samples were also analysed for microbiology including total microorganisms, total bacteria, total fungi, pseudomonas, actinomycetes, gram positive and gram negative bacteria, methane oxidisers, sulphur reducers, anaerobes, protozoa, mycorrhizal fungi and fungi:bacteria ratio.

Table 1 Summary of sample names, numbers, treatments and revegetation goals

Sample #	Site	Sample Name	Treatment	Revegetation Goal
8	Reference	Bell 1	-	-
9	Reference	Bell 2	-	-
20	Reference	Bell 3	-	-
21	Reference	GBREF 3	-	-
22	Reference	GBREF 4	-	-
23	Reference	GBREF 6	-	-
24	Reference	WAMBOGB 01	-	-
25	Reference	WAMBOGB 02	-	-
26	Reference	WAMBOSPOT 1	-	-
27	Reference	WAMBOSPOT 2	-	-
28	Reference	WAMBOSPOT 3	-	-
29	Reference	REF 05	-	-
1	HVO	HVORIV201401	Riverview RL145, spoil/compost, drilled	Pasture/ Light Wooded

Sample #	Site	Sample Name	Treatment	Revegetation Goal
3	HVO	HVORIV201403	Riverview RL155, spoil/compost, drilled	Pasture/ Light Wooded
2	HVO	HVORIV201402	Riverview RL145, subsoil/compost, drilled	Pasture/ Light Wooded
4	HVO	HVORIV201404	Riverview RL155, subsoil/compost, drilled	Pasture/ Light Wooded
5	HVO	HVORIV201405	Riverview RL155, subsoil/compost, drilled	Pasture/ Light Wooded
6	HVO	HVORIV201406	Riverview Ampitheatre, topsoil/compost, natives not sown	Pasture/ Light Wooded
7	HVO	HVORIV201301	Riverview RL145, topsoil/compost, natives not sown	Pasture/ Light Wooded
10	HVO	HVOCHE201301	Cheshunt Rim, topsoil/compost, natives not sown	Woodland
11	HVO	HVOCHE 201201	Cheshunt Rim, topsoil/compost, drilled	Woodland
30	HVO	HVOCAR201401	Carrington, topsoil/compost, natives not sown	Woodland
42	HVO	HVOWES2013-02	Wilton dumps, topsoil/compost, natives not sown	Woodland
43	HVO	HVOCHES2012-03	Cheshunt Rim, topsoil/compost, natives not sown	Woodland
44	HVO	HVOCHE2014-01	Cheshunt Helipad, topsoil/compost, natives not sown	Woodland
39	HVO	HVOWES2008-01	Wilton dumps, topsoil	Woodland
45	HVO	HVOCAR200901	Carrington Western TSF Cell A, topsoil	Woodland
46	HVO	HVOCAR200902	Carrington, topsoil	Woodland
40	HVO	HVOWES2011-01	Dam 6W, spoil/compost, hydroseeded.	Woodland
41	HVO	HVOCHE2013-01	Wilton dumps, spoil/compost, drilled	Woodland
12	MTW	MTWCDD201101	CD RL160 2011, topsoil, native seed hydroseeded	Woodland
15	MTW	MTWWDL201401	Woodlands N Slope 2014, topsoil/compost, natives drilled 2015	Woodland
32	MTW	MTWCDD201301	CD RL160 2013, topsoil/compost, natives not sown	Woodland
35	MTW	MTWNPN200901	Swanlake 2009, topsoil, old seed mix	Woodland
48	MTW	MTWMTO200503	MTO South Dump 2005, topsoil	Woodland
13	MTW	MTWCDD201501	CD RL160 2015, spoil/compost, natives drilled	Woodland
14	MTW	MTWTDI201501	TD1, spoil/compost, native seed drilled 2015	Woodland
16	MTW	MTWNPN201403	NPN 2014, subsoil/compost,	Woodland

Sample #	Site	Sample Name	Treatment	Revegetation Goal
			natives drilled 2014	
17	MTW	MTWNPN201301	NPN 2013, topsoil/compost, natives drilled Winter 2015	Woodland
18	MTW	MTWNPN201101	NPN 2011, topsoil, natives hydroseeded 2011	Woodland
31	MTW	MTWSPN201401	SPN 2014, topsoil/compost, natives not sown	Woodland
33	MTW	MTWWDL201402	Woodlands S Slope 2014, topsoil/compost, natives not sown	Woodland
36	MTW	MTWNPN201401	NPN 2014, topsoil/compost, natives drilled 2014	Woodland
19	MTW	MTWNPN200501	NPN 2005, topsoil	Pasture/ Light Wooded
34	MTW	MTWNPN200502	NPN 2005, topsoil	Pasture/ Light Wooded
47	MTW	MTWTO200001	MTO North Dump 2000, topsoil	Pasture/ Light Wooded
37	MTW	MTWNPN201402	NPN 2014, fresh sand topsoil/compost, natives drilled 2014	Woodland

Notes: sample 10 renamed to HVOCHE 201301, and soil/compost treatment
Sample 38 deleted – not part of this project

Objective

This report discusses the soil properties at each site under different treatments, and compares the results to the reference sites. It also compares the soil in the reference sites under two different vegetation communities.

1 RESULTS

Table A in Appendix A provides data for each site, and includes maximum, minimum and average values for each treatment. The minimum to maximum values are called the 'range', and this section compares the values for the various soil treatments to the reference site ranges.

The reference sites have variable soil chemistry. pH range is acidic ranging from 5.4 to 6.6 in water, and the ECEC from 5.2 to 17.9. Lower ECEC is a feature of sandier soils, as they have less of an ability to retain cations. None of the samples are saline, with the maximum ECe 1.7 dS/m which is considered non-saline. One sample is sodic (ESP >6%), while the rest of the samples and the average are not sodic. Exchangeable hydrogen levels are highly variable ranging from 0 (for five samples) up to 59%, and reflects the variability in soil pH – exchangeable hydrogen levels increase as pH decreases. Organic matter levels range from 2.8 to 9.3%. Compared to a balanced agricultural soil, average cations are low in exchangeable calcium, and high in exchangeable magnesium. However, if this soil is 'natural' for the environment, the revegetation species tolerate high levels of exchangeable hydrogen (stemming from a more acidic pH) and magnesium, and lower levels of exchangeable calcium.

The sites have good levels of microorganisms in total, however microbial diversity is below the ideal range set by Microbial Laboratories Australia. This simply indicates the reference sites naturally have high levels of only a few species of microorganisms.

Table 2 below presents a summary of key chemical parameters for the reference sites and each treatment. Table 3 presents a summary of microbial results.

Table 2 Summary of key parameters between sites

Treatment		pH (H_2O)	pH ($CaCl_2$)	ECe (dS/m)	ECEC (meq)	Ca (%)	Mg (%)	K (%)	Na (%)	H (%)	OM (%)
Reference Sites	Average	**5.9**	**5.2**	**0.7**	**12.3**	**37.3**	**24.3**	**3.8**	**2.7**	**31.4**	**5.1**
	Max	**6.6**	**6.1**	**1.7**	**17.9**	**73.7**	**46.7**	**7.1**	**8.7**	**58.8**	**9.3**
	Min	**5.4**	**4.6**	**0.4**	**5.2**	**14.9**	**11.8**	**2.4**	**0.2**	**0.0**	**2.8**
1 Subsoil/ Compost	Average	8.4	7.8	1.9	19.8	63.5	27.3	4.4	5.0	0.0	5.4
	Max	9.1	8.2	2.7	27.1	70.9	38.7	6.6	8.5	0.0	6.1
	Min	7.6	7.3	1.0	13.4	50.7	19.7	2.3	1.3	0.0	4.8
2 Topsoil/ Compost	Average	7.8	7.3	1.5	16.2	63.7	28.6	3.9	3.7	0.0	4.7
	Max	8.6	7.8	2.8	23.2	75.3	37.9	4.6	10.0	0.0	8.7
	Min	6.9	6.6	0.6	8.9	48.5	18.7	3.4	0.4	0.0	3.0
3 Topsoil	Average	7.3	6.9	1.2	11.5	50.0	41.3	4.6	4.3	0.0	3.6
	Max	7.9	7.5	3.2	15.9	61.1	53.6	6.8	9.6	0.0	6.1
	Min	6.6	6.2	0.6	1.9	35.7	29.4	2.2	1.0	0.0	1.5
4 Spoil/ Compost	Average	8.7	8.0	2.2	20.5	49.6	36.2	3.1	11.2	0.0	4.4
	Maximum	9.6	8.7	4.2	28.1	70.3	49.1	4.2	43.6	0.0	8.3
	Minimum	8.0	7.6	1.3	14.8	24.1	24.5	2.1	2.1	0.0	2.1
5 Fresh Sand Topsoil/ Compost		6.7	6.1	0.7	3.9	79.7	14.9	3.8	0.5	0.0	3.1

Note: there is only one data point for treatment 5, hence no maximum or minimum values are available

			Bacteria							Eukaryotes, mg/Kg		
Total microorganisms mg/kg	Total bacteria mg/kg	Total fungi mg/kg	Pseudomonas mg/kg	Actinomycetes mg/kg	Gram positive mg/kg	Gram negative mg/kg	Methane oxidisers mg/kg	Sulphur reducers mg/kg	True anaerobes mg/kg	Protozoa mg/kg	Mycorrhizal fungi mg/kg	Microbial diversity
50	*15*	*33.8*	*1*	*1*	*4*	*11*	*0.5*	*<0.005*	*<0.005*	*1.25*	*10*	*8*
73.24	22.12	49.47	1.57	5.11	8.55	13.56	0.03	0.00	0.16	1.65	6.63	53.1
108.36	33.32	74.74	3.55	8.29	11.90	21.41	0.31	0.00	0.30	3.57	22.57	56.6
32.74	9.35	22.89	0.51	2.08	4.00	5.35	0.00	0.00	0.00	0.51	1.42	43.2
106.31	13.35	89.41	2.07	2.00	5.18	8.17	0.00	0.00	0.15	3.55	14.44	40.1
172.25	24.58	141.24	3.38	4.07	9.58	15.00	0.00	0.00	0.38	6.42	27.04	47.4
52.19	6.00	44.62	1.05	0.74	2.36	3.64	0.00	0.00	0.04	1.57	7.36	36.7
95.13	14.96	77.74	2.04	2.54	5.86	9.10	0.00	0.00	0.09	2.43	12.81	46.9
196.05	24.56	168.48	4.00	3.38	9.28	15.28	0.00	0.00	0.27	3.50	16.19	54.3
50.86	10.21	38.11	0.94	2.05	3.80	6.41	0.00	0.00	0.03	1.80	6.98	36.8
105.32	19.14	83.41	2.01	3.97	7.75	11.39	0.00	0.00	0.22	2.77	11.86	48.2
152.83	24.82	125.34	2.75	4.27	9.84	14.98	0.00	0.00	0.53	4.15	15.42	55.1
62.83	14.29	47.05	1.56	3.37	5.91	8.38	0.00	0.00	0.04	1.49	8.70	44.1
55.33	8.58	45.66	1.13	1.04	3.68	4.90	0.00	0.00	0.18	1.09	4.92	44.0
89.11	12.32	73.93	1.76	1.42	5.36	6.97	0.00	0.00	0.49	2.87	7.15	52.7
29.07	4.76	24.31	0.71	0.68	1.90	2.86	0.00	0.00	0.00	0.00	2.78	37.9

s undertaken on the treatment 5 sample.

d by Microbiology Laboratories Australia.

negative bacteria that are decomposers.

ria that grow hyphae like fungi. They are decomposers.

ethane as a fuel source. They can be either anaerobic or aerobic.

sulphur to hydrogen sulphide, and are active in anaerobic conditions.

e in anaerobic conditions.

organisms that feed on bacteria. They play a role in nutrient cycling.

e plant roots and can act as root extensions to access water and nutrients, and protect plant roots from predators and disease.

Treatment 1 Subsoil / compost

Texture ranges from a sandy clay loam to a clay loam. The pH is alkaline ranging from 7.6 to 9.1 in water. Although all electrical conductivity (E.C.) values are above the reference sites maximum, the soil is not saline. The Effective Cation Exchange Capacity (ECEC) indicates a good nutrient holding capacity. Two samples have an Exchangeable Sodium Percentage (ESP) >6%, while two do not, and the soil is on average not sodic. For a soil to be considered sodic the ESP must be greater than 6%. Organic matter levels range from 4.8 – 6.1% and are considered good. Average microbial numbers generally exceed the guidelines except for total bacteria, gram negative bacteria and microbial diversity.

Compared to the reference sites, this treatment has a much higher pH. Salinity levels are higher however the soil is not considered saline. Exchangeable calcium (Ca), magnesium (Mg), sodium (Na) and hydrogen (H) fall within the reference range, however on average Ca, Mg, potassium (K) and Na are higher than the reference average. The ability to retain nutrients is higher. Except for nitrate (NO3) and iron (Fe), average plant available nutrient levels are higher than the reference site. Nitrate, iron and manganese (Mn) values fall within the reference value ranges. All phosphorus (P), calcium, boron (B), copper (Cu) and zinc (Zn) values are above the reference maximum. Potassium, magnesium, sulphate (SO4), and sodium results are within and above the reference range. Organic matter (%) average is similar and all results fall within the reference sites range.

Pseudomonas, methane oxidisers and sulphur reducers fall within the reference sites range. Numbers of actinomycetes, and microbial diversity are mostly below the reference minimum, while total fungi and fungi:bacteria ratio are above the reference maximum. Total microorganisms, total bacterial, gram positive and gram negative bacteria, true anaerobes and mycorrhizal fungi are all have one data point either above the reference maximum or below the reference minimum (see Table C, Appendix A).

Treatment 2 Topsoil / compost

Soil textures range from sandy clay loam to sandy clay. The pH is neutral to alkaline ranging from 6.9 – 8.6 in water. The soil is, on average, not saline although three samples would be considered to have very slight salinity from an agricultural perspective. The ECEC indicates a good nutrient holding capacity. One sample has an ESP > 6% and is considered sodic, however on average the soil is not sodic. Organic matter levels range from 3.0 – 8.7% and are considered good. Average microbial numbers generally exceed the guidelines except for gram negative bacteria and microbial diversity.

Compared to the reference sites, this treatment has a higher pH. Salinity (ECe) values fall within the reference range, with five samples above the reference maximum. Overall the soil is not saline. The

ECEC (ability to retain nutrients) is on average higher, with some values within the reference range and some above it. All exchangeable magnesium, potassium, and hydrogen values fall within the reference range. Most exchangeable sodium and calcium levels fall within the reference range. Apart from nitrate, with all values falling within the reference range, all other plant available nutrients are on average higher than the reference average. Except for one value, magnesium, sodium, iron and manganese fall within the reference range. Most phosphate, calcium, sulphate, boron, copper, and zinc values are above the reference maximum. All organic matter values fall within the reference range.

Total bacteria, gram negative bacteria, methane oxidisers, sulphur reducers, true anaerobes, protozoa, and mycorrhizal fungi fall within the reference sites range. Total microorganisms, total fungi, and pseudomonas have values within the reference range and above the reference maximum. Actinomycetes, gram positive bacteria, and microbial diversity have values within and below the reference range. The fungi:bacteria ratio values range from below the reference minimum to above the reference maximum.

Treatment 3 Topsoil

Soil textures range from sandy clay loam to light clay. The pH is slightly acidic to alkaline, ranging from 6.6 to 7.9 in water. The soil is on average not saline. The ECEC indicates an average ability to retain nutrients. One sample has an ESP > 6% and is considered sodic, and on average the soil is not sodic. Organic matter levels range from 1.5 – 6.1% and are considered good. Average microbial numbers generally exceed the guidelines except microbial diversity.

Compared to the reference sites, this treatment has a higher pH, and higher average salinity however most values fall within the reference range and the soil is not considered saline. The ECEC is similar with all but one value falling within the reference range. All exchangeable calcium and hydrogen values fall within the reference range. Exchangeable magnesium, sodium and potassium are mostly within the reference range, with three Mg and one Na value above the reference maximum, and one K value below the reference minimum. All nitrate, phosphate, potassium, calcium, magnesium, sulphate, sodium, and boron values fall within the reference range. All copper levels are above the reference maximum. Iron, manganese and zinc are generally within the reference range. All organic matter values fall within the reference range.

Total fungi, pseudomonas, methane oxidisers and sulphur reducers fall within the reference sites range. Total microorganisms, total bacteria, gram positive and gram negative bacteria, protozoa and microbial diversity have values within and below the reference range. All actinomycetes values are below the reference minimum. The fungi: bacteria ratio ranges from within the reference range to above the reference maximum.

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Treatment 4 Spoil / compost

Soil texture ranges from clay loam to light clay. The pH is very alkaline, ranging from 8.0 – 9.6 in water. The soil is on average very slightly saline. The ECEC indicates an excellent ability to retain nutrients. Two samples have an ESP > 6% and are considered highly sodic. The rest of the samples are not sodic. Organic matter levels range from 2.1 – 8.3%. Average microbial numbers are variable - total bacteria, gram positive and gram negative bacteria, protozoa, mycorrhizal fungi, and microbial diversity are below the guidelines. Total microorganisms, total fungi, pseudomonas, actinomycetes, and fungi:bacteria ratio are above the guidelines.

Compared to the reference sites, this treatment has a significantly higher pH. Salinity levels are higher and on average are considered very slightly saline. Two sites are causing this reading, with the remaining four sites considered not-saline. All exchangeable calcium and hydrogen values fall within the reference range. Exchangeable magnesium, sodium and potassium are mostly within the reference range, with two Mg and two Na values above the reference maximum, and one K value below the reference minimum. On average all plant available nutrients except for nitrate, iron and manganese are above the reference average. All phosphorus, sulphate, copper and zinc levels are above the reference maximum. Most nitrate, potassium, sodium and manganese values fall within the reference range, with one nitrate and two manganese results below the reference minimum, and one potassium and two sodium values above the reference maximum. All organic matter values except one fall within the reference range.

Total bacteria, pseudomonas, actinomycetes, gram positive and gram negative bacteria, methane oxidisers, sulphur reducers, mycorrhizal fungi, and microbial diversity fall within the reference sites range. Total microorganisms, total fungi, true anaerobes, and protozoa have values within the reference range and above the reference maximum. The fungi:bacteria ratio values range from below the reference minimum to above the reference maximum.

Treatment 5 Fresh sand topsoil / compost

There was only one soil sample taken for treatment five. This sandy soil has a slightly acidic pH, and is not saline. The ECEC is very low indicating a poor ability to retain nutrients. This is to be expected from a sand. The soil is not sodic. Organic matter is 3.1% which is considered moderate.

Compared to the reference sites, this soil has a similar pH and salinity level. The ECEC is lower. All exchangeable cations fall within the reference range. Nitrate, phosphorus, potassium, calcium, boron, copper, manganese and zinc fall within the reference range. Magnesium, sulphate, sodium, and iron are below the reference minimum. Organic matter levels are within the reference range.

Microbial analysis was not conducted on the treatment 5 sample.

Vegetation Communities

Selected soil characteristics of the Central Hunter Ironbark/Spotted Gum/Grey-box forest, and the Central Hunter Grey-box/Ironbark woodland are compared in Table 4 below. All data is presented in Table B, Appendix A.

Table 4 Soil characteristics of different reference site vegetation communities

Vege-tation	Sample Name	Texture	pH (H_2O)	pH $CaCl_2$	Ece (dS/m)	ECEC (Meq)	Ca (%)	Mg (%)	K (%)	Na (%)	H (%)	OM (%)
Central Hunter Ironbark-Spotted Gum-Grey Box Forest	Bell 1	Loam Fine Sandy	5.6	4.64	0.5	12.0	15.2	21.6	3.3	2.1	55.8	6.4
	Bell 2	Loam Fine Sandy	6.3	5.72	0.7	10.3	73.7	20.8	3.8	1.5	0	7.1
	Bell 3	Loam Fine Sandy	5.9	5.03	0.7	17.0	31.2	22.4	2.6	2.9	40.2	9.3
	WAMBO SPOT 1	Sandy Loam	5.9	5.08	0.6	10.7	38.4	11.8	3.3	0.2	46.5	4.6
	WAMBO SPOT 2	Clay Loam	6.6	5.6	1	17.9	47	40.6	3.6	8.7	0	4.9
	WAMBO SPOT 3	Sandy Loam	6.3	5.52	0.4	5.2	64.8	27.3	7.1	0.6	0	2.8
		AVERAGE	**6.10**	**5.27**	**0.65**	**12.2**	**45.1**	**24.1**	**3.9**	**2.7**	**23.8**	**5.9**
		MAX	**6.60**	**5.72**	**1.00**	**17.9**	**73.7**	**40.6**	**7.1**	**8.7**	**55.8**	**9.3**
		MIN	**5.60**	**4.64**	**0.40**	**5.2**	**15.2**	**11.8**	**2.6**	**0.2**	**0.0**	**2.8**
Central Hunter Grey Box-Ironbark Woodland	GBREF 3	Fine Sandy Clay Loam	5.7	5.06	0.4	15.6	43.1	16	3.7	1	36	6.8
	GBREF 4	Light Sandy Clay Loam	5.4	4.6	0.4	8.7	20.8	16	3.8	1.7	56.7	2.9
	GBREF 6	Sandy Clay Loam	5.7	5.14	0.6	13.2	23.4	25	2.4	2	47.1	3.9
	WAMBO GB 01	Clay Loam	5.9	5.22	0.4	15.7	30.7	27.5	3.5	2.3	35.8	4.6
	WAMBO GB 02	Clay Loam	6.6	6.06	0.5	14.2	44.9	46.7	5.6	3.2	0	5.3
	REF 05	Sandy Loam	5.4	4.72	1.7	7.4	14.9	15.6	3.2	6.6	58.8	2.8
		AVERAGE	**5.78**	**5.13**	**0.67**	**12.47**	**29.6**	**24.5**	**3.7**	**2.8**	**39.1**	**4.4**
		MAX	**6.60**	**6.06**	**1.70**	**15.70**	**44.9**	**46.7**	**5.6**	**6.6**	**58.8**	**6.8**
		MIN	**5.40**	**4.60**	**0.40**	**7.40**	**14.9**	**15.6**	**2.4**	**1.0**	**0.0**	**2.8**

The Ironbark-spotted gum-grey box forest has an acidic ph. The soil is not saline. The ECEC suggests an average ability to retain nutrients. Exchangeable cations, particularly calcium, are highly variable. Organic matter levels are also highly variable, ranging from 2.8 – 9.3%.

The Grey box-ironbark woodland has an acidic pH. The soil is not saline. The ECEC suggests an average ability to retain nutrients. Exchangeable cations, particularly calcium, are highly variable. Organic matter levels are also highly variable, ranging from 2.8 – 6.8%.

2 DISCUSSION

Treatments

The various soil treatments have produced growth mediums with different soil properties compared to the reference sites. The following conclusions have been drawn by comparing the average, maximum and minimum soil chemical data from treatments 1 – 5, with the average, maximum and minimum reference sites data. Neither target plant species nor site (MTW vs HVO) have been included in this assessment. Table 1 provides a summary of the average, maximum and minimum values per treatment. Table 3 provides microbial data. Tables A and C in Appendix A present all the data.

Treatment 1 subsoil / compost, has higher pH, ECEC, and salinity levels than the reference sites. Nitrogen, iron and manganese values are within the reference range, and all other plant available nutrients have increased compared to the reference data. Phosphorus levels are significantly higher than the reference average and range. Organic matter levels fall within the reference range. Microbes are variable, ranging from below the reference minimum to above the reference maximum.

Treatment 2 topsoil/compost, has higher pH, ECEC, salinity, and on average all plant available nutrient levels except for nitrate. Phosphorus levels are significantly higher than the reference average and range. Organic matter levels fall within the reference range. Microbes are variable, ranging from below the reference minimum to above the reference maximum, however in general results are within the reference range.

Treatment 3 topsoil, has slightly higher pH and salinity, however the soil is not considered saline. On average, all plant available nutrients except iron and manganese have increased. Phosphorus levels are on average slightly higher than the reference average. Organic matter results are on average lower but all fall within the reference range. Microbial results are general within or above the reference range.

Treatment 4 spoil / compost, has significantly higher pH and salinity compared to the reference sites. The ECEC in this treatment is greater than the other treatments. On average this treatment is sodic (ESP>6%), however this is caused by one result of 12%, and a second of 44%. This result suggests highly variable sodium content in the mine spoils that have been used on each of these rehabilitation sites. Phosphorus levels are significantly higher than the reference average and range. Organic matter levels fall within the reference range. Microbial results are generally within or below the reference range.

Treatment 5 fresh sand topsoil / compost, has lower OM and nutrients levels than the other treatments. The ECEC is lower, and salinity levels are the same as the reference sites. The one site sampled has high exchangeable calcium levels however having only one sample makes it difficult to determine trends. The available phosphorus level is higher than the reference average but still suitable for moderately P sensitive species. Organic matter % is the lowest of all the treatments, but still falls within the reference site range. No microbial data is available.

Comparing the reference site averages to the various treatments, it is clear the treatments substituting spoil and subsoil for topsoil as the growth medium are resulting in growth mediums with increased pH and salinity. Based on advice provided by the Client, the virgin (pre-ameliorant) spoil and subsoil material used on the rehabilitation sites typically ranges in pH from 8.4 – 10 and 6.6 – 9.6 respectively; and the compost from 5.5 – 8.5. The highly alkaline nature of the spoil is reflected in the treatment 4 results which have the highest pH of all the treatments. The source spoil and subsoil material is likely to be the main cause of the observed increase in pH, however the compost may also be causing an increase in pH. This effect is seen in the higher pH levels observed between the Treatment 2 results for topsoil/compost plots compared to the treatment 3 samples taken from topsoil areas without compost applied to them.

Given that the subsoils, associated with the duplex soils that are common on the site (information from Client), are alkaline and plant roots are accessing these subsoils, it is therefore likely that the vegetation communities tolerate this high pH. The spoil appears to have variable levels of exchangeable sodium, causing extreme sodicity in one sample, and moderate sodicity in a second.

Although salinity levels have increased, the treatments are still not-saline or only very slightly saline.

Plant available nutrients have increased in treatments 1, 2 and 4, and is likely caused by the compost additions. Compost contains many plant available nutrients which become more available as the compost breaks down. Nutrients are generally within the reference range in treatment 3, and are within the range / declining in treatment 5. Treatments 1, 2 and 4 have also significantly increased available phosphorus levels. It is expected that over time the topsoil will acidify as calcium and other base cations are removed, and the will P become less available.

Microbial diversity is generally within the reference range, except for treatment 4 where results are within or below the reference range. The lack of sulphur reducers and anaerobes indicate the treatments aren't causing anaerobic conditions.

Vegetation communities

The soils taken from reference sites within the Central Hunter Ironbark/Spotted Gum/Grey-box forest and the Central Hunter Grey-box/Ironbark woodland are very similar. Notable differences lie in exchangeable calcium levels, with the Ironbark/Spotted Gum/Grey-box forest having more variable levels. Nitrate, sodium, manganese and organic matter levels in the Ironbark/Spotted Gum/Grey-box forest are more variable, potassium in the Grey-box/Ironbark woodland are more variable, while phosphorus, calcium, magnesium, sulphate, boron, copper, iron and zinc have similar averages and ranges. The soil microbes have similar ranges and averages between the two communities.

Overall the soils in the two communities are similar.

3 Conclusions

The reference vegetation is growing in soils that are generally acidic, not saline, and have highly variable cation balance and plant available nutrient levels. Soil biology in the reference sites is on average above the guideline values, except for microbial diversity and mycorrhizal fungi. The soil in the two reference site vegetation communities is similar.

Based on this analysis, treatment 3 (topsoil) is producing soil most similar to the reference site range. Treatment 5 (sand topsoil / compost) has caused a general decline in soil fertility. Treatments 1, 2, and 4 have produced growth mediums with increased pH and nutrient levels, with most values above the reference maximums. Treatment 4 has also caused a general decline in microbial numbers. The spoil and subsoil are alkaline, causing the increase in pH. The compost is likely to be variable, and could be occasionally alkaline and contributing to the rise in pH.

The duplex soils at HVO and MTW tend to have acidic topsoils overlaying alkaline subsoils (Bill Baxter pers comms). Given that the vegetation communities have roots accessing the subsoil zones, it is likely that the plants making up these communities are tolerant of alkaline conditions. The increase in pH caused by the use of spoils and subsoils in rehabilitation areas may therefore be less of a concern. It is recommended however that the relationship between the pH of growth mediums and the level of establishment of the desired vegetation continue to be monitored. This monitoring will be important to determine if the use of spoils and subsoils should continue or alternative growth mediums used that more closely mimic the natural site soil pH levels.

Please do not hesitate to contact our office if you have any questions.

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Appendix A
Laboratory Results

Bell 1	Loam Fine Sandy	5.6	4.64	0.05	0.5	12	15.2	21.6	3.3	2.1	55.8	8.82	8.3	156	365	315	10	57.6	0.1	0.64	293
Bell 2	Loam Fine Sandy	6.3	5.72	0.07	0.7	10.3	73.7	20.8	3.8	1.5	0	18	6.4	152	1522	260	11	34.9	0.4	0.64	198
Bell 3	Loam Fine Sandy	5.9	5.03	0.07	0.7	17	31.2	22.4	2.6	2.9	40.2	6.93	6.4	170	1064	463	11	116	0.3	0.64	257
GBREF 3	Fine Sandy Clay Loam	5.7	5.06	0.05	0.4	15.6	43.1	16	3.7	1	36	3.51	10	226	1346	303	14	34.1	0.2	0.6	196
GBREF 4	Light Sandy Clay Loam	5.4	4.6	0.04	0.4	8.7	20.8	16	3.8	1.7	56.7	1.96	6.8	130	363	169	11	33.7	0.1	0.64	254
GBREF 6	Sandy Clay Loam	5.7	5.14	0.06	0.6	13.2	23.4	25	2.4	2	47.1	1.4	13.2	125	619	401	11	62.9	0.1	0.64	241
WAMBOG B 01	Clay Loam	5.9	5.22	0.05	0.4	15.7	30.7	27.5	3.5	2.3	35.8	1.94	6.3	216	967	525	9.7	83.3	0.1	0.64	188
WAMBOG B 02	Clay Loam	6.6	6.06	0.06	0.5	14.2	44.9	46.7	5.6	3.2	0	2.58	3.3	309	1277	806	8.2	104	0.2	0.64	130
WAMBOS POT 1	Sandy Loam	5.9	5.08	0.04	0.6	10.7	38.4	11.8	3.3	0.2	46.5	10.1	8.3	138	823	154	9.4	4.5	0.1	0.64	173
WAMBOS POT 2	Clay Loam	6.6	5.6	0.12	1	17.9	47	40.6	3.6	8.7	0	0.942	4.1	256	1688	884	12	359	0.2	0.64	162
WAMBOS POT 3	Sandy Loam	6.3	5.52	0.03	0.4	5.2	64.8	27.3	7.1	0.6	0	2.18	12.6	143	674	173	7.6	6.5	0.1	0.64	129
REF 05	Sandy Loam	5.4	4.72	0.12	1.7	7.4	14.9	15.6	3.2	6.6	58.8	0.265	4.2	94.4	220	140	12	113	0.1	0.64	237
	Average	**5.9**	**5.2**	**0.06**	**0.7**	**12.3**	**37.3**	**24.3**	**3.8**	**2.7**	**31.4**	**4.9**	**7.5**	**176.3**	**910.7**	**382.8**	**10.6**	**84.1**	**0.2**	**0.6**	**204.8**
	MAX	**6.6**	**6.1**	**0.12**	**1.7**	**17.9**	**73.7**	**46.7**	**7.1**	**8.7**	**58.8**	**18.0**	**13.2**	**309.0**	**1688.0**	**884.0**	**14.0**	**359.0**	**0.4**	**0.6**	**293.0**
	MIN	**5.4**	**4.6**	**0.03**	**0.4**	**5.2**	**14.9**	**11.8**	**2.4**	**0.2**	**0.0**	**0.3**	**3.3**	**94.4**	**220.0**	**140.0**	**7.6**	**4.5**	**0.1**	**0.6**	**129.0**
HVORIV2 01402	Clay Loam	9.1	8.15	0.29	2.5	27.1	50.7	38.7	2.3	8.5	0	3.07	62.3	239	2752	1274	75	529	1	4.6	131
HVORIV2 01404	Clay Loam	8.5	7.93	0.31	2.7	22.1	62.2	27.6	3.8	6.3	0	6.18	85.2	330	2754	740	112	321	1.2	5.9	210
HVORIV2 01405	Sandy Clay Loam	8.4	7.65	0.11	1	13.4	70	19.7	6.6	3.7	0	4.01	123	346	1880	320	13	115	0.6	4.4	197
MTWNPN 201403	Clay Loam	7.6	7.3	0.17	1.5	16.6	70.9	23.2	4.7	1.3	0	3.72	148	304	2359	468	51	47.5	0.7	4.8	251
	Average	**8.4**	**7.8**	**0.2**	**1.9**	**19.8**	**63.5**	**27.3**	**4.4**	**5.0**	**0.0**	**4.2**	**104.6**	**304.8**	**2436.3**	**700.5**	**62.8**	**253.1**	**0.9**	**4.9**	**197.3**
	Maximum	**9.1**	**8.2**	**0.3**	**2.7**	**27.1**	**70.9**	**38.7**	**6.6**	**8.5**	**0.0**	**6.2**	**148.0**	**346.0**	**2754.0**	**1274.0**	**112.0**	**529.0**	**1.2**	**5.9**	**251.0**
	Minimum	**7.6**	**7.3**	**0.1**	**1.0**	**13.4**	**50.7**	**19.7**	**2.3**	**1.3**	**0.0**	**3.1**	**62.3**	**239.0**	**1880.0**	**320.0**	**13.0**	**47.5**	**0.6**	**4.4**	**131.0**
HVORIV2 01406	Clay Loam	8.1	7.48	0.13	1.1	23.2	63.8	28.8	3.6	3.6	0	6.67	93.6	326	2966	812	22	194	0.8	4.5	262
HVORIV2 01301	Clay Loam	8.6	7.79	0.24	2.1	22.4	48.5	37.9	3.4	10	0	11.6	18.3	300	2177	1031	30	518	0.9	3	162
MTWNPN 201301	Sandy Clay Loam	7	6.96	0.16	1.5	8.9	73.9	19.8	4.6	1.3	0	1.07	28.7	159	1319	214	66	27.3	0.3	1.7	291
MTWNPN 201101	Clay Loam	7.9	7.39	0.07	0.6	12.9	63.5	32.2	3.6	0.4	0	2.01	1.2	184	1641	505	11	11.7	0.4	1.8	129
MTWSPN 201401	Clay Loam	8.1	7.27	0.11	0.9	13.8	67.8	26.5	3.8	2	0	2.09	29.7	208	1877	444	21	62.3	0.5	3.7	226
MTWWDL 201402	Clay Loam	8	7.43	0.27	2.3	17.9	59.1	31.9	4.1	5	0	8.65	67.2	284	2118	693	127	205	0.6	4.7	310
MTWNPN 201401	Fine Sandy Clay Loam	6.9	6.55	0.18	1.5	11.4	59	33.3	4.1	3.9	0	0.9	31.2	184	1348	462	54	102	0.3	3.3	263
HVOCHE 201201	Clay Loam	7.9	7.13	0.13	1.1	15.2	67.2	23.7	4.5	4.5	0	10.9	69.4	267	2047	438	15	157	0.5	4	234
HVOCAR2 01401	Clay Loam	7.5	6.76	0.17	1.5	20.1	59.5	32.1	4.6	3.8	0	1.3	42.2	361	2398	783	50	177	1.4	3.3	192
HVOWES 2013-02	Clay Loam	8	7.45	0.15	1.3	13.6	61.8	32.1	4.2	2.2	0	2.07	23	222	1684	531	26	69.7	0.8	4	188
HVOCHE S2012-03	Sandy Loam	8.2	7.63	0.12	1.7	15.5	73.5	19.4	3.4	3.7	0	3.99	117.1	203	2283	366	21	132	1.2	5.6	199

	Maximum	**8.6**	**7.8**	**0.3**	**2.8**	**23.2**	**75.3**	**37.9**	**4.6**	**10.0**	**0.0**	**11.6**	**128.7**	**361.0**	**3002.0**	**1031.0**	**210.0**	**518.0**	**1.4**	**5.9**	**310.0**
	Minimum	**6.9**	**6.6**	**0.1**	**0.6**	**8.9**	**48.5**	**18.7**	**3.4**	**0.4**	**0.0**	**0.9**	**1.2**	**159.0**	**1319.0**	**214.0**	**11.0**	**11.7**	**0.3**	**1.7**	**129.0**
HVOWES 2008-01	Clay Loam	7.2	6.72	0.08	0.7	12.3	55.4	38.1	5	1.1	0	4.46	2.9	237	1367	569	11	32.1	0.4	1.7	127
HVOCAR2 00901	Light Clay	7.7	6.98	0.07	0.6	15.9	35.7	53.6	5	5.8	0	1.79	2.8	314	1137	1035	8.8	213	0.5	1.7	143
HVOCAR2 00902	Light Medium Clay	7.9	7.53	0.14	1.1	1.9	61.1	33	4.2	3.2	0	2.18	3.4	32.1	232	76	3.2	14.2	0.1	0.64	18.5
MTWCDD 201101	Clay Loam	7.3	6.59	0.09	0.8	12.1	50.6	38.4	5.5	5.7	0	9.68	1	262	1225	564	15	159	0.3	1.3	265
MTWWDL 201401	Clay Loam	7.1	7.08	0.37	3.2	14.3	59.4	29.4	5.3	5.9	0	3.74	90.5	298	1702	510	167	196	0.3	2.2	307
MTWNPN 200901	Clay Loam	6.8	6.36	0.08	0.7	12.6	59	35.5	4.4	1	0	2.7	0.9	220	1490	543	17	26.7	0.3	1.7	221
MTWMTO 200503	Sandy Clay Loam	7.8	7.38	0.26	2.5	12.3	44.5	44.8	2.2	8.6	0	2.24	6	104	1095	670	96	244	0.1	0.64	131
MTWNPN 200501	Clay Loam	7.4	7.05	0.08	0.7	10.9	47.7	44.6	6.8	1.3	0	13.7	2.7	289	1042	591	9.9	33.3	0.3	0.9	166
MTWNPN 200502	Sandy Clay Loam	6.6	6.19	0.08	0.8	10.7	46.4	47.4	5.2	1.2	0	13.1	1.8	220	994	616	15	30.1	0.3	0.9	227
MTWTO2 00001	Sandy Clay	7.6	7.02	0.13	1.1	12	39.9	47.7	2.7	9.6	0	4.67	15.7	126	959	696	20	263	0.1	1.1	186
	Average	**7.34**	**6.89**	**0.138**	**1.22**	**11.5**	**49.97**	**41.25**	**4.63**	**4.34**	**0**	**5.826**	**12.77**	**210.21**	**1124.3**	**587**	**36.29**	**121.14**	**0.27**	**1.278**	**179.15**
	Maximum	**7.9**	**7.53**	**0.37**	**3.2**	**15.9**	**61.1**	**53.6**	**6.8**	**9.6**	**0**	**13.7**	**90.5**	**314**	**1702**	**1035**	**167**	**263**	**0.5**	**2.2**	**307**
	Minimum	**6.6**	**6.19**	**0.07**	**0.6**	**1.9**	**35.7**	**29.4**	**2.2**	**1**	**0**	**1.79**	**0.9**	**32.1**	**232**	**76**	**3.2**	**14.2**	**0.1**	**0.64**	**18.5**
HVORIV2 01401	Clay Loam	9	8.23	0.37	3.2	28.1	43.7	41.3	3.2	11.7	0	6.71	71.4	354	2463	1409	65	755	1.1	4.1	119
HVORIV2 01403	Clay Loam	8.7	7.89	0.15	1.3	22.2	49.7	42	3	5.3	0	2.27	90.9	258	2212	1134	29	272	0.9	6.8	250
HVOWES 2011-01	Light Clay	8.4	7.74	0.19	1.6	22.6	46.7	49.1	2.1	2.2	0	2.04	25.8	186	2115	1349	58	114	0.2	4	88.8
HVOCHE2 013-01	Clay Loam	8.6	7.92	0.15	1.3	19	62.8	32	2.8	2.1	0	3.44	62.3	210	2391	739	22	92.9	0.5	4.8	116
MTWCDD 201501	Clay Loam	8	7.55	0.21	1.8	14.8	70.3	24.5	3.2	2.1	0	13.4	153	186	2087	441	83	72	0.5	5.7	237
MTWTDI2 01501	Clay Loam	9.6	8.66	0.49	4.2	16.5	24.1	28	4.2	43.6	0	0.05	7.5	268	795	560	124	1654	0.4	9.3	262
	Average	**8.7**	**8.0**	**0.3**	**2.2**	**20.5**	**49.6**	**36.2**	**3.1**	**11.2**	**0.0**	**4.7**	**68.5**	**243.7**	**2010.5**	**938.7**	**63.5**	**493.3**	**0.6**	**5.8**	**178.8**
	Maximum	**9.6**	**8.7**	**0.5**	**4.2**	**28.1**	**70.3**	**49.1**	**4.2**	**43.6**	**0.0**	**13.4**	**153.0**	**354.0**	**2463.0**	**1409.0**	**124.0**	**1654.0**	**1.1**	**9.3**	**262.0**
	Minimum	**8.0**	**7.6**	**0.2**	**1.3**	**14.8**	**24.1**	**24.5**	**2.1**	**2.1**	**0.0**	**0.1**	**7.5**	**186.0**	**795.0**	**441.0**	**22.0**	**72.0**	**0.2**	**4.0**	**88.8**
MTWNPN 201402	Sand	6.7	6.11	0.03	0.7	3.9	79.7	14.9	3.8	0.5	0	0.284	20.2	57.7	623	70	7.5	3.6	0.1	0.8	108

	8	Loam Fine Sandy	5.6	4.64	0.05	0.5	12	15.2	21.6	3.3	2.1	55.8	8.82	8.3	156	365	315	10	57.6	0.1	0.64	293
	9	Loam Fine Sandy	6.3	5.72	0.07	0.7	10.3	73.7	20.8	3.8	1.5	0	18	6.4	152	1522	260	11	34.9	0.4	0.64	198
	20	Loam Fine Sandy	5.9	5.03	0.07	0.7	17	31.2	22.4	2.6	2.9	40.2	6.93	6.4	170	1064	463	11	116	0.3	0.64	257
DT	26	Sandy Loam	5.9	5.08	0.04	0.6	10.7	38.4	11.8	3.3	0.2	46.5	10.1	8.3	138	823	154	9.4	4.5	0.1	0.64	173
DT	27	Clay Loam	6.6	5.6	0.12	1	17.9	47	40.6	3.6	8.7	0	0.942	4.1	256	1688	884	12	359	0.2	0.64	162
DT	28	Sandy Loam	6.3	5.52	0.03	0.4	5.2	64.8	27.3	7.1	0.6	0	2.18	12.6	143	674	173	7.6	6.5	0.1	0.64	129
		AVERAGE	**6.10**	**5.27**	**0.06**	**0.7**	**12.2**	**45.1**	**24.1**	**3.9**	**2.7**	**23.8**	**7.83**	**7.68**	**169**	**10223**	**374.83**	**10.17**	**96.42**	**0.20**	**0.64**	**202**
		MAX	**6.60**	**5.72**	**0.12**	**1.0**	**17.9**	**73.7**	**40.6**	**7.1**	**8.7**	**55.8**	**18.00**	**12.60**	**256**	**1688**	**884.00**	**12.00**	**359.00**	**0.40**	**0.64**	**293**
		MIN	**5.60**	**4.64**	**0.03**	**0.4**	**5.2**	**15.2**	**11.8**	**2.6**	**0.2**	**0.0**	**0.94**	**4.10**	**138**	**365**	**154.00**	**7.60**	**4.50**	**0.10**	**0.64**	**129**
	21	Fine Sandy Clay Loam	5.7	5.06	0.05	0.4	15.6	43.1	16	3.7	1	36	3.51	10	226	1346	303	14	34.1	0.2	0.6	196
	22	Light Sandy Clay Loam	5.4	4.6	0.04	0.4	8.7	20.8	16	3.8	1.7	56.7	1.96	6.8	130	363	169	11	33.7	0.1	0.64	254
	23	Sandy Clay Loam	5.7	5.14	0.06	0.6	13.2	23.4	25	2.4	2	47.1	1.4	13.2	125	619	401	11	62.9	0.1	0.64	241
	24	Clay Loam	5.9	5.22	0.05	0.4	15.7	30.7	27.5	3.5	2.3	35.8	1.94	6.3	216	967	525	9.7	83.3	0.1	0.64	188
	25	Clay Loam	6.6	6.06	0.06	0.5	14.2	44.9	46.7	5.6	3.2	0	2.58	3.3	309	1277	806	8.2	104	0.2	0.64	130
	29	Sandy Loam	5.4	4.72	0.12	1.7	7.4	14.9	15.6	3.2	6.6	58.8	0.265	4.2	94.4	220	140	12	113	0.1	0.64	237
		AVERAGE	**5.78**	**5.13**	**0.06**	**0.7**	**12.5**	**29.6**	**24.5**	**3.7**	**2.80**	**39.1**	**1.94**	**7.30**	**183**	**799**	**391**	**10.9**	**71.8**	**0.13**	**0.63**	**208**
		MAX	**6.60**	**6.06**	**0.12**	**1.7**	**15.7**	**44.9**	**46.7**	**5.6**	**6.60**	**58.8**	**3.51**	**13.20**	**309**	**1346**	**806**	**14.0**	**113.0**	**0.20**	**0.64**	**254**
		MIN	**5.40**	**4.60**	**0.04**	**0.4**	**7.4**	**14.9**	**15.6**	**2.4**	**1.00**	**0.0**	**0.27**	**3.30**	**94**	**220**	**140**	**8.2**	**33.7**	**0.10**	**0.60**	**130**

		organisms mg/kg	Total bacteria mg/kg	Total fungi mg/kg	monas mg/kg	mycetes mg/kg	positive mg/kg	negative mg/kg	oxidisers mg/kg	reducers mg/kg	anaerobes mg/kg	Protozoa mg/kg	fungi mg/kg
					Bacteria							Eukaryotes	
	Guideline	***50***	***15***	***33.8***	***1***	***1***	***4***	***11***	***0.5***	***<0.005***	***<0.005***	***1.25***	
8	Bell 1	70.7	24.7	44.8	1.4	6.4	9.6	15.1	0.0	0.0	0.2	1.2	
9	Bell 2	66.0	22.6	42.1	2.0	5.0	8.4	14.3	0.0	0.0	0.2	1.3	
0	Bell 3	94.7	33.3	59.6	2.1	8.3	11.9	21.4	0.0	0.0	0.3	1.7	
1	GBREF 3	102.6	24.5	74.6	1.6	6.0	9.9	14.6	0.0	0.0	0.3	3.6	
2	GBREF 4	52.6	17.0	33.8	1.0	3.5	7.3	9.7	0.0	0.0	0.0	1.8	
3	GBREF 6	87.2	23.7	61.8	1.4	5.7	9.7	13.9	0.0	0.0	0.2	1.8	
4	WAMBOGB 01	86.3	24.0	60.6	1.6	5.4	10.1	13.9	0.0	0.0	0.2	1.7	
5	WAMBOGB 02	108.4	31.4	74.7	3.5	5.4	11.1	20.3	0.3	0.0	0.2	2.2	2
6	WAMBOSPOT 1	54.7	17.4	36.1	1.1	4.3	6.2	11.2	0.0	0.0	0.0	1.1	
7	WAMBOSPOT 2	75.3	21.8	51.5	1.5	5.4	8.4	13.4	0.0	0.0	0.2	2.1	
8	WAMBOSPOT 3	47.7	15.6	31.2	1.1	3.8	6.1	9.6	0.0	0.0	0.2	0.9	
9	REF 05	32.7	9.3	22.9	0.5	2.1	4.0	5.3	0.0	0.0	0.0	0.5	
	AVERAGE	**73.2**	**22.1**	**49.5**	**1.6**	**5.1**	**8.6**	**13.6**	**0.0**	**0.0**	**0.2**	**1.7**	
	MAX	**108.4**	**33.3**	**74.7**	**3.5**	**8.3**	**11.9**	**21.4**	**0.3**	**0.0**	**0.3**	**3.6**	**2**
	MIN	**32.7**	**9.3**	**22.9**	**0.5**	**2.1**	**4.0**	**5.3**	**0.0**	**0.0**	**0.0**	**0.5**	
2	HVORIV201402	52.2	6.0	44.6	1.0	0.7	2.4	3.6	0.0	0.0	0.1	1.6	
4	HVORIV201404	105.7	11.9	92.0	1.8	1.7	4.7	7.2	0.0	0.0	0.1	1.8	
5	HVORIV201405	95.1	10.9	79.8	2.0	1.5	4.1	6.8	0.0	0.0	0.0	4.4	1
6	MTWNPN201403	172.2	24.6	141.2	3.4	4.1	9.6	15.0	0.0	0.0	0.4	6.4	2
	AVERAGE	**106.3**	**13.4**	**89.4**	**2.1**	**2.0**	**5.2**	**8.2**	**0.0**	**0.0**	**0.1**	**3.5**	**1**
	MAX	**172.2**	**24.6**	**141.2**	**3.4**	**4.1**	**9.6**	**15.0**	**0.0**	**0.0**	**0.4**	**6.4**	**2**
	MIN	**52.2**	**6.0**	**44.6**	**1.0**	**0.7**	**2.4**	**3.6**	**0.0**	**0.0**	**0.0**	**1.6**	
6	HVORIV201406	196.1	24.6	168.5	4.0	3.4	9.3	15.3	0.0	0.0	0.3	3.0	1
7	HVORIV201301	76.7	14.9	59.0	1.8	2.6	6.1	8.8	0.0	0.0	0.1	2.7	1
7	MTWNPN201301	50.9	10.2	38.1	0.9	2.3	3.8	6.4	0.0	0.0	0.0	2.5	1
8	MTWNPN201101	109.5	12.1	93.9	1.9	2.4	4.3	7.7	0.0	0.0	0.0	3.5	1
1	MTWSPN201401	119.9	16.2	101.8	2.4	2.2	6.5	9.6	0.0	0.0	0.2	1.8	1
1	HVOCHE 201201	70.4	14.9	53.4	1.8	2.9	5.9	9.0	0.0	0.0	0.1	2.0	
0	HVOCAR201401	60.8	14.1	44.9	1.4	2.4	5.9	8.1	0.0	0.0	0.1	1.8	1
0	HVOCHE201301	76.9	12.8	62.2	2.1	2.0	5.0	7.8	0.0	0.0	0.0	1.9	1
	AVERAGE	**95.1**	**15.0**	**77.7**	**2.0**	**2.5**	**5.9**	**9.1**	**0.0**	**0.0**	**0.1**	**2.4**	**1**
	MAX	**196.1**	**24.6**	**168.5**	**4.0**	**3.4**	**9.3**	**15.3**	**0.0**	**0.0**	**0.3**	**3.5**	**1**
	MIN	**50.9**	**10.2**	**38.1**	**0.9**	**2.0**	**3.8**	**6.4**	**0.0**	**0.0**	**0.0**	**1.8**	
2	MTWCDD201101	100.3	18.3	77.9	1.7	4.3	7.5	10.8	0.0	0.0	0.1	4.2	1
5	MTWWDL201401	152.8	24.8	125.3	2.8	4.3	9.8	15.0	0.0	0.0	0.5	2.7	1

	MIN	**62.8**	**14.3**	**47.1**	**1.6**	**3.4**	**5.9**	**8.4**	**0.0**	**0.0**	**0.0**	**1.5**	
1	HVORIV201401	29.1	4.8	24.3	0.7	0.7	1.9	2.9	0.0	0.0	0.0	0.0	
3	HVORIV201403	55.8	6.3	48.7	1.0	0.7	2.6	3.7	0.0	0.0	0.0	0.8	
3	MTWCDD201501	89.1	12.3	73.9	1.8	1.4	5.4	7.0	0.0	0.0	0.2	2.9	
4	MTWTDI201501	47.3	11.0	35.7	1.1	1.4	4.9	6.1	0.0	0.0	0.5	0.7	
	AVERAGE	**55.3**	**8.6**	**45.7**	**1.1**	**1.0**	**3.7**	**4.9**	**0.0**	**0.0**	**0.2**	**1.1**	
	MAX	**89.1**	**12.3**	**73.9**	**1.8**	**1.4**	**5.4**	**7.0**	**0.0**	**0.0**	**0.5**	**2.9**	
	MIX	**29.1**	**4.8**	**24.3**	**0.7**	**0.7**	**1.9**	**2.9**	**0.0**	**0.0**	**0.0**	**0.0**	

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