Bowen River Coal Pty Ltd

Cows Coal Mine Progressive Rehabilitation and Closure Plan



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1. Project Planning

1.1. Introduction

The Cows Coal Mine (CCM) is an open cut coal mine within the northern Bowen Basin in Central Queensland, located within the Whitsunday Regional Council (WRC) Local Government Area. It is approximately 9km south of the town of Collinsville, and 82km southwest of the regional centre of Bowen (see **Figure 1**). The CCM is situated on the western side of the state-controlled Bowen Development Road (which is the primary access to the site) and the Newlands Rail line.

The CCM is one of four adjoining coal mines managed by QCoal, the others being the Sonoma Coal Mine (SCM), the Drake Coal Mine (DCM) and the Jax Coal Mine (JCM). Each mine has a separate Environmental Authority (EA) and EA holder. However the four mines are collectively operated and managed under a co-development agreement as an integrated mining operation by QCoal Pty Ltd (QCoal), referred to as the QCoal Northern Hub (QNH), with pits, dumps, haul roads and other infrastructure spanning the tenure boundaries of the sites. Mining operations are conducted by a single mining contractor, with planning, management, operational and environmental resources also integrated across the QNH. **Figure 1** also shows the location of the CCM relative to the other QNH mines.

The CCM is wholly contained within Mining Lease (ML) 10345, a 211Ha ML over a road reserve between the SCM to the north and the DCM to the south. The granting of ML 10345 enabled the mining of a small coal resource (~2.5mt) within the CCM area and allowed for continuous mining of the same coal seams to span across the boundaries of the SCM, CCM and DCM MLs. Further details on ML 10345 are provided in **Section 1.1.5**.

Mining commenced at the CCM in January 2013, using conventional open-cut mining methods to target the Q seam and B seam of the Moranbah Coal Measures in two pits (i.e. Q-Pit and B-Pit respectively). Both pits were a southward continuation of mining from the SCM into the CCM and in the case of B-Pit, continuing into the DCM. Mine waste was placed in out-of-pit waste rock dumps until sufficient void was available within the pits to allow for in-pit dumping via and advancing low-wall (progressively backfilling). B-Pit has been progressively backfilled by continued advancement of the pit into the DCM, while Q-Pit has been directly backfilled since the reaching the economic limit of coal recovery by a specific backfilling campaign using additional waste rock from the DCM. As such, no voids currently exist on ML 10345. The out of pit dumps and other infrastructure on ML 10345 (such as haul roads) continue to be utilised by activities on the QNH.

The QNH mines utilise processing and support infrastructure at the SCM, including the Coal Handling and Preparation Plant (CHPP), rejects management system (co-disposal facility), train load-out, Run of Mine (ROM) pad, product stockpile area, heavy vehicle workshop, offices and fuel storage. Infrastructure on the CCM is limited to haul roads and access tracks to support the mining activities on the QNH, particularly continued haulage of ROM coal from the JCM and DCM into the SCM for processing and train loading of product coal. During mining, ROM coal from the CCM was

also hauled to the SCM for processing and train loading of product coal for transport to the Abbott Point Coal terminal.

Ongoing activities at the CCM include the continued haulage of ROM coal via existing haul roads as part of the wider QNH operations, facilitating movement of light vehicles across the QNH via existing access tracks, continued dumping of waste rock from the DCM on existing CCM waste rock dumps, rehabilitation activities in available areas and environmental monitoring. The use of haul roads through the CCM to support the wider QNH operations will be required to provide access to the SCM from the southern DCM and JCM mines for the life of mine of the DCM and JCM. Therefore, areas required for the continued haulage will not be available for rehabilitation until the completion of mining activities at the DCM and JCM.

1.1.1. Project Ownership

The QNH sites have ownership makeups as follows:

- CCM is owned by Bowen River Coal Pty Ltd (BRC).
- SCM is a joint venture between QCoal Sonoma Pty Ltd, JS Sonoma Pty Ltd, CSC Sonoma Pty Ltd and Watami (Qld) Pty Ltd.
- DCM is owned by Northern Hub (Drake) Pty Ltd and Drake Coal Pty Ltd.
- JCM is owned by Jax Coal Pty Ltd.

BRC, QCoal Sonoma Pty Ltd, Northern Hub (Drake) Pty Ltd, Drake Coal Pty Ltd, and Jax Coal Pty Ltd, are wholly or majority owned subsidiaries of QCoal Pty Ltd. The owner and Managing Director of QCoal Pty Ltd is Mr Christopher Wallin.

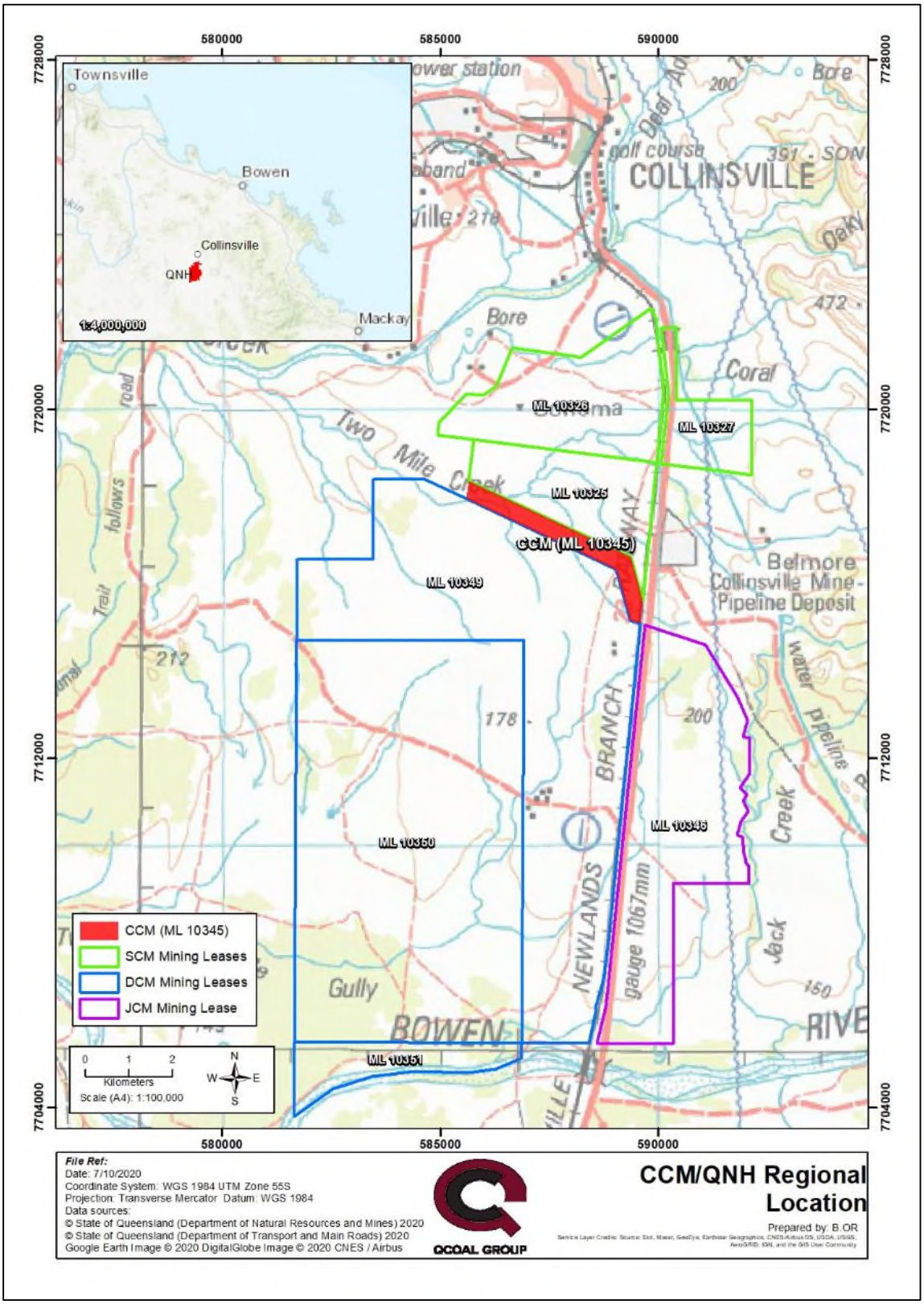


Figure 1 – CCM Regional Location

1.1.2. Progressive Rehabilitation and Closure Plan Legislation and Guideline

The *Mineral and Energy Resources (Financial Provisioning) Act 2018* (MERFP Act) was passed by the Queensland Parliament on 30 November 2018 which, amongst other changes, amended the *Environmental Protection Act 1994* (EP Act). One of the key changes introduced by this legislation was to the requirement for new and existing mines to develop and submit a Progressive Rehabilitation and Closure Plan (PRC Plan) detailing how rehabilitation will be planned, scheduled and progressed to bring mine-disturbed land to a stable condition, as defined in Section 111A of the EP Act:

111A Meaning of stable condition

Land is in a ***stable condition*** *if –*

(a) the land is safe and structurally stable; and
(b) there is no environmental harm being caused by anything on or in the land; and
(c) the land can sustain a post-mining land use.

A PRC Plan must address the requirements in sections 126C and 126D of the EP Act, pursuant to section 754 of the EP Act. Further guidance on the required content is contained in the *Guideline Progressive Rehabilitation and Closure Plans (*DES, 2019*) (*PRCP Guideline*)*.

The PRC Plan comprises two components (as required by the EP Act):

- The PRC Plan – Rehabilitation Planning Part, which provides information on:
  - site characteristics;
  - pre-mining conditions;
  - post-mining land-uses (PMLUs);
  - community consultation;
  - rehabilitation methodology and criteria;
  - a risk assessment; and
  - a monitoring program.

- The PRC Plan - Schedule, which:
  - Allocates all mine disturbance to a designated rehabilitation area which has a specific PMLU;
  - nominates rehabilitation milestones (which when all achieved represents completed rehabilitation);
  - provides a detailed schedule for the progressive rehabilitation of all rehabilitation areas to achieve the rehabilitation milestones.

The EP Act includes transitional provisions for the application of the PRC Plan requirement to existing mines. Holders of an existing site-specific mining EA will be issued with a notice from the administering authority within the first three years following the PRC Plan start date (being 1 November 2019). The notice will specify a date by which a PRC Plan must be developed and submitted to the Department of Environment and Science (DES) as the administering authority.

A Progressive Rehabilitation and Closure Plan Transition Notice (the Notice) for the CCM was issued to BRC by DES on 30 June 2020. The Notice required BRC to submit a PRC Plan to the administering authority by 29 January 2021.

1.1.3. Document Purpose and Interaction Between the PRC Plan Components

This document in its entirety (including appendices) represents the PRC Plan for the CCM, developed in accordance with the requirements of the EP Act and PRCP Guideline. The components of the PRC Plan within this document are as follows:

- the “PRC Plan – Rehabilitation Planning Part” which is provided as the body of this document; and
- the “PRC Plan – Schedule” is provided as Appendix A of this document.

The PRC Plan – Rehabilitation Planning Part and the PRC Plan – Schedule can be considered, reviewed, and implemented separately. Additionally, both components can be amended independently without requiring amendment of the to the other; however, where such an amendment results in an inconsistency between the two components, that inconsistency requires resolution.

Where the PRC Plan - Schedule is amended and as a result the PRC Plan – Rehabilitation Planning Part requires amendment to resolve an inconsistency between the components, a copy of the amended PRC Plan – Rehabilitation Planning Part will be provided to the administering authority within 10 business days as required by section 316H of the EP Act.

1.1.4. Land Outcome Documents

The CCM is an existing mine that was approved and commenced prior to the PRC Plan start date (1 November 2019); therefore, the transitional arrangements detailed in Section 6 of the PRCP Guideline apply to this PRC Plan. This includes the use of existing Land Outcome Documents (LODs), the purpose of which is to facilitate existing mines with existing landforms and mine plans into the PRC Plan framework, by nominating pre-existing documents related to rehabilitation and closure, the contents of which the regulatory authority gives continued approval for implementation on the site. As such the contents and findings of an LOD can be relied upon as stated and adopted into the PRC Plan framework. Relevant content examples in an LOD include nominated PMLUs, non-use-management-areas (NUMA), rehabilitation methodologies, completion criteria and the related antecedent studies.

LODs are defined under section 750 of the EP Act as:

***land outcome document**, for land, means the following documents relating to the land—*

(a) an environmental authority for a resource activity on the land;
(b) a document made under a condition of an environmental authority mentioned in paragraph (a), if—
(i) the document relates to the management of a void within the meaning of section 126D on the land, or the rehabilitation of the land; and

(ii) the document was received by the administering authority before the assent date; and
(iii) the administering authority has not, within 20 business days after the assent date, given notice to the holder of the environmental authority that the document is insufficient in a material particular relevant to a mater mentioned in subparagraph (i); and
(iv) before the assent date, the document had not been superseded;

(c) a document made under a condition of an environmental authority mentioned in paragraph (a) if—
(i) the document relates to the management of a void within the meaning of section 126D on the land, or the rehabilitation of the land; and
(ii) the environmental authority requires the document to be given to the administering authority on a stated day that is on or after the assent date, or does not state a day when the document must be given; and
(iii) the document is received by the administering authority within 3 years after the assent date; and
(iv) the administering authority does not, within 20 business days after receiving the document, give the holder of the environmental authority notice that the document I insufficient in a material particular to a matter mentioned in subparagraph (i);

(d) a report evaluating an EIS under the State Development and Public Works Organisation Act 1971, *section 34D;*

(e) an EIS assessment report;

(f) a written agreement between the holder of an environmental authority mentioned in paragraph (a) and the State that is in force on the assent date.

Following this hierarchy, the relevant LODs for the CCM are detailed in **Table 1**.

Table 1 – CCM Land Outcome Documents

Land Outcome Document	Approval Date	Disturbance Area	Document Reference	Outcome and Detail
EA EPML00334613	Granted: 05/06/2012 Current 9/03/2020	Residual Void	Condition H13 / Table H1	Condition H13/Table H1 nominates that the B-Pit and Q-Pit voids will be backfilled
		'All other areas'	Condition H1	Condition H1 nominates that all areas other than residual voids will have a PMLU of grazing pasture
QNH Rehabilitation Management Plan	Notification of DES Acceptance: 2/07/2020	-	-	Subordinate LoD to the EA but provides further detail regarding the rehabilitation methodology, completion criteria, etc.

The EP Act requires that all areas disturbed for mining activities under an EA within a relevant mining tenure be rehabilitated to either a specified PMLU (see **Section 3**), or where a PMLU cannot be sustained, rehabilitated to a NUMA (see **Section 3.1 and Section 4**).

Under **Condition H1** of the CCM EA, all areas significantly disturbed by mining activities must be rehabilitated to achieve a PMLU of grazing pasture, with the exception of residual voids (which are addressed in **Table H1** and **Condition H13** of the EA). Under **Table H1** of the CCM EA, both the B-Pit and Q-Pit voids are to be backfilled (i.e. there are no residual voids to remain in these areas). In the absence of any residual voids, the adopted PMLU for the CCM for all areas (except for any areas requested to remain unrehabilitated by the landholder) is grazing pasture.

The QNH Rehabilitation Management Plan (QNH RMP) includes the approved rehabilitation methodology, adopted parameters for design of the final landforms, and acceptance and completion criteria to demonstrate achievement of the PMLU for rehabilitated areas at the CCM. The QNH RMP reflects the approach that has been adopted for rehabilitation works to date at the CCM. The QNH RMP was submitted to DES on 27 April 2020 and was subsequently approved on 2 July 2020. Relevant content from the QNH RMP is detailed in **Section 3**.

1.1.5. Site History and Existing Approvals

QCoal has held Exploration Permit Coal (EPC) 586 and 639, which were the exploration tenements underlying the QNH including the CCM, since 1995 and 2001 respectively. Exploration within these EPCs defined coal resources which has led to the progressive development of the QNH (SCM, CCM, DCM and JCM) since 2006. This progressive development, along with the different ownership structure for each of the QNH mines, has required separate MLs and EAs for each mine, with the approval process required dependent on the proposed scale and the level of impact to environmental values for each individual mine. The completed QNH approval processes include the following:

- SCM – Level 1 Non-Code Compliant EA application assessed by Environmental Impact Statement (EIS), process completed in 2006;
- CCM – Level 1 Non-Code Compliant EA application assessed by Environmental Management Plan (EMP), process completed in 2012;
- JCM – Level 1 Non-Code Compliant EA application assessed by EMP, process completed in 2013;
- DCM – Level 1 Non-Code Compliant EA application assessed by EMP, process completed in 2014.

BRC obtained Prospecting Parcel Permit PP 10762 (the pre-requisite tenure for the CCM) over Lot A on AP2839 in 2009, enabling a Mining Lease Application (MLA) to be lodged. MLA 10345 was submitted to the Department of Natural Resources and Mine (DNRM) in November 2009 and was subsequently granted in August 2012. A Level 1, Non-Code Compliant EA application for MLA 10345 with an EMP was also submitted to the (then) Department of Environment and Resource Management (DERM) in November 2009. The Environmental Authority for the CCM was subsequently granted in June 2012. **Table 2** provides further details on the CCM ML and EA.

Table 2 – CCM ML and EA Details

Details	ML 10345	EA EPML00334613
Permit Type	Mining Lease	Environmental Authority
Permit Status	Granted	Granted
Lodgement Date	4/11/2009	04/11/2012
Grant Date	16/08/2012	05/06/2012 (current 9/03/2020)
Expiry Date	31/08/2027	-
Authorised Holder	Bowen River Coal Pty Ltd	Bowen River Coal Pty Ltd
Area	210.5 ha	-
Permit ID	108636	EPML00334613 (previously MIN100942709)
Native Title Category	Exclusive Land	-

The Environmentally Relevant Activities (ERAs) authorised to be undertaken under EA EPML00334613 are listed in **Table 3**:

Table 3 – CCM ERAs

ERA	Description	Status
Resource Activity, Schedule 3, 09	A mining activity involving drilling, costeaning, pitting or carrying out geological surveys causing significant disturbance	This ERA has been undertaken at the CCM
Resource Activity, Schedule 3, 13	Mining black coal	This ERA has been undertaken at the CCM
Resource Activity, Ancillary 15 - Fuel burning	Using fuel burning equipment that is capable of burning at least 500kg of fuel in an hour	No equipment capable of burning 500kg/hour has been utilised at the site, other than mobile plant for Resource Activity, Schedule 3, 13, therefore this ERA has not been undertaken at the CCM
Resource Activity, Ancillary 16 - Extraction and Screening, 2	Extracting, other than by dredging, in a year, the following quantity of material, (b) more than 100,000t but not more than 1,000,000t	Extraction and screening has not been undertaken at the CCM to date (other than under ERA 13), therefore this ERA has not been undertaken at the CCM
Resource Activity, Ancillary 33 - Crushing, milling, grinding or screening,	Crushing, grinding, milling or screening more than 5000t of material in a year	Crushing, milling, grinding and screening has not been undertaken at the CCM, therefore this ERA has not been undertaken at the CCM
Resource Activity, Ancillary 60 - Waste disposal, 1:	Operating a facility for disposing of, in a year, the following quantity of waste mentioned in subsection (1)(a), (a) less than 50,000t	No waste has been disposed of within the CCM, therefore this ERA has not been undertaken at the CCM
Resource Activity, Ancillary 63 - Sewage Treatment, 1	Operating sewage treatment works, other than no release works, with a total daily peak design capacity of, (b-i) more than 100 but not more than 1500EP if treated effluent is discharged from the works to an infiltration trench or through an irrigation scheme	Sewage treatment works have not been installed or operated at the CCM, therefore this ERA has not been undertaken at the CCM

The CCM was referred to the (then) Department of Environment, Water, Heritage and the Arts in November 2009 under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act). BRC was notified in March 2010 that the CCM was determined to be 'not a controlled action'.

The CCM previously operated under a Plan of Operations (latest version valid from: 13 March 2019 – 13 March 2021) and associated financial assurance calculator. BRC subsequently received Deemed Estimated Rehabilitation Cost Decision for the CCM confirming the amount of existing financial assurance to be the deemed ERC. The existing ERC period for the CCM expires on 13 March 2021, to that end, an Application for a new ERC Application was submitted by BRC to DES on 11 December 2020 as required.

Due to the CCM being a continuation of the integrated QNH (i.e. adjoining MLs, the overlapping catchments and study areas, contiguous geology, soils, vegetation, groundwater and other matters across the sites), information from the adjoining mines within the QNH is routinely utilised as a source of baseline and impact assessment. This approach has been accepted by DES as appropriate across the QNH.

Technical studies and data from operational activities within the four QNH mines are also applied across the QNH, including geological, hydrogeological, geochemical, and soil assessments. This is especially appropriate considering that a single mining pit on the QNH can span two or three individual mines, and that the QNH mines share common upstream and downstream hydrology and catchments. Due the integrated nature of the operations, a number of key management plans required under the various QNH EAs have been developed as integrated QNH-wide documents in consideration of cumulative impact assessment, rather than as an individual document for each mine. Documents which encompass the entire QNH operations include:

- QNH Rehabilitation Management Plan (2020, See **Appendix D**)
- QNH Weed Management Plan (2020)
- QNH Water Management Plan (2020)
- QNH Receiving Environmental Management Program (2015)
- QNH Residual Voids on the QCoal Northern Hub Mining Complex (2020)
- QNH Residual Void Hydrology Study – QCoal Northern Hub Mines (2020)
- QNH Mine Waste Management Plan (2021)

1.2. Pre-Mining Land Use

The CCM is located within the Collinsville region which has been utilized for the production of beef, sugar and gold since the late 1800s. Coal mining commenced at Collinsville in the early 1900s and has continued in the region through to the current day. Other land uses in the region include quarrying and power generation (coal-fired and solar). As a result of these land uses, the natural landscape in the region has undergone considerable disturbance and modification.

The CCM is situated in an unformed road reserve which was previously a gazetted stock route. The site was previously used over a prolonged period for beef cattle grazing and as a result, the natural landscape had undergone considerable disturbance and modification prior to the

commencement of mining activities. The land had previously been largely cleared for grazing in the 1950s and 1960s, with property improvements undertaken on the land including fencing, thinning of the remnant vegetation and the establishment of improved pasture. There were a number of areas of retained vegetation and regrowth, with the vegetation communities including mixed eucalypt woodlands and acacia shrublands. **Figure 2** shows the pre-mining aerial imagery of the site, demonstrating the extent of historical disturbance prior to the grant of the CCM ML. The existing mining operations at the SCM to the immediate north are also clearly visible.

The CCM area was previously assessed as being Land Suitability Class 3 (fair) for beef cattle grazing prior to the commencement of mining activities (refer to **Section 1.14.5**).

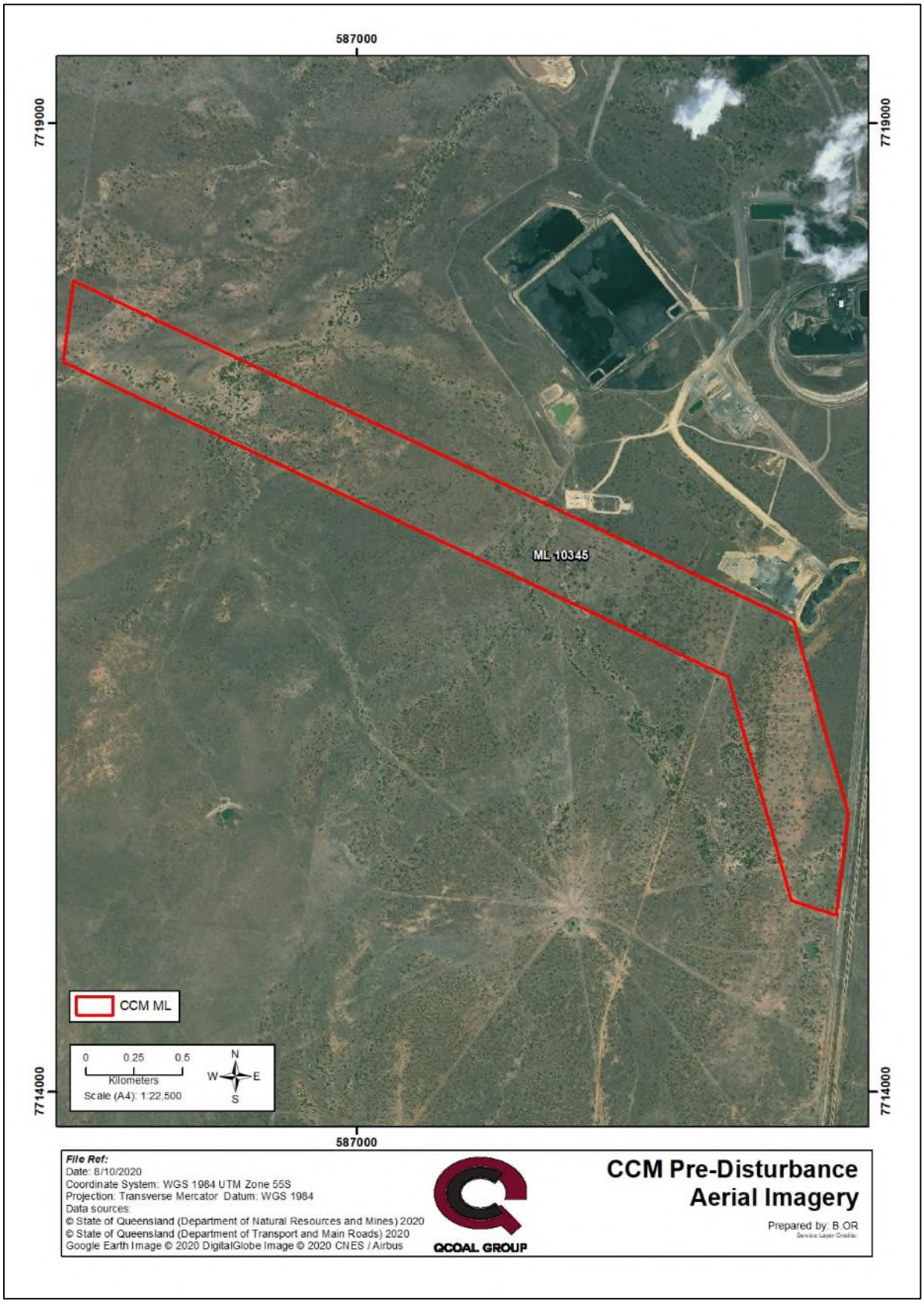


Figure 2 – CCM Pre-Disturbance Aerial Imagery

1.3. Underlying Properties and Landholders

Land tenure details for the real property within the CCM are shown in Error! Reference source not found.. **Figure 3** shows the location of the property boundaries and land tenure within and adjoining the CCM.

ML 10345 is located over part of Lot A on AP2839, which is a road parcel that has never been utilised as a road, having previously been a declared stock route under the LP (PSRM) Act and having been utilised for grazing since the 1950s. While the lot was never actually used as a road, the 'road' was temporarily closed by gazettal in 1962, never permanently closed. As such, it continues to be designated as a 'road'. Since 1981, the property has been utilised for grazing activities under successive Permits to Occupy.

The current Permit to Occupy has been held by Mr Christopher Wallin (owner and Managing Director of QCoal, of which BRC is a wholly owned subsidiary) since 20 June 2008 and has no fixed term. The conditions of the Permit to Occupy authorise the Permit Holder to use the property for grazing purposes.

Lot A on AP2839 is a road reserve and is therefore state-owned land. As a non-state-controlled road, however, the Whitsunday Regional Council (WRC) is responsible for management of the land, including issues related to use, access, construction, maintenance and closure. For the purposes of the *Mineral Resources Act*, WRC is deemed to be the owner of the road. During the approvals process for the CCM, BRC engaged with the WRC (as the road owner) and a compensation deed between BRC and WRC for the land underlying MLA 10345 was signed in 2009, enabling the road to be included in the ML application area.

Table 4 – CCM Land Tenure

Lot/Plan	Tenure	Holder/Owner
Lot A on AP2839	Permit to Occupy for grazing purposes (Title Reference 40056806, No Term)	Mr Christopher Wallin
	Road	Whitsunday Regional Council

Recent consultation with WRC has been undertaken, during which WRC has indicated that there is no intention to 'reopen' the road, permanently close the road, or otherwise change the authorised use of Lot A on AP2839. On that basis, the designated land-use will continue to be 'Grazing – Reserve, Road or Stock Route', as authorised by the Permit to Occupy. This is consistent with the nominated PMLU for the CCM.

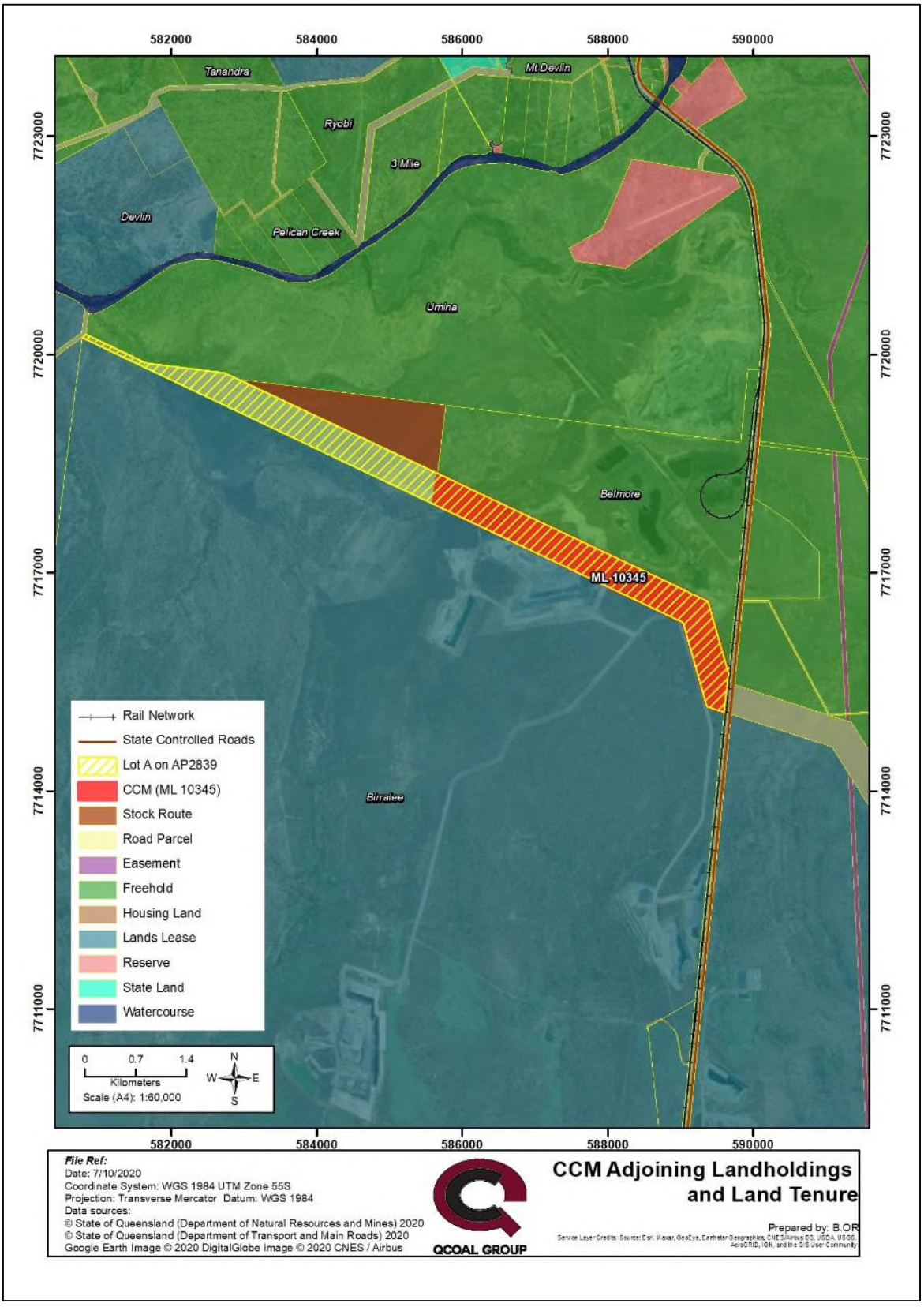


Figure 3 – Adjoining Landholdings and Land Tenure

1.3.1. Sensitive Places

The CCM is bordered by active QNH MLs to the north (SCM), south (DCM) and south-east (JCM). *Sensitive Places* and *Commercial Places* relevant to the CCM are defined in the CCM EA as follows:

'sensitive place' *means:*

a) *A dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or*
b) *A motel, hotel or hostel; or*
c) *An educational institution; or*
d) *A medical centre or hospital; or*
e) *A protected area under the* Nature Conservation Act 1992*, the* Marine Parks Act 1992 *or a World Heritage Protection Area; or*
f) *A public park or gardens.*

'commercial place' *means a workplace used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees' accommodation or public roads*

The nearest sensitive and commercial places to the CCM are detailed in **Table 5** and **Figure 4**, along with the closest population centres.

Table 5 - Proximity of Sensitive and Commercial Places to the CCM

Description	Type	Distance from Operational Area	Notes
Belmore Homestead	Sensitive Place	3.1km	Privately Owned
Sonoma Homestead	Sensitive Place	3.2km	Privately Owned
Collinsville Airport	Commercial Place	4.7km	Operated by WRC
Pelican Creek Residence #1	Sensitive Place	5.1km	Privately Owned
Pelican Creek Residence #2	Sensitive Place	5.2km	Privately Owned
Pelican Creek Residence #3	Sensitive Place	5.5km	Privately Owned
Pelican Creek Residence #4	Sensitive Place	6.0km	Privately Owned
Scottsville	Township	7.3km	Within WRC area
Collinsville	Township	8.9km	Within WRC area

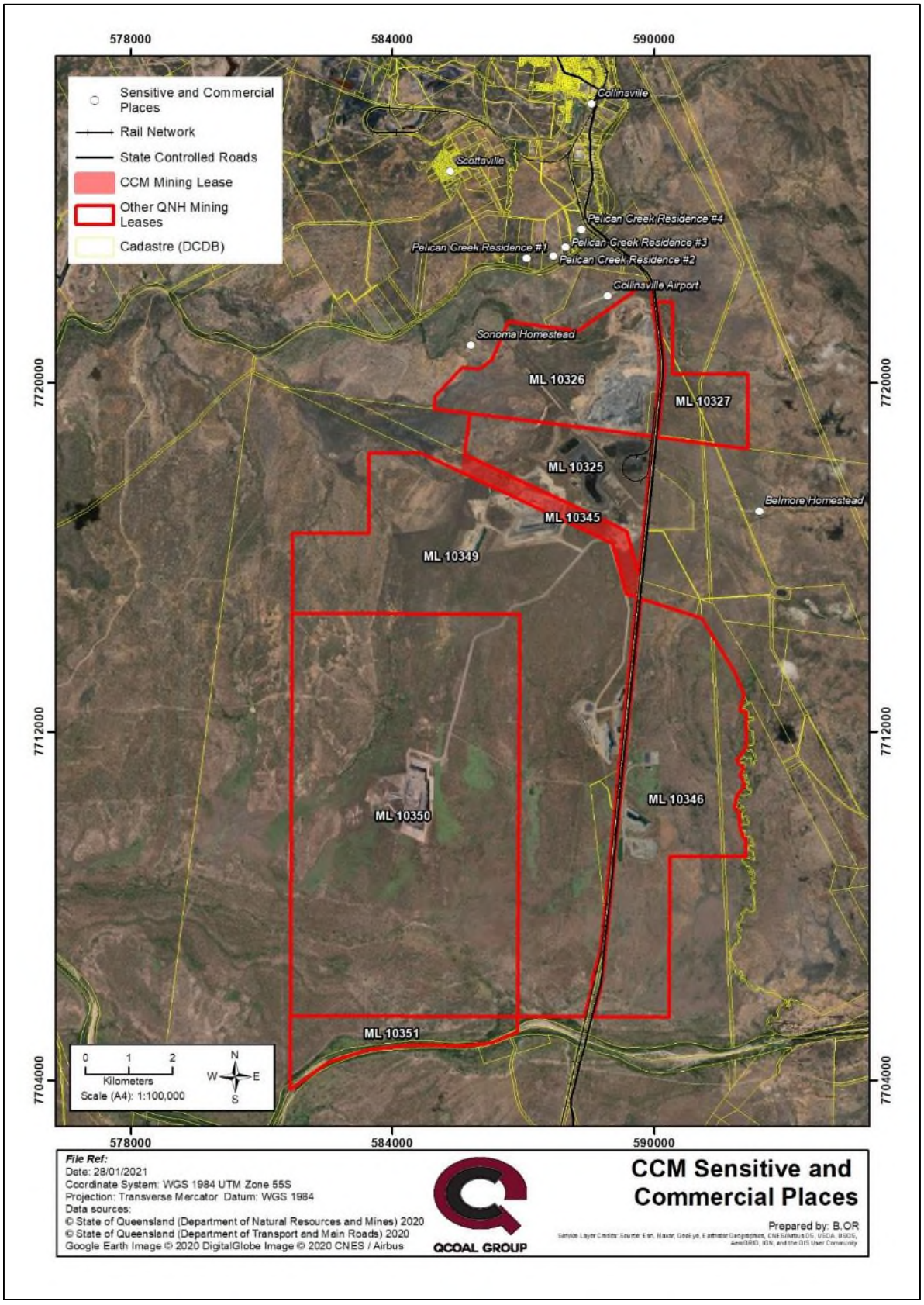


Figure 4 – CCM Sensitive and Commercial Places

1.4. Operational Site Layout

The extent and type of disturbance that is authorised at the CCM is detailed in Conditions A3 and A4 of the CCM EA as follows:

A3 *In carrying out the mining activity authorised by this environmental authority, disturbance of land on Figure 1- Site map, domains and groundwater monitoring locations:*

- *a) may occur in the areas marked 'A';*
- *b) must not occur in the areas marked 'B'; and*
- *c) may occur in the areas marked 'C', but only in accordance with Condition A4.*

A4 *Any disturbance within the areas marked 'C' on Figure 1- Site map, domains and groundwater monitoring locations:*

- *a) is only authorised to the extent reasonably necessary for exploration activities, roads, fences, underground services, low-impact telecommunications facilities, electrical sub-stations, transmission grid works and supply network works, storage depots, similar minor infrastructure and ancillary facilities for any of the above; and*
- *b) any disturbance within areas marked 'A' or 'C' is not to impact adversely on areas marked 'B'.*

Figure 5 shows the extent of EA disturbance categories A, B and C permitted at the CCM, as per CCM EA *Figure 1 – Site Map, domains and groundwater monitoring bores*

Figure 6 shows the site layout with imagery from February 2020, with key operational areas labelled.

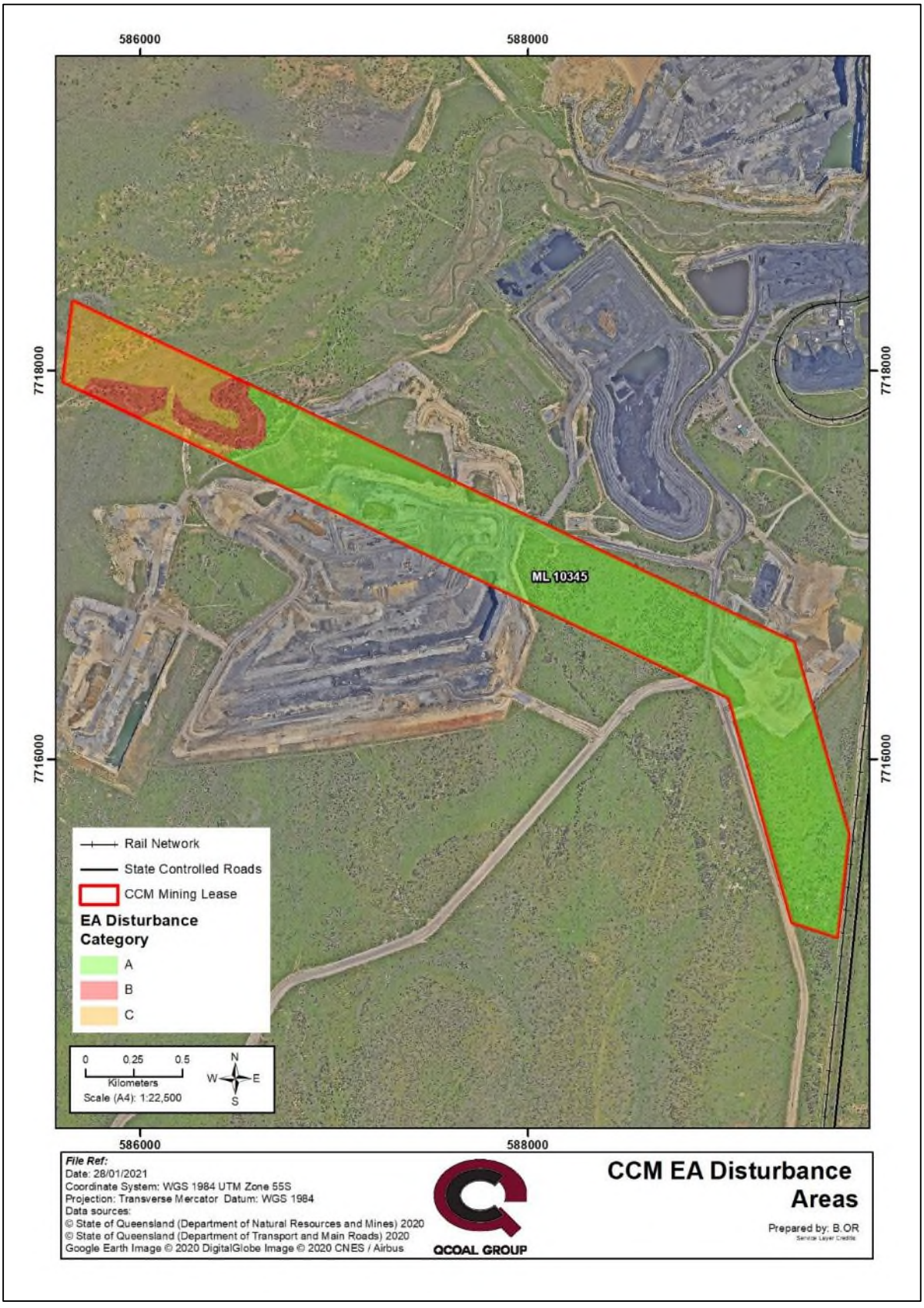


Figure 5 - EA Disturbance Areas

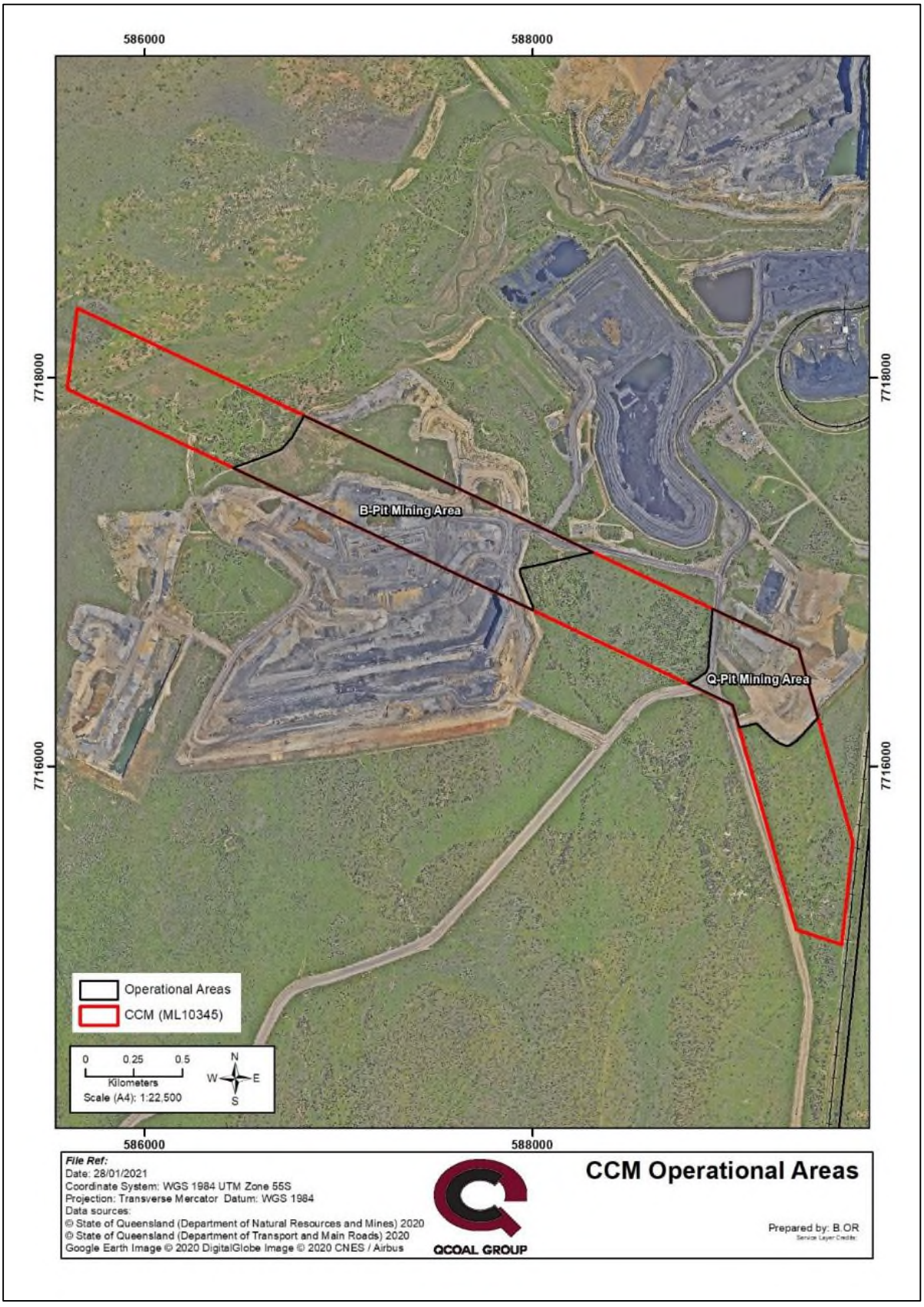


Figure 6 – CCM Operational Areas

1.4.1. Rehabilitation Areas

When an area of disturbance is no longer required for any operational usage it becomes available for rehabilitation. Where an area is still required for any operational purpose (including roads, tracks and support infrastructure) it remains un-available for rehabilitation.

A Rehabilitation Area (RA) within the PRC Plan framework is defined as a geographically delineated parcel of land within which any mining related disturbance is subject to the same PMLU and the same rehabilitation milestones. As mining progresses through the RA, sub-sections of land become available for rehabilitation at different times, which is captured in the PRC Plan – Schedule.

Refer to **Section 5.2.1** for a description of the rehabilitation activities undertaken to date at the CCM.

To date only part of the area authorised for disturbance at the CCM (as shown in **Figure 5**) has been (or is planned to be) disturbed for the mining activities. The mining related disturbance which has been undertaken at the CCM has been allocated into two separate RAs, as detailed in **Table 6** and shown in Error! Reference source not found.. The CCM RAs have been aligned such that each RA only comprises areas which share a common PMLU and rehabilitation methodology

The extent of disturbance shown in the RAs in Error! Reference source not found. represents the maximum planned disturbance for the life of mine (LOM) on the CCM.

Table 6 – Rehabilitation Areas at the CCM

Domain	Description	Area (Ha)
RA1	Waste Rock Dumps (including backfilled pits, out-of-pit dumps and associated haulage ramps/roads	86.84
RA2	Western Diversion Drain	0.28
Total Disturbance		87.12

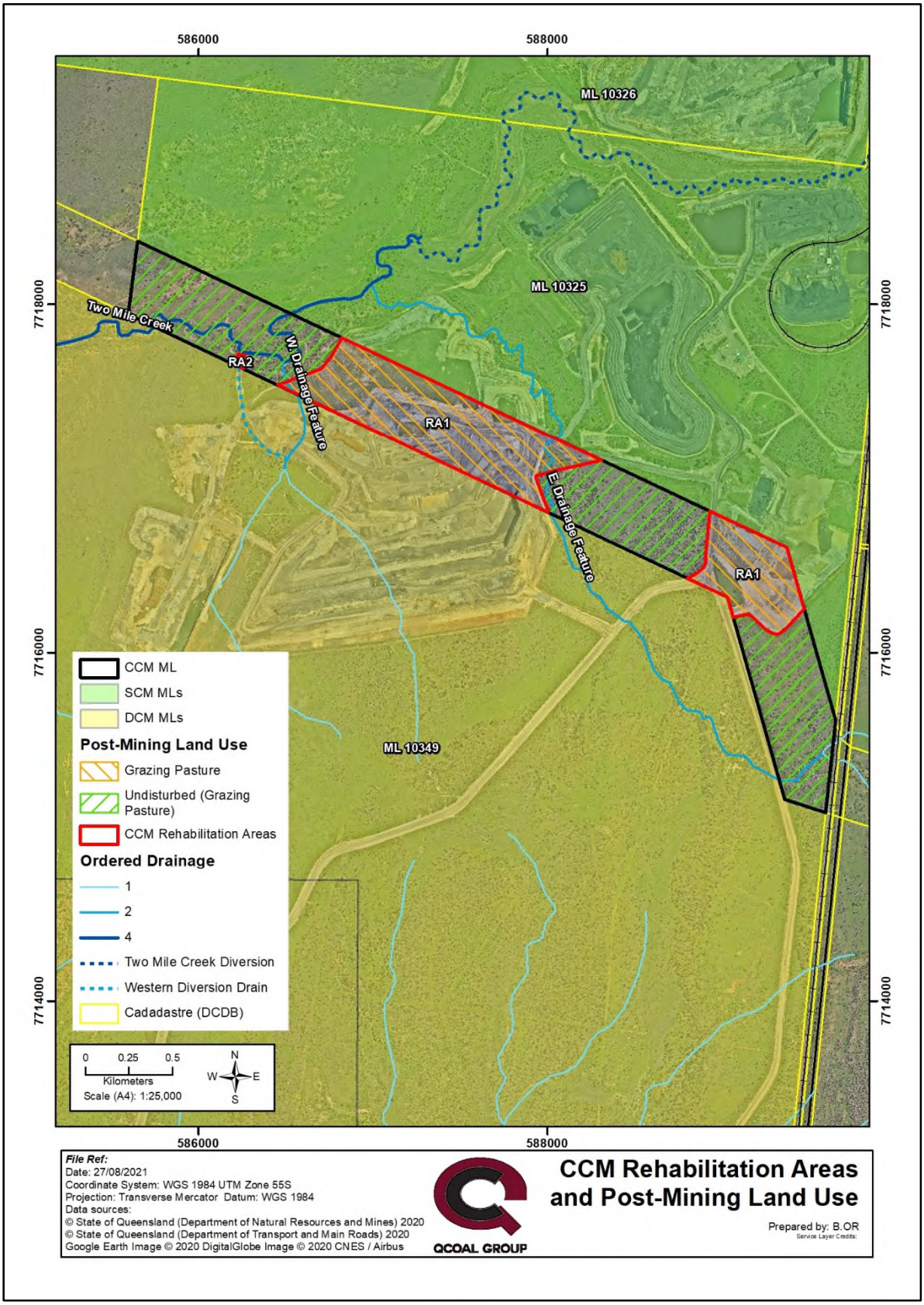


Figure 7 – CCM Rehabilitation Areas and PMLU

1.5. Mining Methods

Mining activities at the CCM have generally occurred in the following general sequence:

- Ongoing coal resource definition (code-compliant exploration activities);
- Vegetation clearing (where required);
- Topsoil removal and stockpiling;
- Construction of haul roads;
- Construction of drainage structures (where required);
- Removal of waste rock by drill and blast and truck and excavator and initial placement in out-of-pit waste rock dumps;
- Extraction of coal from the active mining area with ROM coal transported directly from the CCM to the SCM ROM Pad (i.e. offsite);
- Transition to in-pit waste rock dumping once sufficient void was created for sustained mining operations;
- Completion of coal mining within the CCM Pits and backfilling of the final voids using mine waste from later mining areas;
- Rehabilitation in line with the nominated PMLU.

The QNH including the CCM operates as a conventional truck and excavator mining operation, using the industry standard model of contract mining. On the CCM the surface Cenozoic waste material was free dug, while the remaining waste was blasted and excavated by large hydraulic excavators and rear dump trucks. ROM Coal was excavated by hydraulic excavator and hauled by dump truck to the SCM ROM for washing at the SCM CHPP, and for subsequent transport of product coal via the SCM rail load-out. An additional fleet of ancillary equipment (dozers, graders, water trucks, etc) is also used in the mining operations as required.

Generally pits on the QNH commence as an initial box cut and follow the dip of the coal seam by advancing the high wall in an advancing high-wall bench process. Waste rock is initially placed in an out-of-pit dump located adjacent to the box-cut pit, until sufficient void is created by advancing the high-wall to allow in-pit dumping to commence behind the advancing mining area (advancing the low-wall by progressive backfilling). The pit advances until an economic limit is reached at which point the remaining pit is either retained as a residual void or actively backfilled with a specific backfilling campaign.

1.5.1. Q-Pit

Mining within the CCM Q-Pit commenced in February 2013, when the SCM Q-Pit advanced into CCM ML10345 (CCM Q-Pit). Progressive backfilling was ongoing during operation. Q-Pit reached the economic limit in December 2013, leaving a void on the SCM and CCM. That void was utilised as bulk water storage for the QNH until 2018, at which time a specific active backfilling campaign commenced (using waste material from a separate DCM pit) which was completed in 2019.

1.5.2. B-Pit

Mining within the CCM B-Pit commenced in December 2013, when the SCM B-Pit advanced into CCM ML10345 (CCM B-Pit). The CCM B-Pit continued to advance southward through the CCM and into the DCM (November 2014), where the pit was referred to as the “Drake 1 Pit”. Final coal from the CCM B-Pit was recovered in 2018. Progressive backfilling was ongoing during operation and continues within the Drake 1 Pit, such that the CCM B-Pit was fully backfilled by 2020.

1.5.3. Integration with Other QNH Mines

As previously noted, the CCM is operated as part of the integrated QNH operations. Due to the location and east-west orientation of the CCM ML, access across the CCM is required to link the southern QNH mines (DCM and JCM) to the QNH processing, maintenance, administration and train loading facilities at the SCM in the north. **Figure 8** shows the extent to which the CCM is currently integrated with the other QNH Mines, including the location of key infrastructure and mining areas.

Areas within the CCM will be required to support ongoing mining activities for the LOM of the QNH including (but not limited to) the following mining activities:

- Ongoing dumping of waste rock from the Drake 1 Pit within the CCM B-Pit waste rock dump (above the backfilled CCM B-Pit footprint). As previously noted, the Drake 1 pit is a continuation of the SCM and CCM B-Pit, with the only distinction being the tenure boundary. The specific location of the haulage ramps for waste rock and ROM coal within the B-Pit area are subject to change as the waste rock dumping progress.

- Ongoing access for ROM coal haulage and light and heavy vehicle access from the Drake 1 and Drake 2 Extended mining areas via existing haul roads and ramps through the B-Pit area. This will require the retention of haul roads and ramps (as well as areas above the haul road batters to enable eventual battering of these slopes), which provide access from the Drake pits to the south-west of the CCM, across the CCM B-Pit area, and into the SCM.

- Ongoing access for ROM coal haulage and light and heavy vehicle access from the Drake 5 mining area through the Q-Pit area. This will require the retention of existing haul roads (as well as areas above the haul road batters to enable eventual battering of these slopes), which provide access from the Drake pits to the south-west of the CCM, across the CCM Q-Pit area, and into the SCM.

- Ongoing access for ROM coal haulage and light and heavy vehicle access from the Drake 3, Drake 4 and Jax Main and East mining areas through the Q-Pit area. This will require the retention of existing haul roads (as well as areas above the haul road batters to enable eventual battering of these slopes), which provide access from the JCM via the DCM to the south-west of the CCM, across the CCM Q-Pit area, and into the SCM.

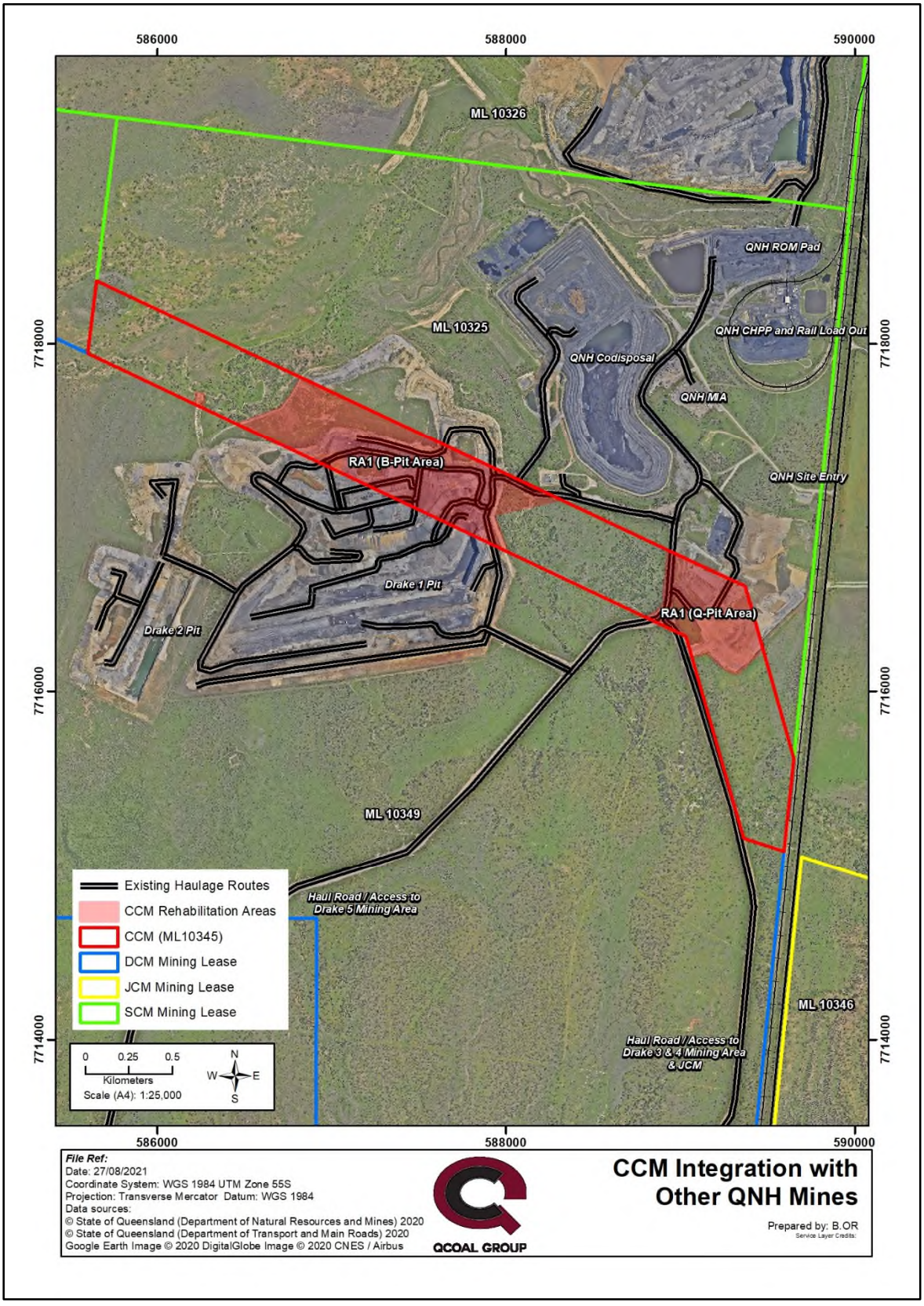


Figure 8 - CCM Interaction with Other QNH Mines

1.6. Site Topography

The CCM is located in the northern Bowen Basin, which extends over approximately 60,000km^2 (60,000,000 ha) of Central Queensland from the town of Collinsville in the north to Theodore in the south. The QNH MLs cover approximately 13,500 ha of that area, of which the CCM (ML10345) covers approximately 211 ha. The topography of the broader QNH is characterized as a flat-to-undulating landscape of alluvial plains and terraces bordering Coral Creek in the north, Two Mile Creek in the centre and the Bowen River in the south.

The topography within the CCM area is flat to slightly undulating, with elevation ranging from 189 m AHD in the east to 153 m AHD in the west. The CCM is located to the north of a low ridgeline which runs east-west and represents a sub-catchment boundary between the Two Mile Creek sub-catchment to the north and the Twelve Mile Gully sub-catchment to the south. Several un-named drainage features traverse the CCM and drain to the north-east towards Two Mile Creek, an ephemeral drainage system which forms an upper tributary of the Bowen River catchment (refer to **Section 1.12.2** for further details). The pre-mining contours and drainage lines (overlain with the February 2020 aerial photography for context) within the CCM area are shown in

Figure 9. Slopes within the CCM generally are less than 3%, with slightly steeper slopes present in some areas adjacent to drainage lines and watercourses.

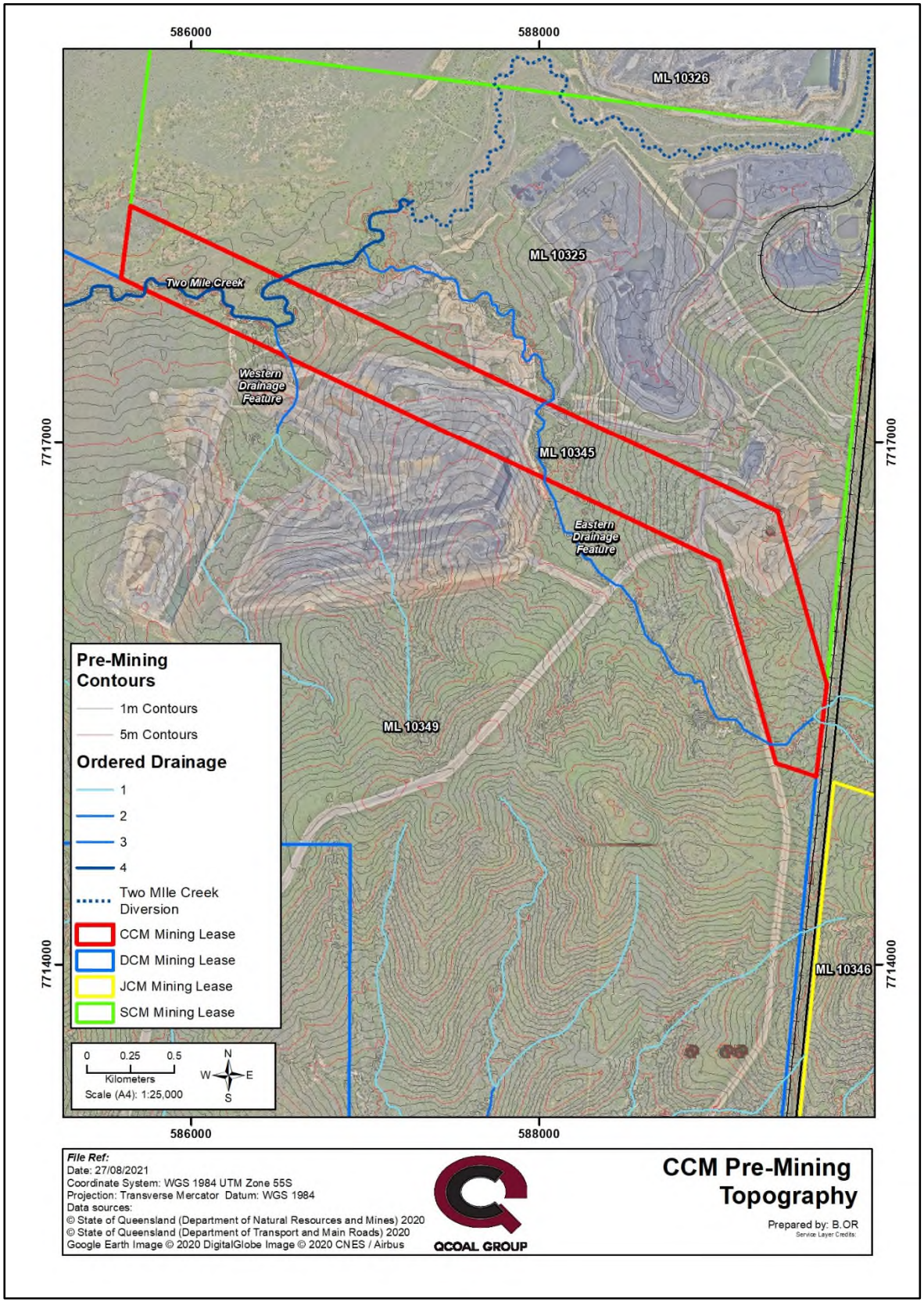


Figure 9 – Pre-Mining Topography

1.7. Climate

The region is characterised by distinct wet and dry seasons, with the majority of rainfall occurring during the summer months, along with higher temperatures and evaporation rates. Average monthly temperature, rainfall and evaporation statistics, as collected at the Bureau of Meteorology's (BoM) Collinsville Post Office Station (no. 033013) are presented in Figure 10 – CCM Climate Averages**Figure 10**.

The average annual rainfall for the CCM area is 701.6 mm and the average annual evaporation is 1,861.5 mm (BoM, 2019). As such, the region is subject to net annual evaporation, and is dry for much of the year. The rainfall averages indicate a distinct wet season between December and March and dry season between June and October. Predominant winds are south-easterly for the majority of the year.

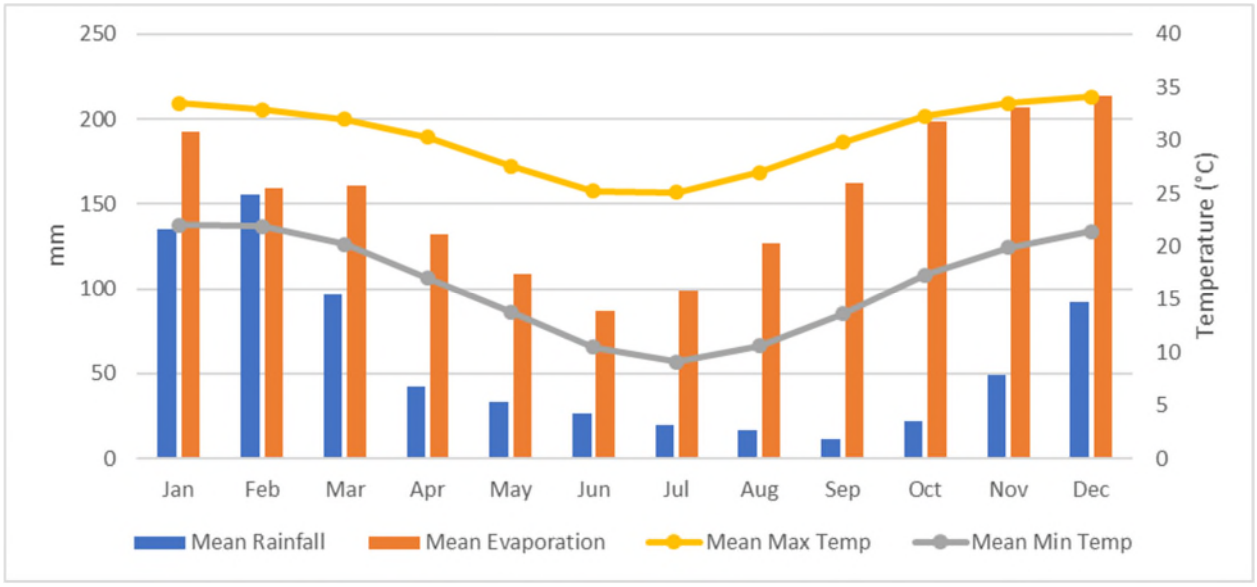


Figure 10 – CCM Climate Averages

1.8. Geological Setting

The CCM is located in the northern Bowen Basin, with the target seams forming part of the Moranbah Coal Measures (MCM). The stratigraphic sequence for the CCM represents a continuation of the same geology from the SCM through the CCM and into the DCM and JCM (as evidenced by Q-Pit and B-Pit targeting the same coal seams across ML boundaries). As such the stratigraphy (coal seams, overburden and interburden sequences) and the associated characteristics of the various stratigraphic units is generally consistent across the four QNH mines. Geotechnical, geochemical and coal quality characteristics observed in one QNH mine can therefore be adopted for the same material in another of the QNH mines.

1.8.1. Regional Geology

The CCM is located in the northern Bowen Basin, where active subsidence and deposition during the Permo-Triassic was centred within an extensional terrain known as the Taroom Trough. This deposition centre was situated marginal to the Collinsville Shelf in the west, which typically behaved as a stable platform throughout. The deformed Taroom Trough is defined by the Nebo Synclinorium, where contained sediments and volcanics of the western two-thirds dip gently toward the major synclinal axis in the east. Post-depositional compression has resulted in a fold-and-thrust style of deformation, particularly on the eastern side of the basin where sediments along this margin tend to dip steeply westward.

Economic coal measures within the Bowen Basin have been classified into four groups (Mutton, 2003):

I. The oldest (Early Permian) coals are restricted to the southwest areas of the Bowen Basin (e.g. at Minerva, south of Emerald).

II. The Group II (Early Permian) coal measures comprise several unconnected deposits around the northern and western margins of the Bowen Basin which have been mined by open-cut and underground methods. They include the Blair Athol Coal Measures near Clermont, the Rugby Coal Measures southwest of Moranbah and the Collinsville Coal Measures at Collinsville.

   Martini and Johnson (1987) identified six sedimentary environments in the Collinsville Coal Measures: fluvial, fluvial to paralic, barrier-strand plain, back-barrier, tidal flat and open marine. The basal coal formed from peat of swamps of abandoned areas of gravelly braided streams; the coals are massive, dull and sulphur contents are low (1%). Overlying coals developed from peats formed in fluvial to paralic and paralic environments; these thicker coal seams are generally brighter and have moderate to high total sulphur contents (1-6%). Seams associated with coastal deposits show high sulphur levels (up to 21%).

III. The Group III (Late Permian) coals were deposited on the Collinsville Shelf under conditions which fluctuated between marine-influenced deltaic environments to a fluvial flood-plain environment (Moranbah Coal Measures). The former Belmore Pipeline Mine (Glencore) and the QNH operation (comprising the SCM, CCM, JCM and DCM) occur within the MCM.

   The MCM were deposited in a deltaic environment during the early stage of foreland basin development (Hodgkinson, 2008). The MCM were overlain by the heavily tuff banded Fort Cooper Coal Measures.

   Geochemical analyses for the MCM have shown significantly lower total sulphur content in comparison to the Group II Collinsville Coal Measures described above.

IV. Group IV (Late Permian) coal measures are the most widely distributed in the Basin and were deposited under fluvial, lacustrine and paludal environments. They include the Rangal Coal Measures, Baralaba Coal Measures and equivalents which have been extensively mined since the 1960s.

The wide variety of depositional environments is reflected in the diversity of coal measures (seam thickness, lateral extent and coal quality) within the Bowen Basin, however for the Group III coals (as targeted at the QNH), the physical and chemical characteristics of the non-productive geological sequences (waste rock or spoil materials) are similar throughout the basin.

1.8.2. Site Geology

The local stratigraphy in the CCM area comprises the basal Blenheim Formation overlain by the marine Exmoor Formation, non-marine Blackwater Group, and Tertiary sediments of the Suttor Formation and equivalents (**Figure 11**). The Blackwater Group includes the target Moranbah Coal Measures.

As previously noted, the stratigraphic sequence for the CCM is mirrored at each of the four QNH mines. The coal seams, together with the waste rock, are readily correlated between all four sites. Accordingly, analysis of the waste rock at each of the mines has confirmed similar waste rock characteristics (see **Section 1.10**). In the specific case of the CCM, both the B-Pit and Q-Pit were continuations of pits from the adjoining SCM (and for the B-Pit further continuation into the DCM). Pits and waste rock dumps span the MLs and consequentially the material being mined in the CCM is the same as the adjoining SCM and DCM for each respective pit.

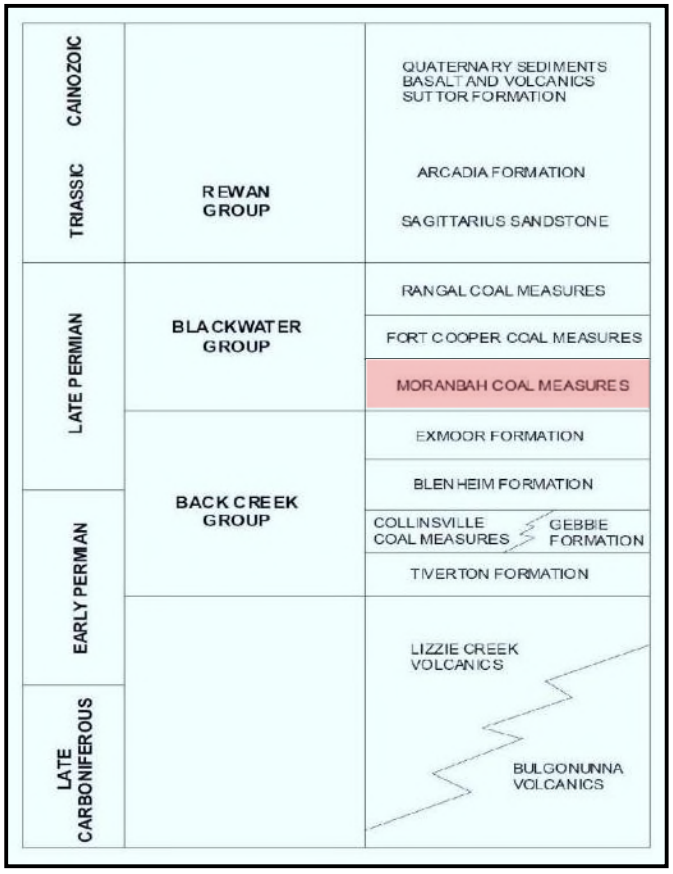


Figure 11 – Bowen Basin Stratigraphy

Geological detail in the QNH area is intermittently obscured by a cover of alluvium and gravel, particularly adjacent to drainage lines and watercourses. This recent (Cainozoic) cover comprises unconsolidated fine to very coarse-grained sand, along with occasional irregularly interbedded silt, clay and gravel lenses. The most persistent gravel bed occurs at the base of the unit and generally comprises markedly rounded pebble to cobble-sized clasts of predominantly andesitic to basaltic composition, set in a silt to clay-rich matrix. The alluvial unit ranges in thickness from a thin veneer in the CCM area to a maximum of 24m to the north of the SCM.

1.8.3. Coal Geology

The MCM contain between three and eight major seams, two of which have been mined at the CCM (refer to **Figure 12**). Historically, the seams have been given the letter designations from A (deepest) to R in accordance with stratigraphic order for seams in the Bowen River area. The relatively thick, low-ash seams distinguish the MCM unit from the overlying Fort Cooper Coal Measures. Interburden rocks consist of quartz-poor lithic sandstones, siltstone, shale, and mudstone. The waste rock sequences have been named based on the underlying and overlying coal seam nomenclature for identification purposes.

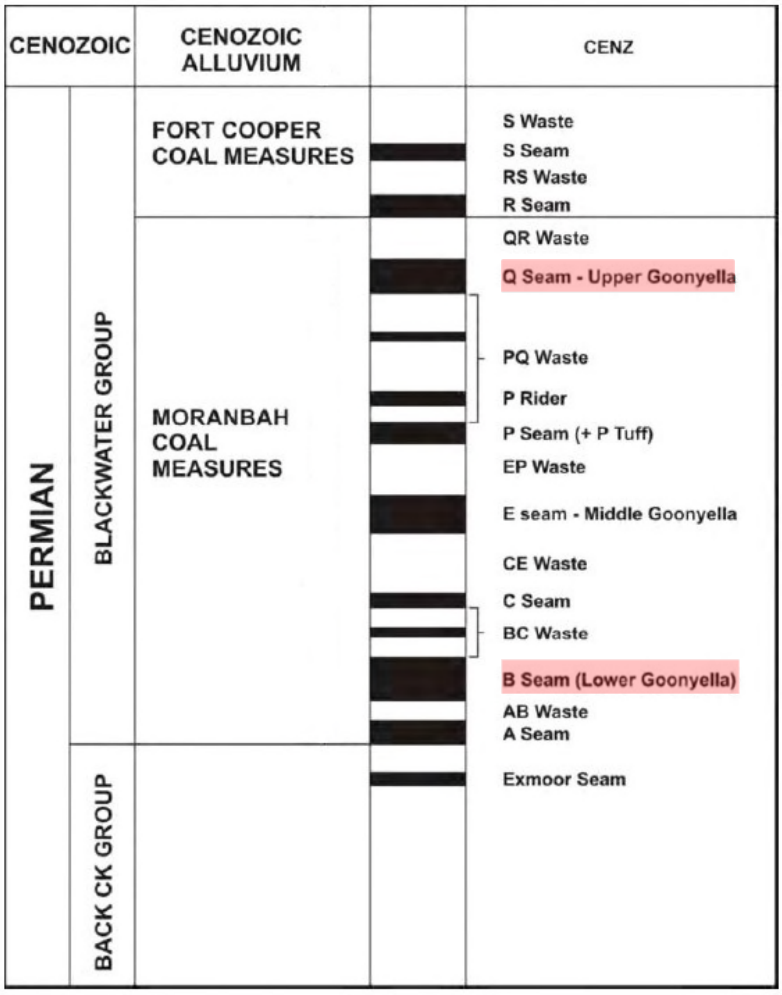


Figure 12 – MCM Coal Seams within the CCM Area

Throughout the QNH area, the geological structure has been subject to igneous intrusions which, where present, have either intruded or otherwise rendered sections of the MCM seams uneconomic. Exploration programs (including airborne magnetic surveys, radiometric surveys, and in particular, exploration drilling) were successful in defining several areas of sub-cropping shallow un-intruded coal.

Figure 13 shows a representative cross-section of the seams present at the CCM (note the underlying A seam is uneconomic and has not been mined at the CCM). A full sequence of MCM seams (refer to **Figure 12**) is not present within the CCM due to northwest trending faulting through the central part of the lease. The target seams at the CCM are described as follows:

- The Q seam (known elsewhere as the Upper Goonyella seam) was identified as subcropping in the north-western corner of the CCM. Q Seam deposits are typically small (<2Mt) deposits of hard coking coal, with an example being the Belmore – Pipeline deposit which is located to the immediate east on the eastern side of the Bowen Development Road, which was mined by the Collinsville Coal Company (owned by Mt Isa Mines, later Xstrata/Glencore) in the early 2000s. A single deposit of high-quality Q seam resource (known as Q-Pit) was identified in the eastern area of the CCM. The Q-Pit was the initial focus of the mining activities at the CCM;
- The B seam (known elsewhere as the Lower Goonyella seam) is separated from the underlying A seam by 15m to 24m of dark grey, fine-grained sandstone, siltstone and carbonaceous mudstone. The B seam at the QNH subcrops at the northern end of the adjacent SCM in the vicinity of Coral Creek. The seam consistently dips at approximately 5° to 7° towards the south and south-southeast. In the area of the CCM, the B seam was approximately 4.5m thick. A single deposit of high-quality B seam resource (known as B-Pit) was identified in the western area of the CCM;

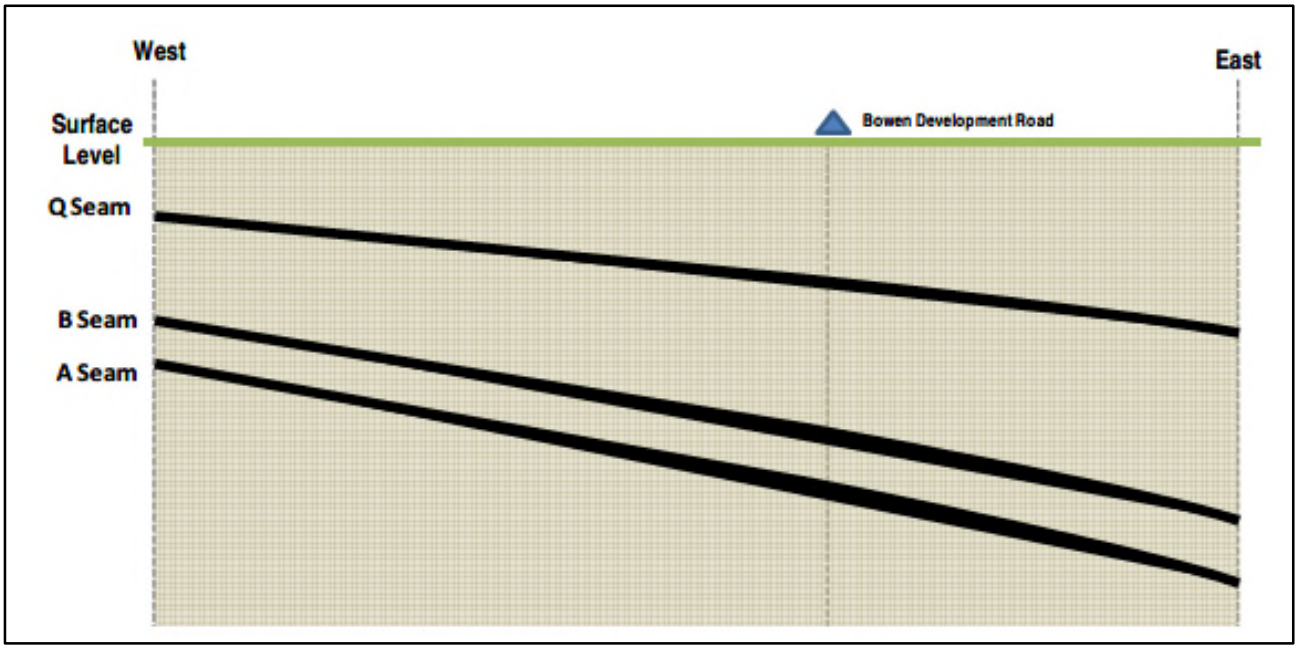


Figure 13 – Representative Cross Section of the Moranbah Coal Seams within the CCM

1.9. Coal and Waste Rock Volumes

Table 7 outlines the mined coal quantities and waste rock volumes for the LOM of the CCM.

Table 7 – CCM LOM Coal and Waste Rock Figures

Pit	Seam	Coal Mined (ROM t)	Total Mined Volume* (bank cubic metres - bcm)	Total Waste Rock Volume** (loose cubic metres - lcm)
Q-Pit	Q	246,788	1,985,285	2,604,285
B-Pit	B	2,211,036	24,246,250	31,147,652
Total		**2,457,824**	**26,231,535**	**33,752,201*** **

*Represents the total volume of the excavated mine pits at the CCM, including coal volumes.
**Includes waste rock used to backfill the voids and waste rock stockpiles.
***Includes 3.5m LCM of waste rock yet to be placed.

A pre-mining estimate was made of the relative proportions for each lithology comprising the waste rock materials at the CCM by reviewing the drill logs of 30 bore holes for a transect across the MCM in the DCM area. With the continuity of the stratigraphic profiles between the DCM and the CCM (as evidenced by the continuation of CCM B-Pit into DCM Drake 1-Pit), this estimate for relative proportion was also utilised at the CCM. Applying the waste rock lithology relative proportions to the total waste rock volume for the CCM (as shown in **Table 7**) gives an estimate for total waste rock volumes for each lithology at the CCM, as presented in **Table 8**.

Table 8 –CCM Waste Rock Volume Estimate by Lithology

Waste Rock Lithologies	Sandstone	Siltstone	Mudstone (Carbonaceous	Igneous	Coal	Total
Ratio to Total Depth Drilled (%)	53.5	21.0	9.0	6.6	9.9	100
Proportion of Waste Rock (%)	59.3	23.3	10.0	7.3	-	100
Indicative Waste Rock Volume (Mlcm)	18.1	7.1	3.0	2.2	-	33.7
Number of Samples	42	23	6	4	0	75

The waste rock at the CCM comprises mainly interbedded quartzose sandstones and siltstones (82.6%), with far lesser quantities of finer-grained sediments such as mudstone/shale/ carbonaceous shale (10.0%) and intrusive lithologies (7.3%).

1.10. Waste Rock Characterisation

A number of geochemical investigations have been undertaken on the QNH sites and other adjoining third-party mines which have provided an understanding of the nature of mining waste to be generated at the QNH mines (including the CCM).

As previously stated, the coal seams and waste rock geology is contiguous through the QNH mines. In the specific case of the CCM, both the B-Pit and Q-Pit were continuations of pits from the adjoining SCM (with the B-Pit further continuing into the DCM). Those pits and waste rock dumps span the MLs and consequentially the material being mined in the CCM is the same as the adjoining SCM and DCM for each respective pit.

Waste rock characterisation investigations/assessments that have been undertaken for the QNH mines and other relevant adjoining mines include, but are not limited to, the following:

- *Cows Coal Project – Waste Rock Report* (Tecsol, 2011)
- *Sonoma Coal Project – Overburden Assessment Report* (Parsons Brinckerhoff, 2006)
- *Drake Coal Project EIS Waste Rock Characterisation Report*. (GHD, 2012)
- *Drake Coal Project SEIS Excavated Waste Characterisation Report* (GHD, 2013)
- *Geochemical Assessment of Mining Waste and Coal Reject Materials, Sonoma Coal Mine* (Terrenus, 2012)
- *Mining Waste and Coal Rejects Management Plan – Sonoma Coal Mine* (Terrenus, 2013)
- *Environmental Management Overview Strategy, Belmore Project - Pipeline Deposit** *(*Collinsville Coal Company, 1999)
  * The Pipeline deposit was geologically contiguous to the CCM/SCM, being a Q-seam deposit located on the eastern side of the Bowen Development Road within ML10250 in close proximity to the CCM/SCM Q-Pit.

The results of these investigations are summarised in the QNH RMP (a LOD), which included geochemical laboratory testing. Those results have informed management of mine waste as is also presented in the QNH RMP.

Results of waste rock analysis undertaken to date across the QNH have been collated to provide a characterisation to assist in the management of mine wastes. **Table 9** details the various geochemical characterisation programs that have been undertaken across the QNH to date.

Table 9 – QNH Geochemical Programs

Year	Site	Bores	Samples Analysed	Study Reference
1999	Belmore (Third-Party Dataset)	7	26	Collinsville Coal Company, 1999
2006	Sonoma	8	14	Parsons Brinckerhoff, 2006
2008	Drake	8	21	GHD, 2012
2008	Jax	22	55	GHD, 2012

2011	Sonoma	4	25	Tecsol, 2011
2012	Drake	16	329	GHD, 2013
Total Samples			444	

Waste rock across the QNH has been found to be non-acid forming (NAF), with only one sample found in carbonaceous shale returning an Uncertain classification (see **Figure 14**). Waste rock was also found to have a low potential for metal leaching and saline runoff. Therefore, the waste rock materials on site are generally classified as low risk for acid mine drainage.

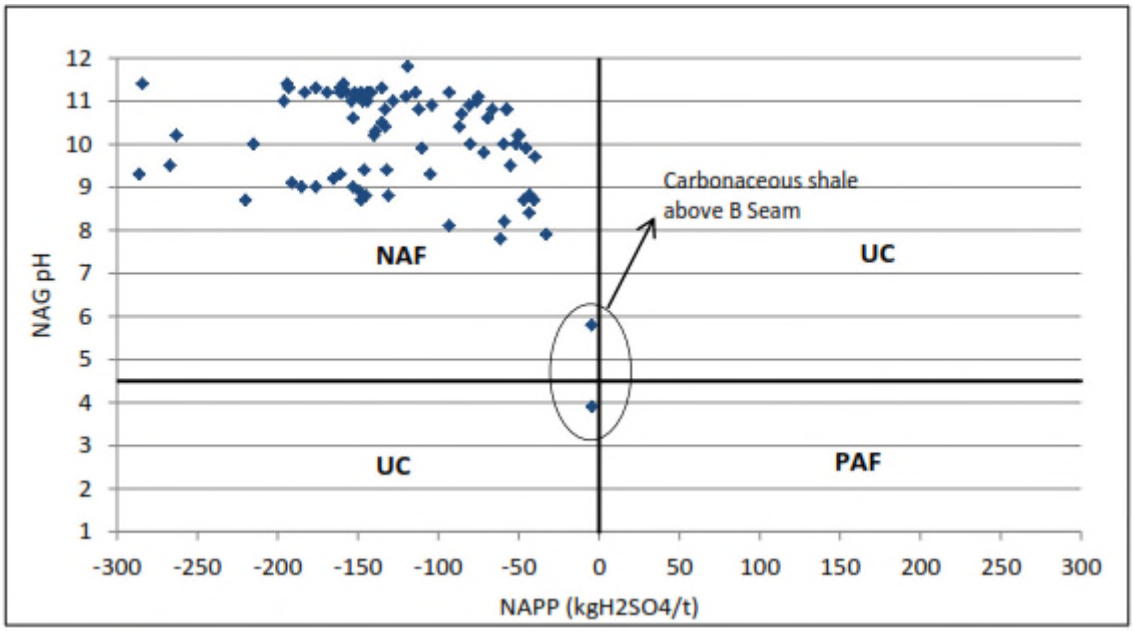


Figure 14 – QNH Waste Rock Characterisation

1.10.1. CCM Waste Rock Characterisation

A review of previous waste rock characterisation studies for the adjacent SCM, DCM as well as the adjacent former Belmore-Pipeline Coal Mine was undertaken to inform CCM waste rock characterisation investigations, as both mines had been developed in the identical and continuous geological formations and stratigraphic sequences to those to be mined at the CCM. These previous investigations had shown that the waste rock is slightly alkaline and has a negligible potential for formation of AMD as follows:

- Waste rock was typically non-acid forming (NAF); however, as a conservative measure, rocks within 1m of coal seams should not be concentrated near the surface of waste rock dumps.
- Tertiary/Quaternary soils were generally slightly alkaline (pH between 7.8 and 8.6) and had low salinity (Electrical Conductivity (EC) of 200 µS/cm) to moderate salinity (EC of 675 µS/cm). A single sample returned moderately high salinity (EC of 924 µS/cm).
- Alluvial soils were found to have low to moderate salinity.

- Weathered Permian rocks were found to have similar salinity, sodicity and alkalinity characteristics to the overlying alluvial soils.
- Fresh Permian rocks had moderately high alkalinity levels and low to moderate salinity.

In order to confirm the above findings and provide CCM specific data as part of the Cows EA application, BRC undertook further testing to assess the geochemical characteristics for a wide range of lithologies from the operating Q-seam pit at Sonoma which abuts the northern boundary (and continued into) the CCM area, and also from the adjoining DCM area.

Results from this additional testing indicated:

- The acid-base accounting (ABA) analyses indicated that waste rock or spoil materials from the Moranbah Coal Measures for the Project area would be non-acid forming (NAF). Coal and other carbonaceous sediments (siltstone and mudstone) have a low potential for acid formation (PAF); however, the impacts of any PAF materials would be negated by the significantly higher neutralising capacity of other lithologies (e.g. quartzose sandstone) placed in the overburden dumps or spoil heaps. Carbonaceous sediments (siltstone and mudstone) which occur interbedded in the coal seams were potentially saline but were intended to be removed from site as a component of the ROM coal.
- Immediately south of the CCM, overburden materials from the DCM and adjacent JCM areas recorded an average EC value of 281.1 µS/cm, which is within the low salinity range of 150 to 450 µS.cm (DME, 1995b). In view of the stratigraphic similarities between mining operations in this region, specific requirements to manage salinity have not been required for overburden dumps in the CCM area, or elsewhere at the QNH mines.
- Total sulphate levels were found to be low. Together, the low sulphate and low EC values provide evidence to support the findings that the overburden materials are not saline.
- Waste rock/soil materials are more likely to disperse when calcium (Ca) / magnesium (Mg) ratios are less than 2 and exchangeable sodium percentages (ESP) are greater than 6%. The analyses confirmed the presence of high Ca/Mg ratios and low ESPs, and therefore significant dispersion of fine materials from overburden dumps is not expected to occur.

Potential environmental risks associated with mining waste (overburden) and coal rejects are mainly associated with Acid Mine Drainage (AMD), the related mobilisation of metals, and saline drainage.

Overburden generated at the CCM is relatively benign and is expected to generate slightly alkaline and low-to-moderately saline runoff and seepage, following surface exposure. No reject material has been generated, handled or disposed of at the CCM, as all coal processing and rejects management occurred offsite at the SCM. Regardless of the classification, waste rock across the four QNH mines sites is managed in accordance with the QNH Mine Waste Management Plan (2020), from which the procedures for managing waste rock have been detailed in **Section 5.2.5**.

Runoff from the CCM is managed under the QNH Water Management Plan (QNH WMP) which includes a specific Erosion and Sediment Control Plan (ESCP), as described in **Section 5.2.8**. Specifically, the runoff from waste rock dumps at the CCM is managed at the SCM for Q-Pit and on both the SCM and DCM for Q-Pit, as the waste rock dump areas on the CCM are shaped to direct

runoff to existing dams on the DM and SCM. However, the non-dispersive nature of the waste rock is such that dispersion of fine materials from overburden dumps is not expected to occur.

These findings have been previously presented in the QNH RMP (a LOD).

1.11. Geotechnical Stability

Assessment of the geotechnical stability of the final landforms is most relevant to walls of any final voids and the slopes of rehabilitated waste rock dumps.

In the case of the CCM there are no final voids requiring consideration, with both pits having been backfilled. When a void is backfilled, waste rock generally fills the void to an elevation which is either a) above the surrounding natural topography in which case by definition the landform becomes a waste rock dump, or b) slightly below the surrounding natural topography to retain a designed and constructed dam. Both the CCM Q-Pit and B-Pit were backfilled to become waste rock dumps.

As such, for the CCM, only the slopes of the rehabilitated waste rock dumps require consideration of geotechnical stability.

Completion criteria for rehabilitation of the QNH mine domains have been developed and are presented in the QNH RMP (a LOD) as measurable/quantifiable criteria which, once achieved, demonstrate that rehabilitated final landforms are (1) safe to humans and wildlife, (2) structurally stable, (3) non-polluting and not causing any environmental harm, and (4) able to self-sustain the agreed post-mining land use).

Specifically Table 12 of the QNH RMP (a LOD) includes approved completion criteria to achieve a geotechnically stable slope of a waste rock dump on the QNH (including the CCM) and states that: "*The nominated maximum slope on dumps is 20% (11.5°), unless otherwise advised by an RPEQ*." Additional completion criteria for slopes also includes groundcover and addressing any observed issues.

The confirmation that the final landforms physically meet the approved design criteria will be done in two stages at the CCM:

- Upon completion of the final landform earthworks in a given area (i.e. RM1), a survey will be undertaken to confirm that the area has been shaped in accordance with the completion criteria (i.e. the slope criteria is achieved). This will be undertaken using internal QCoal engineering/survey resources using either ground or aerial survey equipment and mine planning software; and

- As part of overall certification that a stable landform has been achieved (i.e. RM4), verification of the landform meeting the design criteria will be obtained from an RPEQ.

1.12. Surface Water

1.12.1. Regional Catchment Description

The CCM is located within the Burdekin catchment, which is the second largest in Queensland occupying some 133,000km^2. The Burdekin catchment itself comprises eight major catchments and 52 sub-catchments. Typical annual average rainfalls are 600-700 mm in the upper Burdekin catchment and 800-1000 mm in the lower catchment coastal plains. Dominated by wet summers and dry winters, waterways in the catchment are generally ephemeral and experience peak flows from December to April, with low or negligible flows from May to November.

As shown in **Figure 15**, the CCM is situated within the Pelican Creek sub-catchment of the Bowen Broken Bogie basin, which is located in the upper reaches of the Burdekin catchment. Waterways in the Pelican Creek sub-catchment are highly ephemeral, with flow only occurring after sufficient rainfall events.

The *Burdekin Region Water Quality Improvement Plan 2016* defines priority actions for the management of the Pelican Creek sub-catchment including the management of grazing, mining, industry, and other infrastructure. These actions have been addressed as part of the management of rehabilitation activities at the CCM (refer to **Section 5.1.1**).

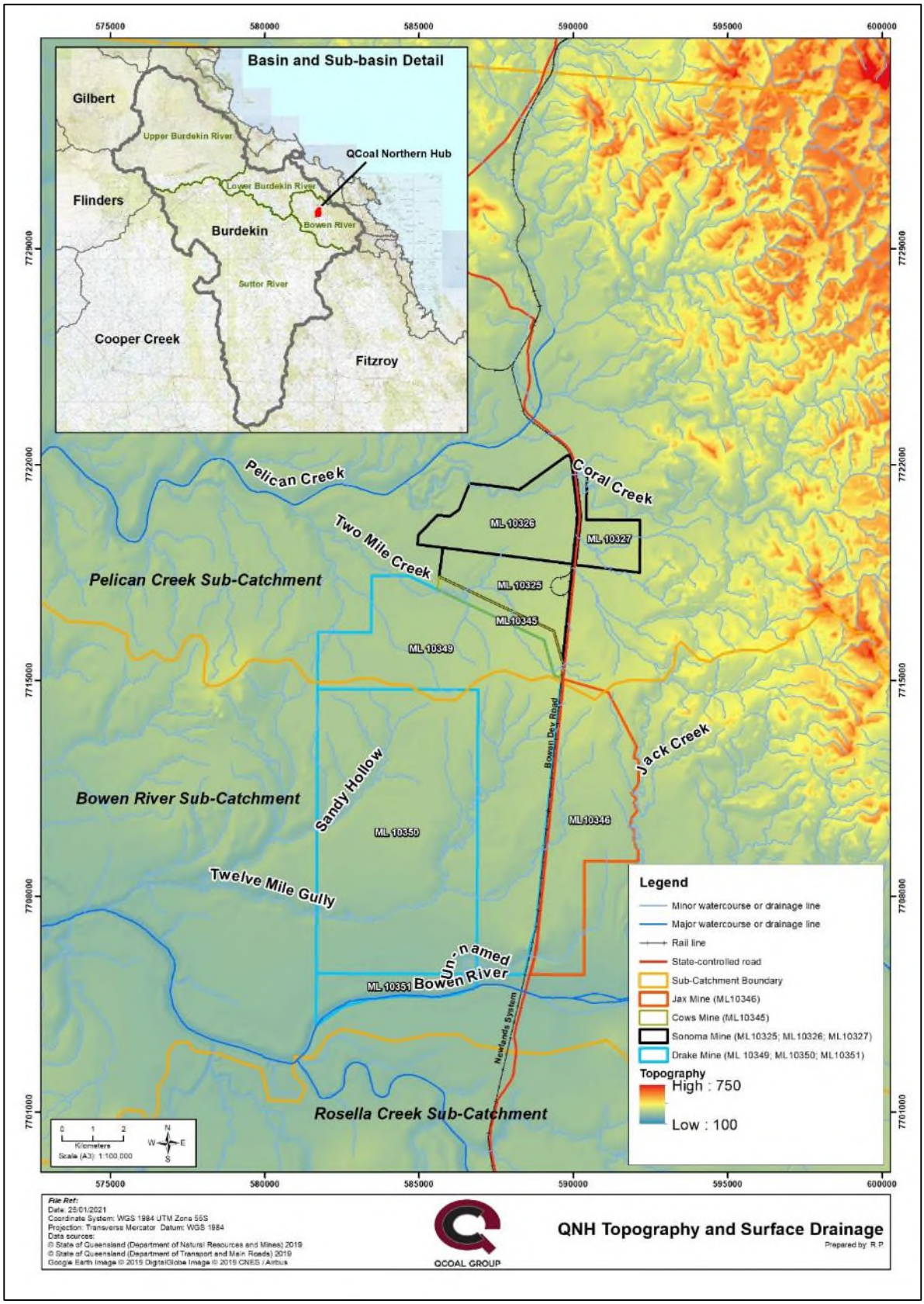


Figure 15 – QNH Topography and Drainage Catchments

1.12.2. Local Catchment Description

The drainage features within the wider QNH and the CCM specifically are shown in **Figure 16** and **Figure 17** and described as follows:

- **Two Mile Creek**: Local surface drainage within the CCM flows to the north-west into Two Mile Creek. Two Mile Creek is an upland ephemeral freshwater stream, only flowing during and immediately after heavy rainfall. Upstream (north) of the CCM, Two Mile Creek previously flowed through the center of the SCM MLs and a section was diverted in 2012 to allow for ongoing mining activities in the southern extent of the SCM Main Pit. This diversion is located entirely upstream of the CCM boundary and the confluences of the drainage lines that traverse the CCM with Two Mile Creek, as shown in **Figure 17**.

  The reach of Two Mile Creek which flows through the CCM is classed as Stream Order 4 under the Strahler Method. The waters of Two Mile Creek flow generally northwest from the western boundary of ML 10345, joining Pelican Creek approximately 6km downstream of the CCM. Pelican Creek (also a highly ephemeral creek that contains occasional intermittent senescing waterholes which dry out during the dry season) then joins the Bowen River approximately 30 km downstream of the Two Mile Creek confluence.

- **Eastern Drainage Feature**: The eastern drainage feature is a Stream Order 2 with a catchment size upstream of the CCM of approximately 500 ha. This drainage feature occurs within a shallow, low-lying area of alluvium which has resulted in a number of braided channels running approximately parallel. The channel upon which the mapped stream is aligned is the more minor of these channels, with a more significant channel running parallel but further east. During operations, the approximately 450m length of the eastern drainage feature within the CCM is crossed by a haul road crossing which will ultimately be removed and rehabilitated when the haul road is no longer required (see **Section 5.3.6**).

- **Western Drainage Feature**: The western drainage feature is a Stream Order 2 with a catchment size upstream of the CCM of approximately 400 Ha. The original alignment of the western drainage feature has been permanently realigned due to the progression of mining activities at the DCM to the south. A 70m length of this realigned drain extends into the CCM area immediately before the confluence with Two Mile Creek, hereafter referred to as the Western Diversion Drain (shown as RA2 in **Figure 7**Error! Reference source not found.).

All drainage features within the CCM area were inspected by the (then) Department of Environment and Resource Management (DERM) during the CCM EA application process. At that time DERM confirmed that only Two-Mile Creek was classified as a ‘watercourse’ under the *Water Act 2000*, and the other drainage features were not considered to be ‘watercourses’.

The drainage features within the site were observed during the field investigations undertaken as part of the CCM approvals process prior to the commencement of mining activities. The drainage

features were observed to be significantly degraded due to long term grazing, with high levels of soil compaction evident across the site.

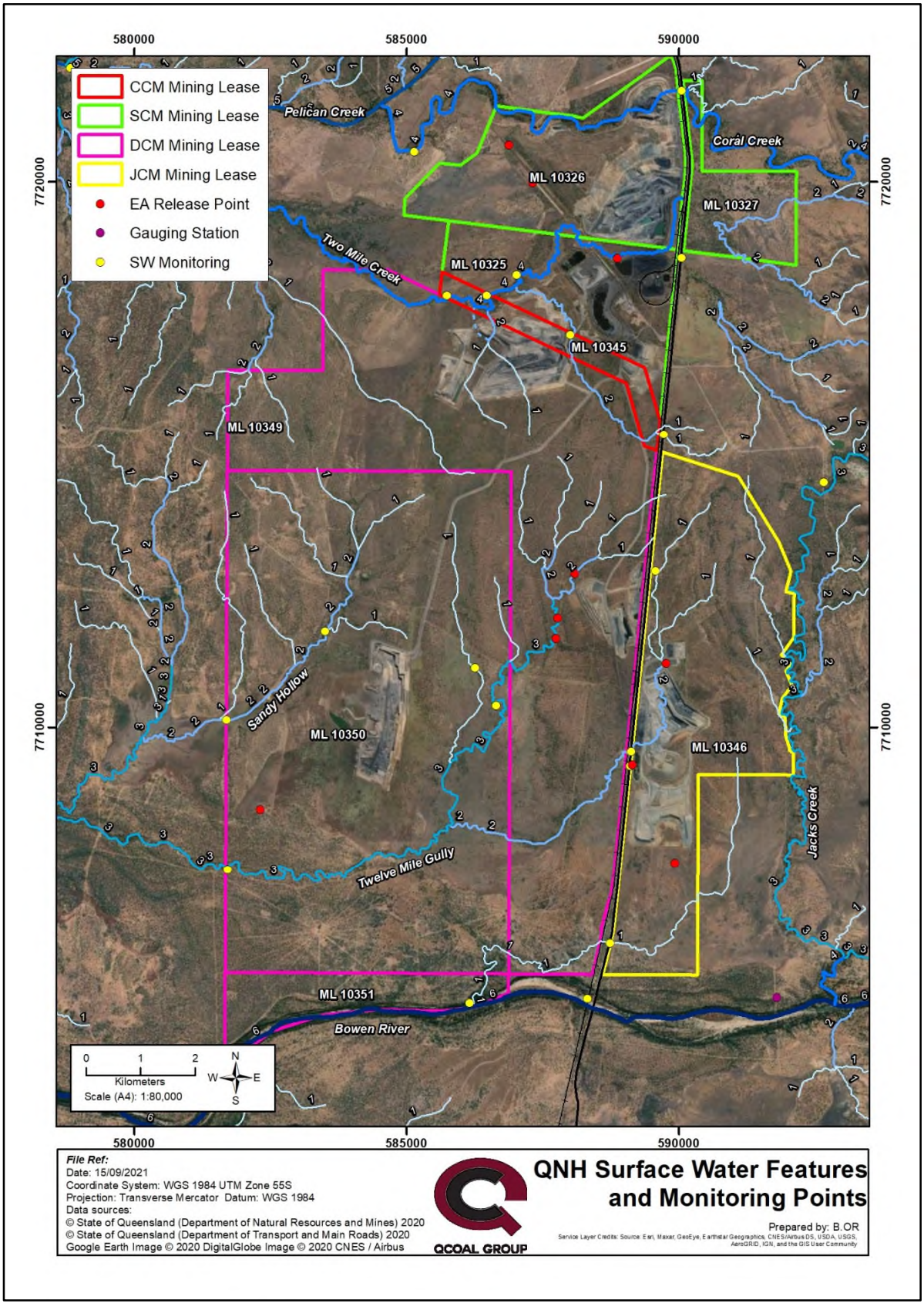


Figure 16 – QNH Surface Water Features

QCOAL GROUP | BOWEN RIVER COAL

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Brisbane Qld 4000

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Cows Coal Mine Progressive Rehabilitation and Closure Plan Consultation Register

Date	Interest Group	Interest Type	Interest Description	Nominated Representative	Consultation Type	Consultation Details	Consultation Outcomes
11/12/2009	Whitsunday Shire Council	Direct - Underlying/ Adjacent Landholder	Landowner - Lot A on AP2839 (Road Reserve) - Entity in control of road/ owner of road under *MR Act*	John Thomas Finlay – Chief Executive Officer	Correspondence Relating to Execution of Compensation Deed	Correspondence relating to the execution of a Compensation Deed for ML10345 application with WRC as 'road owner'	**Decisions:** Agreement to Compensation Deed **Outcomes:** Execution of Compensation Deed **Commitments Made:** Nil
7/10/2020	Mr Christopher Wallin	Direct - Underlying/ Adjacent Landholder	Landholder - Lot A on AP2839 (Road Reserve) - Holder of Permit to Occupy	Christopher Ian Wallin – Managing Director	Meeting in QCoal Corporate Office	Overview of CCM PRC Plan, PMLU and PRCP Schedule.	**Decisions:** Nil **Outcomes:** Nil **Commitments Made:** Nil
7/10/2020	Mr Christopher Wallin	Direct - Adjacent Landholder	Landholder – Belmore West - Lot 1 on SP190745, Freehold	Christopher Ian Wallin – Managing Director	Meeting in QCoal Corporate Office	Overview of CCM PRC Plan, PMLU and PRCP Schedule.	**Decisions:** Nil **Outcomes:** Nil **Commitments Made:** Nil

Date	Interest Group	Interest Type	Interest Description	Nominated Representative	Consultation Type	Consultation Details	Consultation Outcomes
7/10/2020	Captain Nominees Pty Ltd (owned by Mr Christopher Ian Wallin)	Direct - Adjacent Landholder	Landholder – Birralee Station - Lot 618 on SP271121, Lands Lease	Christopher Ian Wallin – Managing Director	Meeting in QCoal Corporate Office	Overview of CCM PRC Plan, PMLU and PRCP Schedule.	**Decisions:** Nil **Outcomes:** Nil **Commitments Made:** Nil
7/10/2020	Sonoma Coal Mine JV (QCoal Sonoma Pty Ltd, JS Sonoma Pty Ltd, CSC Sonoma Pty Ltd and Watami (Qld) Pty Ltd)	Land use – Adjacent Tenure Holder	Owner of adjoining coal mine (MLs 10325, 10326 and 10327)	Christopher Ian Wallin – Managing Director	Meeting in QCoal Corporate Office	Overview of CCM PRC Plan, PMLU and PRCP Schedule.	**Decisions:** Nil **Outcomes:** Nil **Commitments Made:** Nil
7/10/2020	Drake Coal Mine JV (Northern Hub (Drake) Pty Ltd and Drake Coal Pty Ltd)	Land use – Adjacent Tenure Holder	Owner of adjoining coal mine (MLs 10349, 10350 and 10351)	Christopher Ian Wallin – Managing Director	Meeting in QCoal Corporate Office	Overview of CCM PRC Plan, PMLU and PRCP Schedule.	**Decisions:** Nil **Outcomes:** Nil **Commitments Made:** Nil
18/08/2021	Whitsunday Regional Council	Direct - Underlying/ Adjacent Landowner	Landowner - Lot A on AP2839 (Road Reserve) - Entity in control of road/ owner of road under *MR Act*	Jessica Cristaudo	Phone Conversation	Discussion including: - Proposed CCM Final Landform - CCM PMLU - WRC's future intentions for road reserve underlying CCM (Lot A on AP - Potential for future permanent road closure	**Decisions:** Nil **Outcomes:** WRC agreed to provide written confirmation of its intentions regarding the road reserve **Commitments Made:** Nil

Date	Interest Group	Interest Type	Interest Description	Nominated Representative	Consultation Type	Consultation Details	Consultation Outcomes
31/08/2021	Whitsunday Regional Council	Direct - Underlying/ Adjacent Landowner	Landowner - Lot A on AP2839 (Road Reserve) - Entity in control of road/ owner of road under *MR Act*	Jessica Cristaudo	Email Correspondence	Email from WRC confirming that WRC has no intention of changing the existing use of the road reserve (being "Grazing - Reserve, Road or Stock Route"). Noted that should BRC wish to permanently close the road reserve, an application would need to be made through the Department of Resources but continuity of a legal point of access to other properties in the immediate area may be an issue.	**Decisions:** Nil **Outcomes:** WRC confirmed they have no intention of changing the existing use of the road reserve. **Commitments Made:** Nil

Permit

Environmental Protection Act 1994

Environmental authority EPML00334613

This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

Environmental authority number: EPML00334613

Environmental authority takes effect on 9 March 2020

Environmental authority holder(s)

Name(s)	Registered address
Bowen River Coal Pty Ltd	Level 15 40 Creek Street BRISBANE QLD 4001

Environmentally relevant activity and location details

Environmentally relevant activity/activities	Location(s)
Resource Activity, Ancillary 33 - Crushing, milling, grinding or screening, Crushing, grinding, milling or screening more than 5000t of material in a year	ML10345
Resource Activity, Schedule 3, 13: Mining black coal	ML10345
Resource Activity, Ancillary 16 - Extraction and Screening, 2: Extracting, other than by dredging, in a year, the following quantity of material, (b) more than 100,000t but not more than 1,000,000t	ML10345
Resource Activity, Ancillary 63 - Sewage Treatment, 1: Operating sewage treatment works, other than norelease works, with a total daily peak design capacity of, (b-i) more than 100 but not more than 1500EP if treated effluent is discharged from the works to an infiltration trench or through an irrigation scheme	ML10345
Resource Activity, Ancillary 15 - Fuel burning, Using fuel burning equipment that is capable of burning at least 500kg of fuel in an hour	ML10345
Resource Activity, Schedule 3, 09: A mining activity involving drilling, costeaning, pitting or carrying out geological surveys causing significant disturbance	ML10345
Resource Activity, Ancillary 60 - Waste disposal, 1: Operating a facility for disposing of, in a year, the	ML10345

Queensland Government

Environmentally relevant activity/activities	Location(s)
following quantity of waste mentioned in subsection (1) (a), (a) less than 50,000t	

Additional information for applicants

Environmentally relevant activities

The description of any environmentally relevant activity (ERA) for which an environmental authority (EA) is issued is a restatement of the ERA as defined by legislation at the time the EA is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an EA as to the scale, intensity or manner of carrying out an ERA, the conditions prevail to the extent of the inconsistency.

An EA authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the EA specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that an owner or occupier of contaminated land give written notice to the administering authority if they become aware of the following:

- the happening of an event involving a hazardous contaminant on the contaminated land (notice must be given within 24 hours); or
- a change in the condition of the contaminated land (notice must be given within 24 hours); or
- a notifiable activity (as defined in Schedule 3) having been carried out, or is being carried out, on the contaminated land (notice must be given within 20 business days)

that is causing, or is reasonably likely to cause, serious or material environmental harm.

For further information, including the form for giving written notice, refer to the Queensland Government website www.qld.gov.au, using the search term 'duty to notify'.

Take effect

Please note that, in accordance with section 200 of the EP Act, an EA has effect:

a) if the authority is for a prescribed ERA and it states that it takes effect on the day nominated by the holder of the authority in a written notice given to the administering authority-on the nominated day; or

b) if the authority states a day or an event for it to take effect-on the stated day or when the stated event happens; or

c) otherwise- one the day the authority is issued.

However, if the EA is authorising an activity that requires an additional authorisation (a relevant tenure for a resource activity, a development permit under the *Planning Act 2016* or an SDA Approval under the *State Development and Public Works Organisation Act 1971*), this EA will not take effect until the additional authorisation has taken effect.

If this EA takes effect when the additional authorisation takes effect, you must provide the administering authority written notice within 5 business days of receiving notification of the related additional authorisation taking effect.

If you have incorrectly claimed that an additional authorisation is not required, carrying out the ERA without the additional authorisation is not legal and could result in your prosecution for providing false or misleading information or operating without a valid environmental authority.

Gillian Naylor
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

Date issued: 09 March 2020

Enquiries:
Coal & Gemstone Mining
Department of Environment and Science

Phone: 07 4987 9320
Email: crmining@des.qld.gov.au

Obligations under the *Environmental Protection Act 1994*

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the Act:

- general environmental duty (section 319)
- duty to notify environmental harm (section 320-320G)
- offence of causing serious or material environmental harm (sections 437-439)
- offence of causing environmental nuisance (section 440)
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG)
- offence to place contaminant where environmental harm or nuisance may be caused (section 443)

Other permits required

This permit only provides an approval under the *Environmental Protection Act 1994*. In order to lawfully operate you may also require permits / approvals from your local government authority, other business units within the department and other State Government agencies prior to commencing any activity at the site. For example, this may include permits / approvals with your local Council (for planning approval), the Department of Transport and Main Roads (to access state controlled roads), the Department of Natural Resources, Mines and Energy (to clear vegetation), and the Department of Agriculture and Fisheries (to clear marine plants or to obtain a quarry material allocation).

Obligations under the *Mining and Quarrying Safety and Health Act 1999*

If you are operating a quarry, other than a sand and gravel quarry where there is no crushing capability, you will be required to comply with the *Mining and Quarrying Safety and Health Act 1999*. For more information on your obligations under this legislation contact Mine Safety and Health at www.dnrme.qld.gov.au, or phone 13 QGOV (13 74 68) or your local Mines Inspectorate Office.

Development Approval

This permit is not a development approval under the *Planning Act 2016*. The conditions of this environmental authority are separate, and in addition to, any conditions that may be on the development approval. If a copy of this environmental authority is attached to a development approval, it is for information only, and may not be current. Please contact the Department of Environment and Science to ensure that you have the most current version of the environmental authority relating to this site.

Legislative Requirements and Conditions of Environmental Authority

Legislative requirements

Other permits required

This permit only provides an approval under the Environmental Protection Act 1994. In order to lawfully operate you may also require permits / approvals from your local government authority, other business units within the department and other State Government agencies prior to commencing any activity at the site.

Obligations under the Mining and Quarrying Safety and Health Act 1999

If you are operating a quarry, other than a sand and gravel quarry where there is no crushing capability, you will be required to comply with the Mining and Quarrying Safety and Health Act 1999. For more information on your obligations under this legislation contact Mine Safety and Health at www.dnrme.qld.gov.au, or phone 13 QGOV (13 74 68) or your local Mines Inspectorate Office.

Work diary

The environmental authority holder is required under section 318X of the Environmental Protection Act 1994 to maintain a work diary. The work diary is available at www.qld.gov.au using the publication number ESR/2015/1696 as a search term.

Agency interest: General	
Condition number	**Condition**
A1	**Coal extraction** The environmental authority holder is approved for the extraction of **ROM (run-of-mine) coal**.
A2	This environmental authority authorises environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm.
A3	In carrying out the mining activity authorised by this environmental authority, disturbance of land on **Figure 1- Site map, domains and groundwater monitoring locations**: a) may occur in the areas marked 'A'; b) must not occur in the areas marked 'B'; and c) may occur in the areas marked 'C', but only in accordance with **Condition A4**.
A4	Any disturbance within the areas marked 'C' on **Figure 1- Site map, domains and groundwater monitoring locations**: a) is only authorised to the extent reasonably necessary for exploration activities roads, fences, underground services, low-impact telecommunications facilities, electrical sub-stations, transmission grid works and supply network works, storage depots, similar minor infrastructure and ancillary facilities for any of the above; and b) any disturbance within areas marked 'A' or 'C' is not to impact adversely on areas marked 'B'.
A5	The holder of this environmental authority must: a) install all measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority; b) maintain such measures, plant and equipment in a proper and efficient condition; c) operate such measures, plant and equipment in a proper and efficient manner; and d) ensure all instruments and devices used for the measurement or monitoring of any parameter under any condition of this environmental authority are properly calibrated.
A6	**Monitoring** Except where specified otherwise in another condition of this environmental authority, all monitoring records or reports required by this environmental authority must be kept for a period of not less than **five (5) years**.

A7	**Risk management** The holder of this environmental authority must develop and implement a risk management system for mining activities which mirrors the content requirements of the Standard for Risk Management (ISO31000:2009), or the latest edition of an Australian Standard for risk management, to the extent relevant to the environmental management, prior to the commencement of mining activities.
A8	**Notification of emergencies, incidents and exceptions** The holder of this environmental authority must notify the administering authority by written notification within **24 hours**, after becoming aware of any emergency or incident which results in the release of contaminants not in accordance, or reasonably expected to be not in accordance with, the conditions of this environmental authority.
A9	Within **ten (10) business days** following the initial notification of an emergency or incident, or receipt of monitoring results, whichever is the latter, further written advice must be provided to the administering authority, including the following: a) results and interpretation of any samples taken and analysed; b) outcomes of actions taken at the time to prevent or minimise unlawful environmental harm; and c) proposed actions to prevent a recurrence of the emergency or incident.
A10	**Complaints** The holder of this environmental authority must record all environmental complaints received about the mining activities including the following details: a) name, address and contact number for/of the complainant; b) time and date of complaint; c) reasons for the complaint; d) investigations undertaken; e) conclusions formed; f) actions taken to resolve the complaint; g) any abatement measures implemented; and h) person responsible for resolving the complaint.
A11	The holder of this environmental authority must, when requested by the administering authority, undertake relevant specified monitoring within a reasonable timeframe nominated or agreed to by the administering authority to investigate any complaint of environmental harm. The results of the investigation (including an analysis and interpretation of the monitoring results) and abatement measures, where implemented, must be provided to the administering authority within **ten (10) business days** of completion of the investigation, or no later than **ten (10) business days** after the end of the timeframe nominated by the administering authority to undertake the investigation.

A12	**Third Party Reporting** The holder of this environmental authority must: a) within **one (1) year** of the commencement of this authority, obtain from a suitably qualified and experienced third party a report on compliance with the conditions of this environmental authority; b) obtain further such reports at regular intervals not exceeding three years from the completion of the report referred to above; and c) provide each report to the administering authority within **90 days** of its completion.
A13	Where a condition of this environmental authority requires compliance with a standard, policy or guideline published externally to this environmental authority and the standard is amended or changed subsequent to the issue of this environmental authority, the holder of this environmental authority must: a) comply with the amended or changed standard, policy or guideline within **two (2) years** of the amendment or change being made, unless a different period is specified in the amended standard or relevant legislation, or where the amendment or change relates specifically to regulated structures referred to in **Schedule I: *Dams and Levees*** the time specified in that condition; and b) until compliance with the amended or changed standard, policy or guideline is achieved; continue to remain in compliance with the corresponding provision that was current immediately prior to the relevant amendment or change.
Agency interest: Air	
Condition number	**Condition**
B1	**Dust nuisance** The release of dust or particulate matter or (both) resulting from the mining activity must not cause an environmental nuisance at any sensitive or commercial place.

B2	When requested by the administering authority or as a result of a complaint (which is neither frivolous nor vexatious nor based on mistaken belief in the opinion of the authorised officer), dust and particulate monitoring must be undertaken, and the results thereof notified to the administering authority within **14 days** following completion of monitoring. Monitoring must be carried out at a place or places relevant to the potentially affected dust sensitive place as agreed upon with the administering authority. Dust and particulate matter must not exceed the following levels when measured at the agreed locations: a) Dust deposition of 120 milligrams per square metre per day, averaged over **one (1) month**, when monitored in accordance with the most recent version of Australian Standard *AS3580.10.1 Methods for sampling and analysis of ambient air—Determination of particulate matter—Deposited matter – Gravimetric method*; b) A concentration of total particulate matter suspended in the atmosphere of 90 micrograms per cubic metre over a **one (1) year averaging time**, when monitored in accordance with the most recent version of *AS/NZS3580.9.3:2003 Methods for sampling and analysis of ambient air—Determination of suspended particulate matter—Total suspended particulate matter (TSP)—High volume sampler gravimetric method*; c) A concentration of particulate matter with an aerodynamic diameter of less than 10 micrometres (PM_{10}) suspended in the atmosphere of 50 micrograms per cubic metre over a **24-hour averaging time**, when monitored in accordance with the most recent version of either: i) Australian Standard *AS3580.9.6 Methods for sampling and analysis of ambient air—Determination of suspended particulate matter— PM_{10} high volume sampler with size-selective inlet – Gravimetric method*; or ii) Australian Standard *AS3580.9.9 Methods for sampling and analysis of ambient air—Determination of suspended particulate matter— PM_{10} low volume sampler—Gravimetric method*; or iii) Any alternative method of monitoring PM_{10} which may be permitted by the 'Air Quality Sampling Manual' as published from time to time by the administering authority. **NOTE:** The exceedances of PM_{10} above 50 micrograms per cubic metre over a 24-hour averaging time as a result of bushfires, dust storms and fuel reduction burning for fire management purposes are not considered a breach of **Condition B2 (b).**
B3	If the monitoring undertaken as per **Condition B2** indicates an exceedance of the relevant limits in **Condition B2**, then the environmental authority holder must 1) investigate whether the exceedance is due to emissions from the mining activities and if the exceedance is due to mining activities the environmental authority holder must immediately implement dust abatement measures so that emissions of dust from the activity do not result in further environmental nuisance; and 2) notify the administering authority within **seven (7) days** of the exceedance occurring. The notification must also include the actions taken in accordance with **Condition B3(1)**.

B4	**Dust Management Plan** A Dust Management Plan must be developed and implemented by an appropriately qualified person for all stages of the authorised mining activities. The Dust Management Plan must be submitted to the administering authority for review and comment by **30 June 2019**.
B5	The Dust Management Plan required by **Condition B4** must include: a) a preventative management system for dust control; b) Trigger Action Response Program; c) Site background (contextual information); d) Proposed works and potential impacts & impact analysis; e) Site risk assessment; f) Design of an internal operational monitoring program including objectives, separate from any compliance monitoring or limits/levels required by **Condition B2**; g) Performance criteria and monitoring methods; h) Number and location of monitoring sites; i) Quality assurance/quality control (QA/QC) requirements; j) Stakeholder consultation; k) Roles and responsibilities; and l) Reporting
B6	The dust management plan required by **Condition B4** must be reviewed annually and submitted to the administering authority upon request.

Agency interest: Waste Management	
Condition number	**Condition**
C1	**Burning Waste** Unless otherwise permitted by the conditions of this environmental authority or with prior approval from the administering authority and in accordance with a relevant standard operating procedure, waste must not be burnt.
C2	The holder of this environmental authority may burn vegetation cleared in the course of carrying out extraction activities provided that the activity does not cause environmental harm at any sensitive place or commercial place.
C3	Disposing of scrap tyres generated from the mining activities undertaken in spoil emplacements located on ML10345 is acceptable, provided tyres are placed as deep in spoil located on ML10345 as reasonably practicable.
C4	The holder of the environmental authority must keep a record of the number and location of scrap tyres disposed of in accordance with **Condition C4**.
C5	Scrap tyres resulting from the mining activities disposed within the operational land must not impede saturated aquifers or compromise the stability of the consolidated landform.
C6	**Storage of Tyres** Scrap tyres stored awaiting disposal or transport for take-back and recycling, or waste-to-energy options must be stored in stable stacks and at least **ten (10) metres** from any other scrap tyre storage area, or combustible or flammable material, including vegetation.
C7	All reasonable and practicable fire prevention measures must be implemented, including removal of grass and other materials within a **ten (10) metre** radius of the scrap tyre storage area.

C8	**Waste Management** A Waste Management Plan, in accordance with the *Waste Reduction and Recycling Act 2011,* must be implemented and must cover: a) describe how Byerwen Coal Mine recognise and apply the waste and resource management hierarchy; b) identify the waste streams from the project; c) a program for safe recycling or disposal of all wastes- reusing and recycling where possible; d) the waste management control strategies must consider: 1. the type of wastes; 2. segregation of the wastes; 3. storage of the wastes; 4. transport of the wastes; 5. monitoring and reporting matters concerning the waste; 6. emergency response planning; 7. disposal, reused and recycling options; e) detail the hazardous characteristics of the waste generated (if any); f) cover a disposal procedure for hazardous wastes; g) outline the process to be implemented to allow for continuous improvement of the waste management systems h) identify responsible staff (positions) for implementing, managing and reporting the Waste Management Plan; and i) cover a staff awareness and induction program that encourages re-use and recycling.
C9	Regulated waste records must be kept for **five (5) years**, and must include the following information: a) date of pickup of waste; b) description of waste; c) cross reference to relevant waste transport documentation; d) quantity of waste; e) origin of the waste; f) destination of the waste; and g) intended fate of the waste, for example, type of waste treatment, reprocessing or disposal. **Note**: *Records of documents maintained in compliance with a waste tracking system established under the* Environmental Protection Act 1994 *or any other law for regulated waste will be deemed to satisfy this condition.*

C10	Records of trade and regulated wastes or material leaving the mining lease for recycling or disposal, including the final destination and method of treatment, must be in accordance with the Waste Reduction and Recycling Act 2011
C11	All regulated waste received at and removed from the site must be transported by a person who holds a current authority to transport such waste under the provisions of the *Environmental Protection Act 1994*.
C12	Except as otherwise provided by the conditions of this authority, all waste removed from the site must be taken to a facility that is lawfully allowed to accept such waste under the provisions of the *Environmental Protection Act 1994*.

Agency interest: Noise and Vibration	
Condition number	**Condition**
D1	**Noise** Noise resulting from the authorised mining activities must not cause an environmental nuisance at any sensitive or commercial place.
D2	When requested by the administering authority, or as a result of a complaint noise monitoring must be undertaken and the results must be notified within **14 days** to the administering authority following completion of monitoring. Monitoring must be carried out at a place or places relevant to the potentially affected noise sensitive place as agreed upon with the administering authority.
D3	**Low Frequency Noise** Noise emissions from the activity, when including substantial low frequency noise, must not cause an overall sound pressure level at a noise sensitive place exceeding 55 dB(Z). **NOTE***:* "*Substantial low frequency noise*" means a noise emission that has an unbalanced frequency spectrum shown in a one-third octave band measurements, with a predominant component located within the frequency range 10 to 200 Hz.
D4	All noise monitoring which is conducted as per **Condition D2** must be completed in accordance with the following noise monitoring requirements: a) All noise monitoring must be conducted in accordance with the administering authority's most recent version of the Noise Measurement Manual. b) Source noise levels must be expressed as component noise levels for the purposes of comparison with noise limits. c) All noise monitoring devices must be calibrated in accordance with AS IEC 61672.1-2004. d) Monitoring location(s) must be relevant to the matter(s) under investigation.
D5	If the administering authority request for noise monitoring is in relation to a complaint and results exceed the limits in **Table D1 - Noise limits**, then the environmental authority holder must: a) address the complaint including the use of appropriate dispute resolution if required; and b) implement noise abatement measures so that emissions of noise from the activity do not result in further environmental nuisance.
D6	**Blasting** Peak particle velocity and/or air blast overpressure resulting from blasting must not cause an environmental nuisance at any sensitive or commercial place.

D7	The holder of this environmental authority must develop and implement a blast monitoring program to monitor compliance with **Table D2 – Blasting noise limits** for: a) at least 50% of all blasts undertaken on this site in each month at the nearest and most affected sensitive place(s) or commercial place(s). b) all blasts conducted during any time period specified by the administering authority at the nearest and most affected sensitive place(s) or commercial place(s) or another such place to investigate an allegation of environmental nuisance caused by blasting.
D8	If the results of blast monitoring undertaken as per **Condition D7** exceed the limits in **Table D2 – Blasting noise limits**, then the environmental authority holder must investigate and report to the administering authority within **14 days** following completion of monitoring.

Table D1 – Noise limits

Noise level dB(A)	Monday to Sunday (including public holidays)		
	7am – 6pm	6pm – 10pm	10pm – 7am
	Noise measured at a **nuisance sensitive** or **commercial place**		
$LA_{eq\ adj,10}$	Background Plus 5	Background Plus 5	Background Plus 3
$LA_{1adj,10}$	Background Plus 10	Background Plus 10	Background Plus 5

NOTE - Associated notes and requirements:

a) "Background" means background noise level, measured in the absence of the noise under investigation, as **LA90,T** being the A-weighted sound pressure level exceeded for ninety (90) per cent of the time period of 15 minutes, using Fast response.

b) "**LAeq adj,T"** means the equivalent continuous A-weighted sound pressure level, adjusted for noise character, measured in the presence of the noise under investigation over a time period of 10 minutes, using Fast response.

c) "**LA1 adj,T**" means the A-weighted sound pressure level, adjusted for noise character, measured in the presence of the noise under investigation and exceeded for one (1) per cent of the time period of 10 minutes, using Fast response.

Table D2 – Blasting noise limits

Blasting noise limits	Sensitive or commercial Blasting noise limits place limits	
	Daytime 7am to 6pm	**Evening/Night/Early Morning 6pm to 7am**
Airblast overpressure	115 dB (Linear) Peak for nine (9) out of ten (10) consecutive blasts initiated and not greater than 120 dB (Linear) Peak at any time	No blasting is allowed during these times
Ground vibration peak particle velocity	5mm/second peak particle velocity for nine (9) out of ten (10) consecutive blasts and not greater than 10 mm/second peak particle velocity at any time	No blasting is allowed during these times

Agency interest: Groundwater	
Condition number	**Condition**
E1	The holder of this environmental authority must not release contaminants to groundwater.
E2	**Groundwater Monitoring** All determinations of groundwater quality and biological monitoring must be performed by an appropriately qualified person.
E3	**Groundwater quality** Groundwater must be monitored at the locations and frequencies described in **Table E1 - Groundwater monitoring locations and frequency** and **Figure 1- Site map, domains and groundwater monitoring locations.**
E4	The quality characteristics and/or trigger levels must be reviewed in relation to immediately adjacent operating coal mines by **30 June 2021** to adequately determine the water quality characteristics and trigger levels for inclusion in this environmental authority.

E5	**Groundwater standing water level** In the event that groundwater fluctuations in excess of two (2) metres per year are detected at the monitoring bores in **Table E1 - Groundwater monitoring locations and frequency**, the holder of this environmental authority must compare the groundwater fluctuation results to a suitable reference bore for that location and aquifer and: 1) if the bore result is less than the reference bore data, then no action is to be taken; or 2) if the fluctuation in the bore result is greater than the reference bore data, undertake an investigation within **14 days; and** a) Within **ten (10) business days** of receiving the result of the investigation, complete, and submit a report via WaTERS outlining: i. Details of the investigations carried out, ii. Whether the result is directly associated with mining activities, and, if so: 1. Whether environmental harm has occurred, and 2. Any action required to mitigate environmental harm.
E6	**Annual Groundwater Monitoring Review** The groundwater monitoring data must be reviewed on an annual basis. The review must include the assessment of groundwater levels and quality data, and the suitability of the monitoring network. The assessment must be submitted to the administering authority within **28 days** of receiving the report.
E7	**Bore construction and maintenance and decommissioning** The construction, maintenance and management and decommissioning of groundwater bores (including groundwater monitoring bores) must be undertaken in a manner that prevents or minimises impacts to the environment and ensures the integrity of the bores to obtain accurate monitoring.

Table E1 - Groundwater monitoring locations and frequency

Monitoring Point	Location		Aquifer	Screen depth (m)[1]	Surface RL (m)[2]	Monitoring Frequency[3]
	Latitude	Longitude				
CW075	-20.647660	147.848871	Moranbah Coal measures	TBD	174.18	Quarterly
CW079	-20.648400	147.850805	Moranbah Coal measures	TBD	179.38	
CW053	-20.634205	147.826788	Moranbah Coal measures	TBD	156.71	
CW061	-20.635930	147.826884	Moranbah Coal measures	TBD	156.90	

NOTE:
[1]Screen depths are to be installed and will be included in this EA following the review in accordance with condition E6.
[2]RL must be calculated from the nearest 5cm from the top of the bore casing.
[3]Monitoring is not required where a bore has been removed as a direct result of the mining activity.

Agency interest: Water	
Condition number	**Condition**
F1	Contaminants that will, or have the potential to cause environmental harm, must not be released directly or indirectly to any waters as a result of the authorised mining activities, except as permitted under the conditions of this environmental authority.
F2	The release of mine affected water to waters must only occur from the release points specified in **Table F1- Mine affected water release points, sources and receiving waters** and depicted in **Figure 2 - Mine affected water release points, sources and receiving waters** attached to this environmental authority.
F3	The release of mine affected water to waters from the release points must be monitored at the locations specified in **Table F1- Mine affected water release points, sources and receiving waters** for each quality characteristic and at the frequency specified in **Table F2 Mine affected water release limits** and **Table F3 - Release contaminant trigger investigation levels, potential contaminants**. **NOTE:** The administering authority will take into consideration any extenuating circumstances prior to determining an appropriate enforcement response in the event **Condition F5** is contravened due to a temporary lack of safe or practical access. The administering authority expects the environmental authority holder to take all reasonable and practicable measures to maintain safe and practical access to designated monitoring locations.
F4	The release of mine affected water to waters in accordance with **Condition F2** must not exceed the release limits stated in **Table F2 - Mine affected water release limits** when measured at the monitoring points specified in **Table F1- Mine affected water release points, sources and receiving waters** for each quality characteristic.

F5	If quality characteristics of the release exceed any of the trigger levels specified in **Table F3 - Release contaminant trigger investigation levels, potential contaminants** during a release event, the environmental authority holder must compare the downstream results in the receiving waters (**Table F6 - Receiving water upstream background sites and downstream monitoring points**) to the trigger values specified in **Table F3 - Release contaminant trigger investigation levels, potential contaminants** and: 1) where the trigger values are not exceeded then no action is to be taken; or 2) where the downstream results exceed the trigger values specified in **Table F3 - Release contaminant trigger investigation levels, potential contaminants** for any quality characteristic, compare the results of the downstream site to the data from background monitoring sites (**Table F6 - Receiving water upstream background sites and downstream monitoring points**); and a. if the result is less than the background monitoring site data, then no action is to be taken; or b. if the result is greater than the background monitoring site data, notify the administering authority via WaTERS within **24 hours** of receiving the result, and complete an investigation and provide a written report to the administering authority via WaTERS within **28 days** of receiving the result, outlining i. details of the investigations carried out; and ii. whether the result is directly associated with mining activities, and, if so: 1. whether environmental harm has occurred, and 2. actions taken to prevent environmental harm. **NOTE:** Where an exceedance of a trigger level has occurred and is being investigated, in accordance with **F5(2)(b)** of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.
F6	**Mine affected water release events** The holder must ensure a stream flow gauging station/s is installed, operated and maintained to determine and record stream flows at the locations and flow recording frequency specified in **Table F4 - Mine affected water release during flow events**.
F7	The release of mine affected water to waters in accordance with **Condition F2** must only take place during periods of natural flow in accordance with the receiving water flow criteria for discharge specified in **Table F4 - Mine affected water release during flow events** for the release point(s) specified in **Table F1 - Mine affected water release points, sources and receiving waters**.

Table F1 - Mine Affected Water Release Points, Sources and Receiving Waters

Release Point (RP)[1]	Latitude	Longitude	Mine Affected Water Source and Location	Monitoring Point	Receiving waters description
RP1	-20.652768	147.855504	Control Sediment Dam 1	Spillway	Two Mile Creek
RP2	-20.645445	147.847256	Control Sediment Dam 2	Spillway	Two Mile Creek

NOTE: 1. Where fixed release infrastructure is not currently installed portable pipes and pumps will be utilised.

F8	The daily quantity of mine affected water released from each release point must be measured and recorded.
F9	Releases to waters must be undertaken so as not to cause erosion of the bed and banks of the receiving waters, or cause a material build-up of sediment in such waters.
F10	**Notification of release event** The environmental authority holder must notify the administering authority via WaTERS as soon as practicable and no later than **24 hours** after commencing to release mine affected water to the receiving environment. Notification must include the submission of written advice to the administering authority of the following information: a) release commencement date/time; b) release point/s; c) release rate; d) release salinity and/or electrical conductivity; e) receiving water/s including the natural flow rate; and f) details regarding the compliance of the release with the conditions of **Schedule F – Water**.
F11	The environmental authority holder must notify the administering authority via WaTERS as soon as practicable, and no later than **24 hours** after cessation of a release notified under **Condition F10**. The cessation notification must include the following information: a) release cessation date and time; b) release point/s; c) release rate; d) water quality of release; e) total volume of water released; f) natural flow rate in the receiving water; and g) details regarding the compliance of the release with the conditions of this environmental authority. Note: Successive or intermittent releases from a Release Point occurring within 24 hours of the cessation of any individual release can be considered part of a single release event and do not require individual notification for the purpose of compliance with conditions F10, F11 and F12, provided the relevant details of the release are included within the notification provided in accordance with conditions F10, F11 and F12.
F12	The environmental authority holder must within **twenty-eight (28) days** after cessation of a release event notified under **Condition F10** provide a report to the administering authority via WaTERS, which must include the following information: a) all continuous and in-situ water quality monitoring results (including laboratory analyses); and b) any further matters pertinent to the water release event.

F13	**Notification of release event exceedance** If the release limits defined in **Table F2 - Mine affected water release limits** are exceeded, the holder of the environmental authority must notify the administering authority within 24 hours of receiving the results.
F14	The environmental authority holder must, within **28 days** of a release that is not compliant with the conditions of this environmental authority, provide a report to the administering authority via WaTERS detailing: a) the reason for the release; b) the location of the release; c) the total volume of the release and which (if any) part of this volume was non-compliant; d) the total duration of the release and which (if any) part of this period was non-compliant; e) all water quality monitoring results (including all laboratory analyses); f) identification of any environmental harm as a result of the non-compliance; g) all calculations; h) any other matters pertinent to the water release event.
F15	**Receiving environment monitoring and contaminant trigger levels** The quality of the receiving waters must be monitored at the locations specified in **Table F6 - Receiving water upstream background sites and downstream monitoring points** and **Figure 2 Mine affected water release points, sources and receiving waters** for each quality characteristic and at the monitoring frequency stated in **Table F5 - Receiving waters contaminant trigger levels**.

F16	If quality characteristics of the receiving water at the downstream monitoring points (**Table F6 - Receiving water upstream background sites and downstream monitoring points**) exceed any of the trigger levels specified in **Table F5 - Receiving waters contaminant trigger levels** during a release event, the environmental authority holder must compare the downstream results to the results from the upstream monitoring points (**Table F6 - Receiving water upstream background sites and downstream monitoring points**) in the receiving waters and: 1) if the result is less than the upstream monitoring data, then no action is to be taken; or 2) if the result is greater than the upstream monitoring data, notify the administering authority via WaTERS within **24 hours** of receiving the result, and complete an investigation and provide a written report to the administering authority via WaTERS within **28 days** of receiving the result, outlining a. details of the investigations carried out; and b. whether the result is directly associated with the release, and, if so: i. whether environmental harm has occurred, and ii. actions taken to prevent environmental harm. **NOTE:** Where an exceedance of a trigger level has occurred and is being investigated, in accordance with **Condition F16(2)** of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.
F17	All determinations of water quality and biological monitoring must be performed by an appropriately qualified person.

Table F2 - Mine Affected Water Release Limits

Quality Parameter^	Release Limits	Monitoring frequency[1]	Comment
Electrical conductivity (µS/cm)	Release limits specified in **Table F4**	Daily during release (the first sample must be taken within 2 hours of commencement of release)	-
pH (pH Unit)	6.5 (minimum) 9.0 (maximum)	Daily during release (the first sample must be taken within 2 hours of commencement of release)	-
Turbidity (NTU)	300	At commencement and prior to cessation of release (at a minimum) and weekly during a release[3]	Turbidity is required to assess ecosystem impacts and can provide instantaneous results.

NOTE:

^The quality characteristics required to be monitored as per **Table F2** must be reviewed in relation to immediately adjacent operating coal mines by **30 June 2021** to adequately demonstrate negligible environmental risk.

[1]The determination of suitability for release of water should be informed by monitoring undertaken prior to release.

Table F3 - Release contaminant trigger investigation levels, potential contaminants

Quality Parameter	Trigger Levels (µg/L)	Comment on Trigger Level	Monitoring Frequency
Aluminium	82	80th percentile of background	Commencement of release and thereafter weekly during release
Arsenic	13	For aquatic ecosystem protection, based on SMD guideline	
Cadmium	0.2	For aquatic ecosystem protection, based on SMD guideline	
Chromium	1	For aquatic ecosystem protection, based on SMD guideline	
Copper	2	For aquatic ecosystem protection, based on LOR for ICPMS	
Iron	300	For aquatic ecosystem protection, based on low reliability guideline	
Lead	4	For aquatic ecosystem protection, based on SMD guideline	
Mercury	0.2	For ecosystem protection based on LOR for CVFIMS	
Nickel	11	For aquatic ecosystem protection, based on SMD guideline	
Zinc	8	For aquatic ecosystem protection, based on SMD guideline	
Boron	370	For aquatic ecosystem protection, based on SMD guideline	
Cobalt	90	For aquatic ecosystem protection, based on low reliability guideline	
Manganese	1,900	For aquatic ecosystem protection, based on SMD guideline	
Molybdenum	34	For aquatic ecosystem protection, based on low reliability guideline	
Selenium	10	For aquatic ecosystem protection, based on LOR for ICPMS	
Silver	1	For aquatic ecosystem protection, based on LOR for ICPMS	
Uranium	1	For aquatic ecosystem protection, based on LOR for ICPMS	
Vanadium	10	For aquatic ecosystem protection, based on LOR for ICPMS	
Ammonia	900	For aquatic ecosystem protection, based on SMD guideline	
Nitrate	1,100	For aquatic ecosystem protection, based on ambient Qld WQ Guidelines (2006) for TN	
Petroleum hydrocarbons (C6-C9)	20	For aquatic ecosystem protection, based on LOR	
Petroleum hydrocarbons (C10-C36)	100	For aquatic ecosystem protection, based on LOR	
Fluoride (total)	2,000	Protection of livestock and short term irrigation guideline	
Sodium	250,000	Based on Australian Drinking Water Guidelines	

NOTE:

i) All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/metalloids apply if dissolved results exceed trigger.

ii) The quality characteristics required to be monitored as per **Table F3** must be reviewed in relation to immediately adjacent operating coal mines by **30 June 2021** to adequately demonstrate negligible environmental risk, and it may be determined that a reduced monitoring frequency is appropriate or that certain quality characteristics can be removed from **Table F3** by amendment.

iii) SMD – slightly moderately disturbed level of protection, guideline refers ANZECC & ARMCANZ (2000).

iv) LOR – typical reporting for method stated. ICPMS/CV FIMS – analytical method required to achieve LOR.

F18	**Receiving Environment Monitoring Program (REMP)** The environmental authority holder must develop and implement a Receiving Environment Monitoring Program (REMP) to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. This must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine affected water is being discharged from the site. For the purposes of the REMP, the receiving environment is the waters of Two Mile Creek and connected or surrounding waterways within **15km** downstream of the release. The REMP should encompass any sensitive receiving waters or environmental values downstream of the authorised mining activity that will potentially be directly affected by an authorised release of mine affected water.

F19	he REMP must address (but not necessarily be limited to) the following: a) description of potentially affected receiving waters including key communities and background water quality characteristics based on accurate and reliable monitoring data that takes into consideration any temporal variation (e.g. seasonality); and b) description of applicable environmental values and water quality objectives to be achieved (i.e. as scheduled pursuant to the Environmental Protection (Water) Policy 2009); and c) any relevant reports prepared by other governmental or professional research organisations that relate to the receiving environment within which the REMP is proposed; and d) water quality targets within the receiving environment to be achieved, and clarification of contaminant concentrations or levels indicating adverse environmental impacts during the REMP. e) monitoring for any potential adverse environmental impacts caused by the release f) monitoring of stream flow and hydrology; g) monitoring of toxicants should consider the indicators specified in **Table F3** to assess the extent of the compliance of concentrations with water quality objectives and/or the ANZECC and ARMCANZ 2000 guidelines for slightly to moderately disturbed ecosystems; h) monitoring of physico-chemical parameters as a minimum those specified in **Table G2** (in addition to dissolved oxygen saturation and temperature); i) monitoring biological indicators (for macroinvertebrates in accordance with the AusRivas methodology) and metals/metalloids in sediments (in accordance with ANZECC and ARMCANZ 2000, BATLEY and/or the most recent version of AS5667.1 Guidance on Sampling of Bottom Sediments) for permanent, semi-permanent water holes and water storages j) the locations of monitoring points (including the locations specified in **Table F6** which are background and downstream impacted sites for each release point); k) the frequency or scheduling of sampling and analysis sufficient to determine water quality objectives and to derive site specific reference values within two (2) years (depending on wet season flows) in accordance with the Queensland Water Quality Guidelines 2006. For ephemeral streams, this should include periods of flow irrespective of mine or other discharges; l) specify sampling and analysis methods and quality assurance and control; m) any historical datasets to be relied upon; n) description of the statistical basis on which conclusions are drawn, and o) any spatial and temporal controls to exclude potential confounding factors.
F20	A REMP Design Document that addresses the requirements of **Conditions F18** and **F19** must be prepared and made available to the administrating authority upon request.

F21	A report outlining the findings of the REMP, including all monitoring results and interpretations in accordance with **Condition F19** must be prepared and submitted to the administering authority via WaTERS for each year during which a release from a release point occurs. This should include an assessment of background water quality, any assimilative capacity for those contaminants monitored and the suitability of current discharge limits to protect downstream environment values. All REMP water quality data associated with the relevant report must be submitted to the administering authority via WaTERS. Where no releases are made from the release points in any given year (**1 November** to **31 October**), a summary report of the findings of the REMP must be prepared and submitted to the administering authority via WaTERS. The summary report must include the following: a) Introduction; b) Rainfall data; and c) Water course flow data.

Table F4 –Mine affected water release during flow events

Receiving waters/stream	Release Point (RP)	Gauging station	Latitude	Longitude	Receiving water flow recording frequency	Receiving water flow criteria for discharge (m^3/s)	Maximum release rate (for all combined RP flows	Electrical conductivity and Sulfate release limits
Pelican Creek	RP1 RP2	Gauging Station 1	-20.585721	147.851138	Continuous (minimum daily)	Low Flow less than $5m^3/s$ for a period of 4 weeks after natural flow events that exceed 5 m^3/s	Volume/rate to be determined on a case by case basis	Electrical Conductivity: 75^{th} percentile of long term background reference data Sulfate: 250 mg/L
						Medium Flow more than 5 m^3/s	Volume/rate to be determined on a case by case basis or at a 5:1 flow to discharge basis	Electrical Conductivity: <1,500 µS/cm Sulfate: 1,000 mg/L

NOTE:

[1]The characteristics required to be monitored as per **Table F4** must be reviewed in relation to immediately adjacent operating coal mines by **30 June 2021** to adequately demonstrate negligible environmental risk.

Table F5 - Receiving waters contaminant trigger levels

Quality Characteristic[1]	Trigger Level	Monitoring Frequency
pH	6.5 – 9.0	Daily during the release
Electrical Conductivity (μS/cm)	1,000	
Suspended solids (mg/L)	110	
Sulfate (SO_4^{2-}) (mg/L)	250	
Sodium (mg/L)	250	

NOTE:

[1]The receiving waters trigger level quality characteristic required to be monitored as per **Table F5** must be reviewed in relation to immediately adjacent operating coal mines by **30 June 2021** to adequately demonstrate negligible environmental risk.

F22	**Water re-use** Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as farm dams or tanks, or used directly at properties owned by the environmental authority holder or a third party (with the consent of the third party).
F23	If the responsibility of the water contaminated by mining activities (the water) is given or transferred to another person in accordance with **Condition F22**, then: a) the responsibility of the water must only be given or transferred in accordance with a written agreement (the third party agreement); and b) include in the third party agreement a commitment from the person utilising the water to use water in such a way as to prevent environmental harm or public health incidences and specifically make the persons aware of the General Environmental Duty (GED) under section 319 of the *Environmental Protection Act 1994*, environmental sustainability of the water disposal and protection of environmental values of waters.
F24	**Annual Water Monitoring Data Submission** The following information must be recorded in relation to all water monitoring required under the conditions of this environmental authority and submitted to the administering authority via WaTERS with each annual return: a) the date on which the sample was taken; b) the time at which the sample was taken; c) the monitoring point at which the sample was taken; d) the measured or estimated daily quantity of mine affected water released from all release points; e) the release flow rate at the time of sampling for each release point; and f) the results of all monitoring and details of any exceedances of the conditions of this environmental authority
F25	**Water Management Plan** A Water Management Plan must be developed by an appropriately qualified person and implemented for all stages of mining activities.

F26	The Water Management Plan must: a) provide for effective water management of actual and potential environmental impacts resulting from water management associated with the mining activities carried out under this environmental authority; and b) be developed in accordance with the administering authority's most recent version of the guideline for 'Preparation of water management plans for mining activities' (EM324) or any updates that become available from time to time and must include at least the following components: i. a study of the source on contaminants; ii. a water balance model for the site; iii. a map showing the water management system for the site; iv. measures to manage and prevent saline drainage; v. measures to manage and prevent acid rock drainage; and vi. contingency procedures for incidents and emergencies.
F27	On an annual basis the Water Management Plan must be updated and re-issued (in accordance with the requirements of **Conditions F25 and F26**) or reviewed. The update or review must be commenced by **30 November** each calendar year. Where a review is undertaken, the review must: a) include a statement that the review has been undertaken by an appropriately qualified person; b) assess the plan against the requirements under **Condition F25 and F26**; c) identify any actual or potential environmental impacts which are not effectively managed by the Water Management Plan; vii. if required make recommendations to ensure actual or potential environmental impacts are effectively managed viii. if required provide details and timelines to implement the recommendations; and d) make recommendations to amend the Water Management Plan, where required.
F28	**Stormwater and water sediment controls** An Erosion and Sediment Control (ESC) Plan must be developed by an appropriately qualified person and implemented for all stages of the mining activities.

F29	The ESC Plan must: a) demonstrate how ESC control measures adequately minimise the release of sediment to receiving waters and must include at least the following: b) assessment of all catchment areas; c) assessment of soil types, including sodic dispersive soils; d) specify design criteria for ESC structures; e) detail the locations and descriptions of all ESC measures; f) provide an audit schedule to ensure ESC controls are being maintained.
F30	A revision or review of the Erosion and Sediment Control Plan must be undertaken by **30 November** for each calendar year. The revision must: a) include a statement that the Erosion and Sediment Control Plan has been prepared by an appropriately qualified person; b) assess the plan against the requirements under **Condition F29**; c) include recommended actions to ensure actual and potential environmental impacts are effectively managed; d) provide details and timelines of the actions to be taken; and e) identify any amendments made to the Erosion and Sediment Control Plan.
F31	A copy of the Erosion and Sediment Control Plan must be provided to the administering authority on request.
F32	Stormwater, other than mine affected water, is permitted to be released to waters from: a) erosion and sediment control structures that are installed and operated in accordance with the erosion and sediment control plan required by **Condition F28**; b) water management infrastructure that is installed and operated, in accordance with a water management plan that complies with **Condition F25**, for the purpose of ensuring water does not become mine affected water.

Table F6 - Receiving water upstream background sites and downstream monitoring points

Monitoring Points	Receiving Waters Location Description	Latitude	Longitude
Upstream Monitoring Points			
SW1	Un-named tributary of Two Mile Creek	-20.659498	147.861292
SW6	Two Mile Creek	-20.630927	147.865133
BG1	Pelican Creek	-20.587343	147.850063
Downstream Monitoring Points			
SW1-D	Un-named tributary of Two Mile Creek	-20.642358	147.844743
SW5-D	Two Mile Creek	-20.635933	147.830051
SW6-D	Two Mile Creek	-20.636003	147.822988
PC1	Pelican Creek	-20.600134	147.755450

NOTE:

a) The upstream monitoring point should be within 5 km of the release point.

b) The downstream point should not be greater than 5 km from the release point.

c) The data from background monitoring points must not be used where they are affected by releases from other mines.

Agency interest: Sewage Treatment	
Condition number	**Condition**
G1	Treated sewage effluent may only be released to land in accordance with the conditions of this approval at the following locations: a) within a suitable irrigation area to be selected based on the location of mine infrastructure areas and associated sewage treatment plant(s); b) haul roads and areas of mining activity for the purpose of dust suppression; c) re-use in coal processing; d) firefighting.
G2	All effluent released from the treatment plant into the nominated irrigation area identified in **Condition G1** must be monitored at the frequency and for all the parameters specified in **Table G1 - Contaminant release limits to land**.
G3	Irrigation with treated effluent must be carried out in a manner such that: a) vegetation is not damaged; b) there is no surface ponding of effluent; and c) there is no run-off of effluent.
G4	If irrigation areas are accessible to employees or the general public, prominent signage must be provided advising that effluent is present and care should be taken to avoid consuming or otherwise coming into unprotected contact with the effluent.

G5	The daily volume of treated effluent used for irrigation must be measured and records kept of the volumes of effluent released.
G6	When circumstances prevent the irrigation or beneficial reuse of treated sewage effluent such as during or following rain events, waters must be directed to a wet weather storage or alternative measures must be taken to store/lawfully dispose of effluent.
G7	Water or stormwater contaminated by irrigation activities must not be released to any waters or the bed and banks of any waters.
G8	A minimum area of **one (1) ha** of land, excluding any necessary buffer zones, must be utilised for the irrigation of treated sewage effluent.
G9	Treated sewage effluent must only be supplied to another person or organisation that has a written plan detailing how the user of the treated sewage effluent will comply with their general environmental duty under section 319 of the Act whilst using the treated sewage effluent. **NOTE:** The supply of treated wastewater for re-use is regulated under *the Water Supply (Safety and Reliability) Act 2008*.

Table G1 - Contaminant release limits to land

Contaminant	Unit	Release limit	Limit type	Monitoring Frequency
5 day Biochemical oxygen demand (BOD)	mg/L	20	Maximum	Monthly
Total suspended solids	mg/L	30	Maximum	Monthly
Nitrogen	mg/L	30	Maximum	Monthly
Phosphorus	mg/L	15	Maximum	Monthly
E-coli	Organisms/100ml	1000	Maximum	Monthly
pH	pH units	6.0 – 9.0.	Range	Monthly

Agency interest: Land and Rehabilitation	
Condition number	**Condition**
H1	All areas significantly disturbed by mining activities must be rehabilitated to achieve the following rehabilitation goals: a) safe to humans and wildlife; b) stable; c) non-polluting; and d) self-sustaining for the post mining land us of grazing pasture, with the exception of residual voids
H2	A Rehabilitation Management Plan must be developed by **24 April 2020** by a suitably qualified person and submitted to the administering authority for review and comment.
H3	Within **20 business days** of the receipt of comments from the administering authority, the updated Rehabilitation Management Plan must be submitted to the department for approval.
H4	The Rehabilitation Management Plan must include: a) Rehabilitation objectives to achieve the rehabilitation goals for all disturbance areas; b) Detailed rehabilitation methods for each disturbance area; c) Rehabilitation indicators to measure the success of the rehabilitation against the rehabilitation objectives; d) Final completion criteria that will achieve the rehabilitation goals and objectives; e) Details of appropriate monitoring and maintenance of rehabilitation; f) Identification of 3 reference sites to be used to develop rehabilitation success criteria for each disturbance domain; and g) A description of monitoring of reference sites inclusive of statistical design. h) A description of progressive rehabilitation planning
H5	All areas significantly disturbed by mining activities must be rehabilitated in accordance with the Rehabilitation Management Plan to achieve the final completion criteria.
H6	The environmental authority holder must notify the administering authority of any changes to the Rehabilitation Management Plan, and submit the updated document to the administering authority.

H7	**Mining waste management** A waste rock and spoil disposal plan must be developed and include, where relevant, at least: a) effective characterisation of the waste rock and spoil to predict under the proposed placement and disposal strategy the quality of runoff and seepage generated concerning potentially environmentally significant effects including salinity, acidity, alkalinity and dissolved metals, metalloids and non-metallic inorganic substances; b) a program of progressive sampling and characterisation to identify dispersive and non-dispersive spoil and the salinity, acid and alkali producing potential and metal concentrations of waste rock; c) a materials balance and disposal plan demonstrating how potentially acid forming and acid forming waste rock will be selectively placed and/or encapsulated to minimise the potential generation of acid mine drainage; d) where relevant, a sampling program to verify encapsulation and/or placement of potentially acid-forming and acid-forming waste rock; e) how often the performance of the plan will be assessed; f) the indicators or other criteria on which the performance of the plan will be assessed; and g) rehabilitation strategy. Monitoring or rehabilitation, research and/or trials to verify the requirements and methods for decommissioning and final rehabilitation of the placed materials, including the prevention and management of acid mine drainage, erosion minimisation and establishment of vegetation cover.
H8	**Contaminated Land** Before applying for surrender of a mining lease, the holder must (if applicable) provide to the administering authority a site investigation report under the Act, in relation to any part of the mining lease which has been used for notifiable activities or which the holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use.
H9	Before applying for progressive rehabilitation certification for an area, the holder must (if applicable) provide to the administering authority a site investigation report under the Act, in relation to any part of the area the subject of the application which has been used for notifiable activities or which the holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use under **Condition H1**.
H10	Minimise the potential for contamination of land by hazardous contaminants.
H11	**Chemicals and flammable or combustible liquids** All flammable and combustible liquids must be contained within an on-site containment system and controlled in a manner that prevents environmental harm and maintained in accordance with the current edition of *AS 1940 – Storage and Handling of Flammable and Combustible Liquids*.

H12	All chemicals and flammable or combustible liquids stored on site that have the potential to cause environmental harm must be stored in or serviced by an effective containment system that is impervious to the materials stored and managed to prevent the release of liquids to waters or land. Where no relevant Australian standard exists store such materials within an effective on-site containment system, the environmental authority holder must, at a minimum: a) minimise the potential for contamination of land and waters by diverting stormwater around contaminated areas and facilities used for the storage of chemicals and flammable or combustible liquids.
H13	**Residual void outcome** Residual voids must comply with the following outcomes: a) Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifers, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority; b) Residual voids must comply with **Table H1 – Residual void outcomes**; and c) At the completion of decommissioning and rehabilitation, all residual voids must demonstrably have the appropriate level of flood protection from nearby watercourses as approved by the administering authority, such that the protection is sustainable for the foreseeable future.
H14	All reasonable and practical measures must be taken to minimise the size of the void remaining after mining activities cease.
H15	**Weed Management** A weed management plan must be developed and implemented for this site outlining: a) areas of control priority and the methods used to determine such areas: b) strategies to promote dense grass growth (which out-competes weeds) through reduced disturbance; c) monitoring methodologies that document the spread of weeds and any new outbreaks; d) methods for the control of weeds. These methods should include best practice management; e) stringent wash-down and inspection procedures for both machinery involved in clearing/construction activities and those operating outside of designated roads during mine operation; and f) promotion of the awareness of weed management issues at the site.
H16	**Exploration** Land subject to exploration activities previously approved under EPC586 that subsequently became ML10345, must be rehabilitated in accordance with the *Code of Environmental Compliance for Exploration and Mineral Development Projects*.

H17	Land subject to exploration activities carried out on ML10345 subsequent to the grant of the relevant mining lease, must be rehabilitated in accordance with the *Code of Environmental Compliance for Exploration and Mineral Development Projects*.

Table H1 – Residual Void Outcomes

Residual Void	Void Area	Maximum Slope
B Seam Pit	Backfilled	N/A
Q Seam Pit	Backfilled	

Agency interest: Dams and Levees	
Condition number	**Condition**
I1	**Consequence Category** The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* at the following times: a) prior to the design and construction of the structure, if it is not an existing structure; or b) prior to any change in its purpose or the nature of its stored contents.
I2	A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.
I3	Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.
I4	**Design and Construction of a Regulated Structure** All regulated structures must be designed by, and constructed under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.
I5	Construction of a regulated structure is prohibited unless: a) the holder has submitted a consequence category assessment report and certification to the administering authority; and b) certification of the design plan and operating procedures (except where the structure does not require operating procedures such as for levees) has been certified by a suitably qualified and experienced person for compliance with the relevant condition of this authority.
I6	Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*, and must be recorded in the Register of Regulated Structures.
I7	Regulated structures must:

	a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933);* 1. be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of: 2. floodwaters entering the regulated dam from any watercourse or drainage line; and b) wall failure due to erosion by floodwaters arising from any watercourse or drainage line. c) for dams associated with a failure to contain; have the floor and sides of the dam designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam.
I8	Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that: a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure; b) construction of the regulated structure is in accordance with the design plan.
I9	**Operation of a regulated structure** a) Operation of a regulated structure**,** except for an existing structure, is prohibited unless: i. the holder has submitted to the administering authority: ii. one paper copy and one electronic copy of the design plan and certification of the 'design plan' in accordance with **Conditions I4** to **I6**; iii. a set of 'as constructed' drawings and specifications; iv. certification of those 'as constructed drawings and specifications' in accordance with **Condition I8**; v. where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the Design Storage Allowance (DSA) volume across the system, a copy of the certified system design plan; vi. the requirements of this authority relating to the construction of the regulated structure have been met; vii. the holder has entered the details required under this authority, into a Register of Regulated Structures; and viii. there is a current operational plan for the regulated structure (except where the structure does not require operating procedures such as for levees).
I10	Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.

I11	**Mandatory Reporting Level** **Conditions I12** to **I15** inclusive only apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain – overtopping'.
I12	The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable.
I13	The holder must, as soon as practical and within **forty-eight (48) hours** of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.
I14	The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.
I15	The holder must record any changes to the MRL in the Register of Regulated Structures.
I16	**Design storage allowance** The holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to **1 July** of each year.
I17	By **1 November** of each year, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the DSA volume for the dam (or network of linked containment systems).
I18	The holder must, as soon as possible and within **forty-eight (48) hours** of becoming aware that the regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year, notify the administering authority.
I19	The holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems.

I20	**Annual Inspection** Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.
I21	At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure. Regulated structures must be assessed: a) against the most recent hazard assessment report and design plan (or system design plan); b) against recommendations contained in previous annual inspections reports; c) against recognised dam safety deficiency indicators; d) for changes in circumstances potentially leading to a change in hazard category; e) for conformance with the conditions of this authority; f) for conformance with the 'as constructed' drawings; g) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after **31 May** each year but prior to **1 November** of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the dam (or network of linked containment systems); and h) for evidence of conformance with the current operational plan.
I22	The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.
I23	The environmental authority holder must: a) within **twenty (20) business days** of receipt of the annual inspection report, provide to the administering authority: 1. the recommendations section of the annual inspection report; and 2. if applicable, any actions being taken in response to those recommendations; and b) if, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this to the administering authority within **ten (10) business days** of receipt of the request.
I24	**Transfer arrangements** The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority.

I25	**Register of Regulated Structures** A Register of Regulated Structures must be established and maintained by the holder for each regulated dam.
I26	The holder must provisionally enter the required information in the Register of Regulated Structures when a design plan for a regulated dam is submitted to the administering authority.
I27	The holder must make a final entry of the required information in the Register of Regulated Structures once compliance with **Conditions I9** and **I10** has been achieved.
I28	The holder must ensure that the information contained in the Register of Regulated Structures is current and complete on any given day.
I29	All entries in the Register of Regulated Structures must be approved by the chief executive officer for the holder of this authority, or their delegate, as being accurate and correct.
I30	The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Structures, in the electronic format required by the administering authority.

END OF CONDITIONS

Definitions

Words and phrases used throughout this environmental authority are defined below. Where a definition for a term used in this environmental authority is not provided within this environmental authority, but is provided in the EP Act 1994 or subordinate legislation, the definition in the EP Act or subordinate legislation must be used.

'acid mine drainage' means any contaminated discharge emanating from a mining activity formed through a series of chemical and biological reactions, when geological strata is disturbed and exposed to oxygen and moisture.

'affected person' is someone whose drinking water can potentially be impacted as a result of discharges from a dam or their life can be put at risk due to dwellings or workplaces being in the path of a dam break flood.

'airblast overpressure' means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL).

'annual exceedance probability or AEP' the probability that at least one event in excess of a particular magnitude will occur in any given year.

'annual inspection report' means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan);

- against recommendations contained in previous annual inspections reports;
- against recognised dam safety deficiency indicators;
- for changes in circumstances potentially leading to a change in consequence category;
- for conformance with the conditions of this authority;
- for conformance with the 'as constructed' drawings;
- for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after 31 May each year but prior to 1 November of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the **dam** (or network of linked containment systems);
- for evidence of conformance with the current operational plan.

'appropriately qualified person' means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods or literature.

'assessed or **assessment'** by a suitably qualified and experienced person in relation to a consequence assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:

a) exactly what has been assessed and the precise nature of that determination;

b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;

c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

'associated works' in relation to a dam, means:

1) operations of any kind and all things constructed, erected or installed for that dam; and

2) any land used for those operations.

'authority' means an environmental authority or a development approval.

'background', with reference to the water schedule means the average of samples taken prior to the commencement of mining from the same waterway that the current sample has been taken.

'certification', 'certifying' or **'certified'** by an appropriately qualified and experienced person in relation to a design plan or an annual report regarding dams/structures, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

a) exactly what is being certified and the precise nature of that certification;

b) the relevant legislative, regulatory and technical criteria on which the certification has been based;

c) the relevant data and facts on which the certification has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

d) the reasoning on which the certification has been based using the relevant data and facts, and the relevant criteria.

'blasting' means the use of explosive materials to fracture:

a) rock, coal and other minerals for later recovery; or

b) structural components or other items to facilitate removal from a site or for reuse.

'chemical' means:

a) an agricultural chemical product or veterinary chemical product within the meaning of the *Agricultural and Veterinary Chemicals Code Act 1994* (Commonwealth); or

b) a dangerous good under the Australian Code for the Transport of Dangerous Goods by Road and Rail approved by the Australian Transport Council; or

c) a lead hazardous substance within the meaning of the *Workplace Health and Safety Regulation 1997*;

d) a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers' Advisory Council and published by the Commonwealth; or

e) any substance used as, or intended for use as:

   i. a pesticide, insecticide, fungicide, herbicide, rodenticide, nematocide, miticide, fumigant or related product; or

   ii. a surface active agent, including, for example, soap or related detergent; or

   iii. a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide; or

   iv. a fertiliser for agricultural, horticultural or garden use; or

   v. a substance used for, or intended for use for mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater; or

   vi. manufacture of plastic or synthetic rubber.

'commercial place' means a workplace used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees' accommodation or public roads.

'consequence' in relation to a structure as defined, means the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances.

'consequence category' means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

'construction' or **'constructed'** in relation to a regulated structure includes building a new regulated structure and lifting or otherwise modifying an existing regulated structure, but does not include investigations and testing necessary for the purpose of preparing a design plan.

'dam' means a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and **associated works**.

'dam crest volume' means the volume of material (liquids and/or solids) that could be within the walls of a dam at any time when the upper level of that material is at the crest level of that dam. That is, the instantaneous maximum volume within the walls, without regard to flows entering or leaving (for example, via spillway).

'design plan' is a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure.

'design storage allowance or DSA' means an available volume, estimated in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an **annual exceedance probability** (AEP) specified in that Manual.

'designer' for the purposes of a regulated dam, means the certifier of the design plan for the regulated dam.

'disturbance' of land includes:

a) compacting, removing, covering, exposing or stockpiling of earth;

b) removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion;

c) carrying out mining within a watercourse, waterway, wetland or lake;

d) the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls;

e) temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be removed after the mining activity has ceased; or

f) releasing of contaminants into the soil, or underlying geological strata.

However, the following areas are not included when calculating areas of 'disturbance':

a) areas off lease (e.g. roads or tracks which provide access to the mining lease);

b) areas previously disturbed which have achieved the rehabilitation outcomes;

c) by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions);

d) areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be left by agreement with the landowner; or

e) disturbance that pre-existed the grant of the tenure.

'effluent' treated waste water released from sewage treatment plants.

'emergency action plan' means documentation forming part of the operational plan held by the holder or a nominated responsible officer, that identifies emergency conditions that sets out procedures and actions that will be followed and taken by the dam owner and operating personnel in the event of an emergency. The actions are to minimise the risk and consequences of failure, and ensure timely warning to downstream communities and the implementation of protection measures. The plan must require dam owners to annually update contact information.

'existing structure' means a structure that prior to 18 September 2014 meets any or both of the following, a structure:

a) with a design that is in accordance with the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* and that is considerably in progress;

b) that is under considerable construction or that is constructed.

'extreme storm storage' – means a storm storage allowance determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

'flowable substance' means matter or a mixture of materials which can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension.

'hazard category' means a category, either low significant or high, into which a dam is assessed as a result of the application of tables and other criteria in '*Manual for Assessing Hazard Categories and Hydraulic Performance of Dams*'.

'holder' means:

a) where this document is an environmental authority, any person who is the holder of, or is acting under, that environmental authority; or

b) where this document is a development approval, any person who is the registered operator for that development approval.

'hydraulic performance' means the capacity of a regulated dam to contain or safely pass flowable substances based on the design criteria specified for the relevant consequence category in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

'infrastructure' means water storage dams, levees, roads and tracks, buildings and other structures built for the purpose of the mining activity.

'land' in 'Schedule H – Land and rehabilitation' of this document means land excluding waters and the atmosphere, that is, the term has a different meaning from the term as defined in the *Environmental Protection Act 1994*. For the purposes of the *Acts Interpretation Act 1954*, it is expressly noted that the term 'land' in this environmental authority relates to physical land and not to interests in land.

'land use' –means the selected post mining use of the land, which is planned to occur after the cessation of mining operations.

'leachate' means a liquid that has passed through or emerged from, or is likely to have passed through or emerged from, a material stored, processed or disposed of at the operational land which contains soluble, suspended or miscible contaminants likely to have been derived from the said material.

'levee' means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of **water** or **flowable substances** at any other times.

'low consequence dam' means any dam that is not a high or significant consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

'm' means metres.

'mandatory reporting level or MRL' means a warning and reporting level determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/933)* published by the administering authority.

'manual' means the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

'measures' includes any measures to prevent or minimise environmental impacts of the mining activity such as bunds, silt fences, diversion drains, capping, and containment systems.

'mine affected water':

a) means the following types of water:

   i) pit water, tailings dam water, processing plant water;

   ii) water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the *Environmental Protection Regulation 2008* if it had not formed part of the mining activity;

   iii) rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water;

   iv) groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated;

   v) groundwater from the mine's dewatering activities;

   vi) a mix of mine affected water (under any of paragraphs i)-v) and other water.

b) does not include surface water runoff which, to the extent that it has been in contact with areas disturbed by mining activities that have not yet been completely rehabilitated, has only been in contact with:

   i) land that has been rehabilitated to a stable landform and either capped or revegetated in accordance with the acceptance criteria set out in the environmental authority but only still awaiting maintenance and monitoring of the rehabilitation over a specified period of time to demonstrate rehabilitation success; or

   ii) land that has partially been rehabilitated and monitoring demonstrates the relevant part of the landform with which the water has been in contact does not cause environmental harm to waters or groundwater, for example:

1. areas that are been capped and have monitoring data demonstrating hazardous material adequately contained with the site;
2. evidence provided through monitoring that the relevant surface water would have met the water quality parameters for mine affected water release limits in this environmental authority, if those parameters had been applicable to the surface water runoff; or

iii) both.

'mining waste' means waste rock, spoil, overburden and interburden.

'modification or modifying' (see definition of 'construction').

'natural flow' means the flow of water through waters caused by nature.

'non polluting' means having no adverse impacts upon the receiving environment.

'operational plan' includes:

a) normal operating procedures and rules (including clear documentation and definition of process inputs in the DSA);

b) contingency and emergency action plans including operating procedures designed to avoid and/or minimise environmental impacts including threats to human life resulting from any overtopping or loss of structural integrity of the regulated structure.

'register of regulated structure' includes**:**

a) date of entry in the register;

b) name of the structure, its purpose and intended/actual contents;

c) the consequence category of the dam as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635);

d) dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;

e) name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;

f) for the regulated dam, other than in relation to any levees –

   a. the dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;

   b. coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area

   c. dam crest volume (megalitres);

   d. spillway crest level (metres AHD).

   e. maximum operating level (metres AHD);

   f. storage rating table of stored volume versus level (metres AHD);

   g. design storage allowance (megalitres) and associated level of the dam (metres AHD);

h. mandatory reporting level (metres AHD);

g) the design plan title and reference relevant to the dam;

h) the date construction was certified as compliant with the design plan;

i) the name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;

j) details of the composition and construction of any liner;

k) the system for the detection of any leakage through the floor and sides of the dam;

l) dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;

m) dates when recommendations and actions arising from the annual inspection were provided to the administering authority;

n) dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

'peak particle velocity (ppv)' means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s).

'protected area' means – a protected area under the *Nature Conservation Act 1992*; or

a) a marine park under the *Marine Parks Act 1992*; or

b) a World Heritage Area.

'receiving environment' in relation to an activity that causes or may cause environmental harm, means the part of the environment to which the harm is, or may be, caused. The receiving environment includes (but is not limited to):

a) a watercourse;

b) groundwater; and

c) an area of land that is not specified in of this environmental authority.

The term does not include land that is specified in Authorised Activities of this environmental authority.

'receiving waters' means the waters into which this environmental authority authorises releases of mine affected water.

'regulated structure' means any structure in the significant or high consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority. A regulated structure does not include:

a) a fabricated or manufactured tank or container, designed and constructed to an Australian Standard that deals with strength and structural integrity of that tank or container;

b) a sump or earthen pit used to store residual drilling material and drilling fluid only for the duration of drilling and well completion activities;

c) a flare pit.

'rehabilitation' the process of reshaping and revegetating land to restore it to a stable landform.

'release event' means a surface water discharge from mine affected water storages or contaminated areas on the licensed place meaning the mining activities carried out at the mining tenements detailed in **Figure 1 – Site map, domains and groundwater monitoring locations** of this environmental authority.

'residual drilling material' means waste drilling materials including muds and cuttings or cement returns from well holes and which have been left behind after the drilling fluids are pumped out.

'RL' means reduced level, relative to mean sea level as distinct from depths to water.

'representative' means a sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activities.

'sensitive place' means:

a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or

b) a motel, hotel or hostel; or

c) an educational institution; or

d) a medical centre or hospital; or

e) a protected area under the *Nature Conservation Act 1992*, the *Marine Parks Act 1992* or a World Heritage Area; or

f) a public park or gardens.

Note: The definition of 'sensitive place' and 'commercial place' is based on Schedule 1 of EPP Noise. That is, a sensitive place is inside or outside on a dwelling, library & educational institution, childcare or kindergarten, school or playground, hospital, surgery or other medical institution, commercial & retail activity, protected area or an area identified under a conservation plan under *Nature Conservation Act 1992* as a critical habitat or an area of major interest, marine park under *Marine Parks Act 2004*, park or garden that is outside of the mining lease and open to the public for the use other than for sport or organised entertainment. A commercial place is inside or outside a commercial or retail activity.

A mining camp (i.e., accommodation and ancillary facilities for mine employees or contractors or both, associated with the mine the subject of the environmental authority) is not a sensitive place for that mine or mining project, whether or not the mining camp is located within a mining tenement that is part of the mining project the subject of the environmental authority. For example, the mining camp might be located on neighbouring land owned or leased by the same company as one of the holders of the environmental authority for the mining project, or a related company. Accommodation for mine employees or contractors is a sensitive place if the land is held by a mining company or related company, and if occupation is restricted to the employees, contractors and their families for the particular mine or mines which are held by the same company or a related company.

For example, a township (occupied by the mine employees, contractors and their families for multiple mines that are held by different companies) would be a sensitive place, even if part or all of the township is constructed on land owned by one or more of the companies.

'spillway' means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges form the dam, normally under flood conditions or in anticipation of flood conditions.

'structure' means dam or levee.

'suitably qualified and experienced person' in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

a) for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design.

b) for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology.

'system design plan' means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

'the Act' means the *Environmental Protection Act 1994*.

'µS/cm' means micro Siemens per centimetre.

'void' means any constructed, open excavation in the ground.

'watercourse' has the same meaning given in the *Water Act 2000*.

'water quality' means the chemical, physical and biological condition of water.

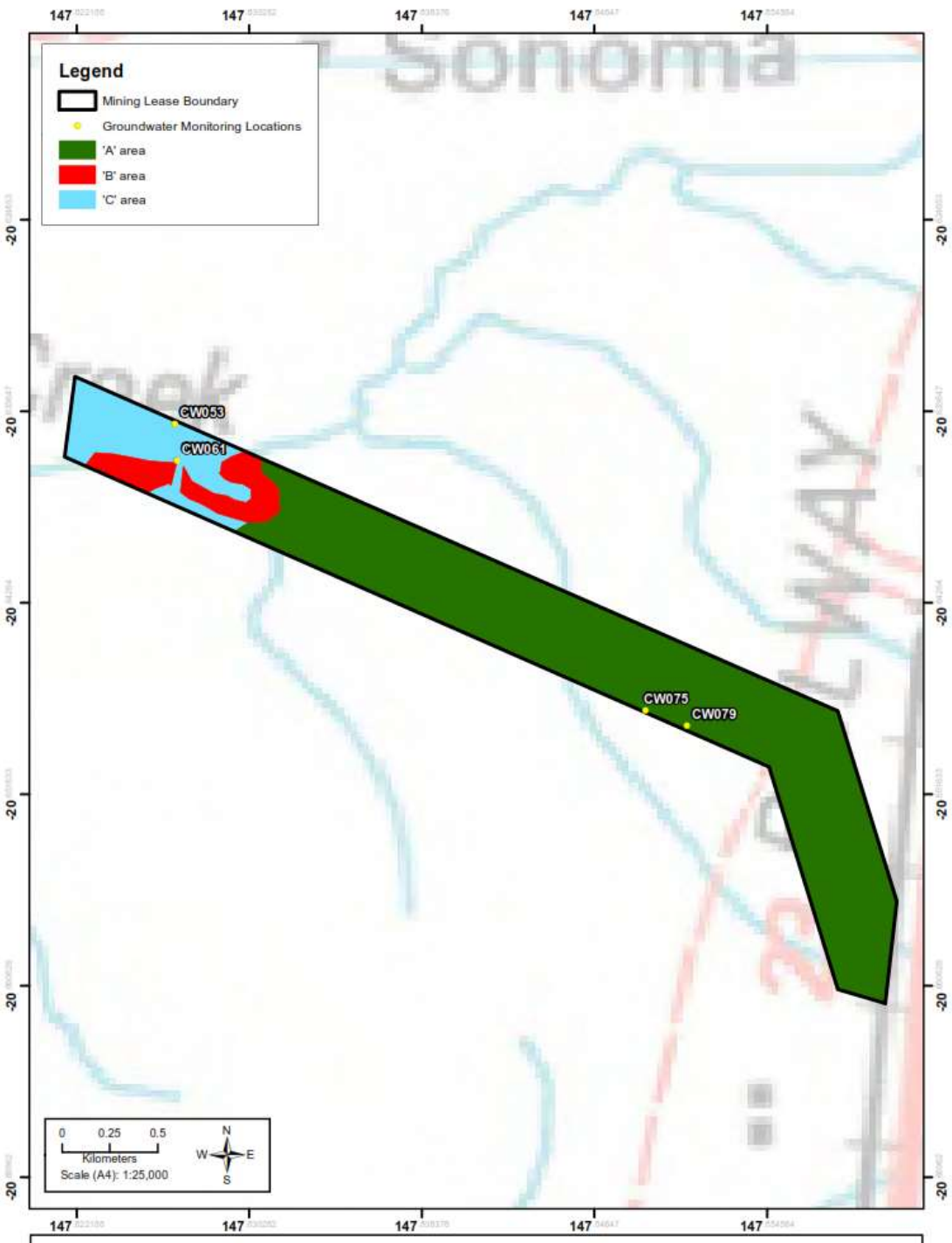
'water year' means the 12-month period from 1 July to 30 June.

'waters' includes river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined natural or artificial watercourse, bed and bank of any waters, dams, non-tidal or tidal waters (including the sea), storm water channel, storm water drain, and groundwater and any part thereof.

'WaTERS' means the Queensland Government's WaTERS database system.

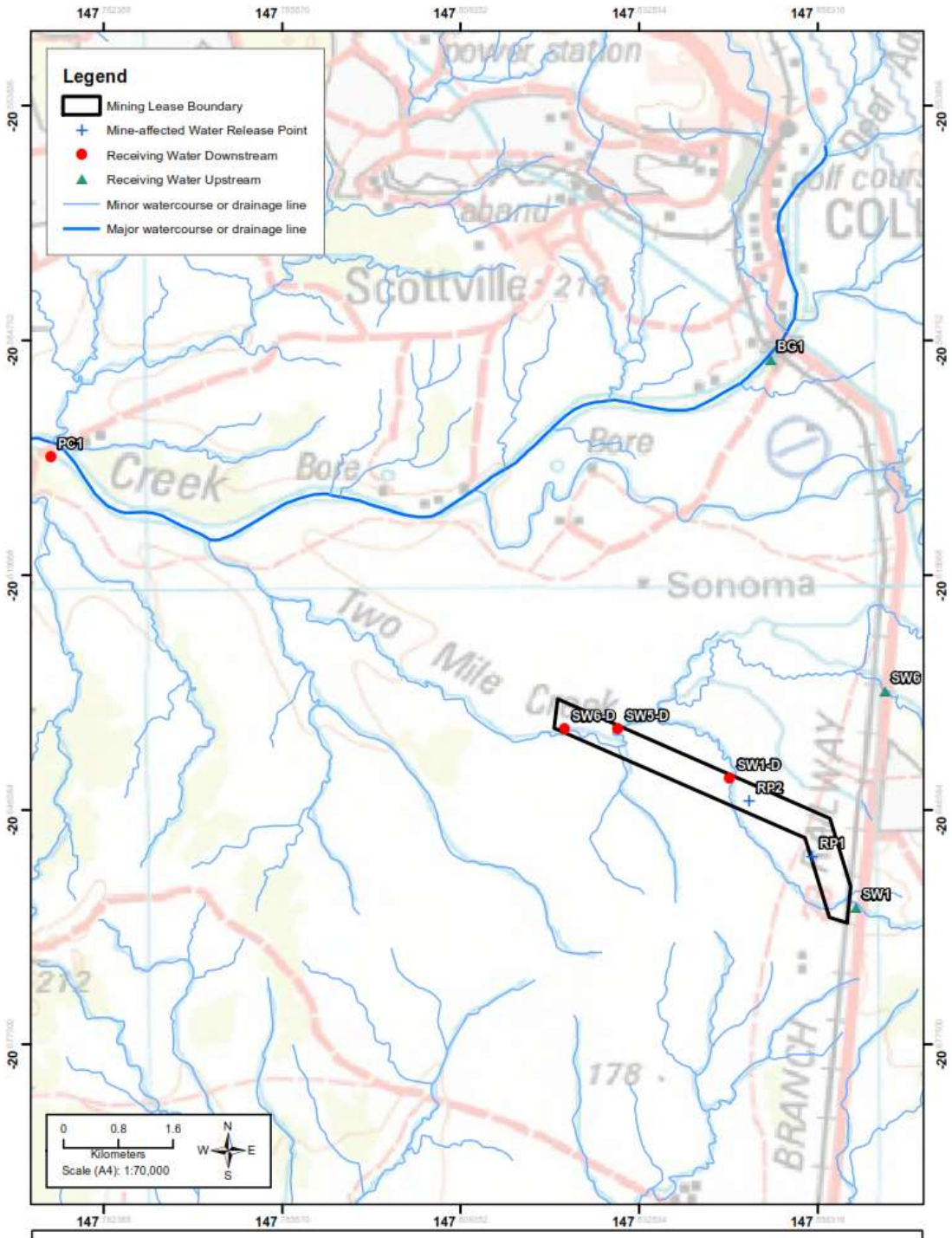
'wet season' means the time of year, covering one or more months, when most of the average annual rainfall in a region occurs. For the purposes of DSA determination this time of year is deemed to extend from 1 November in one year to 31 May in the following year inclusive.

END OF DEFINITIONS



Date: 18/09/2019
Coordinate System: GCS GDA 1994
Datum: GDA 1994
Data sources:
© State of Queensland (Department of Natural Resources and Mines) 2018
© State of Queensland (Department of Transport and Main Roads) 2018

Figure 1 - Site map, domains and groundwater monitoring locations



Date: 18/09/2019
Coordinate System: GCS GDA 1994
Datum: GDA 1994
Data sources:
© State of Queensland (Department of Natural Resources and Mines) 2018
© State of Queensland (Department of Transport and Main Roads) 2018

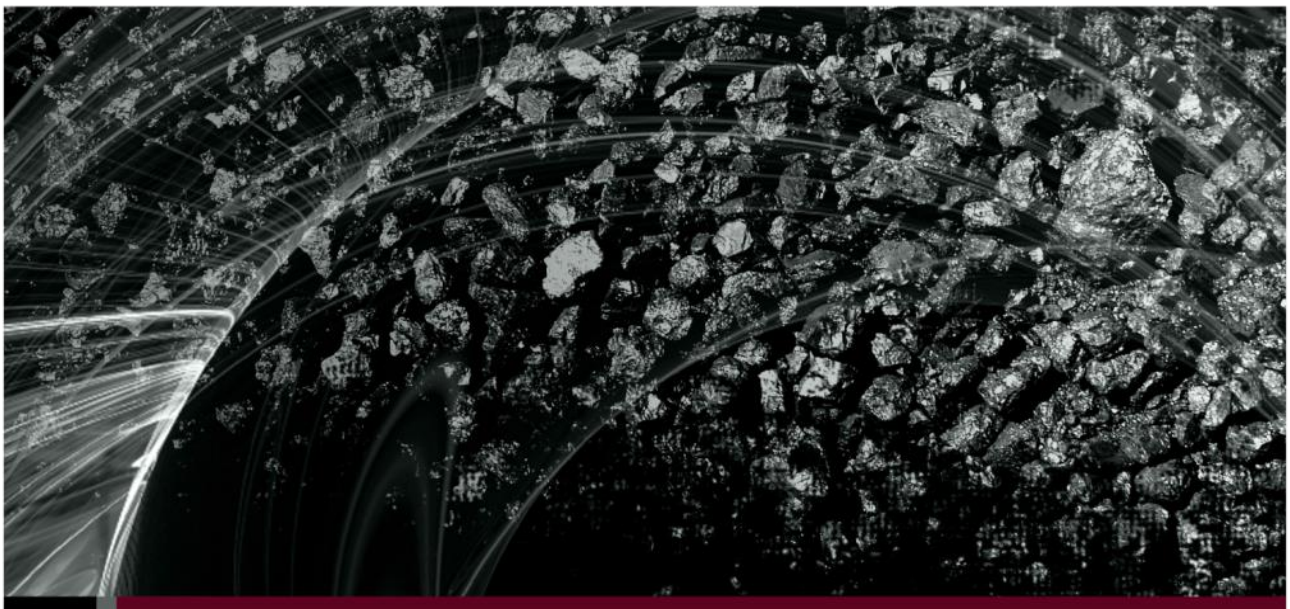
Figure 2 - Mine-affected water release points, sources and receiving waters

END OF PERMIT

QCOAL GROUP

QCoal Northern Hub

Rehabilitation Management Plan



(Draft) April 2020

Submitter information	
Report type	Rehabilitation Management Plan
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Project(s)	Sonoma Coal Mine Cows Coal Mine Drake Coal Mine Jax Coal Mine
Date of report	June 2020

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1 Introduction

QCoal Pty Ltd (QCoal) manages four (4) adjacent open cut coal mines located approximately six (6) km south of the town of Collinsville in Central Queensland. The four mines are Sonoma Coal Mine (SCM), Cows Coal Mine (CCM), Drake Coal Mine (DCM), and Jax Coal Mine (JCM), with pits, dumps, haul roads and water management infrastructure spanning the boundaries of the various mining leases (MLs). Each mine has its own approval, being an environmental authority (EA); however, as with physical infrastructure, operational and environmental management and resources are integrated across the four mines.

The mines that make up the QNH are directly adjacent to one another on the western side of Bowen Development Road and the parallel Newlands rail line, with the exception of JCM, which is on the eastern side (see **Figure 1**).

Accordingly, these four (4) mines are collectively managed and operated as a single multi-pit operation, which is referred to as the QCoal Northern Hub (QNH).

1.1 Rehabilitation Management Plan Objectives

Presented in **Section 2.5** are the details of the four (4) QNH EAs. Condition H3 of all four (4) site EAs requires the development of an RMP, due for submission by **24 April 2020**. As such, this QNH Rehabilitation Management Plan (QNH RMP) has been developed to:

- Satisfy the EA conditions within each of the four (4) QNH mines which require an RMP;
- Present a consistent approach to rehabilitation across the QNH, which will:
  - Improve final landform planning and design (especially for landforms that cross EA boundaries),
  - Maximise efficiency in undertaking rehabilitation activities, and
  - Allow for assessment of rehabilitation success on a whole-of-operation basis.

This QNH RMP will supersede any existing rehabilitation management plan applicable to any of the QNH mines.

In preparing the QNH RMP, reference has been made to previous QNH investigations and reports, as well as regulatory documents which provide direction on rehabilitation (e.g. requirements, methods, or outcomes), including, but not limited to, the following:

- Relevant conditions of site EAs.
- Commitments made by individual sites in other statutory documentation.
- *Design of Two Mile Creek Diversion* (BSM, 2012)
- *North Sonoma Creek Diversion Design Plan* (Engeny, 2018)
- *Investigation into Residual Void Sonoma Coal Mine* (QCoal, 2016)
- *Residual Voids on the QCoal Northern Hub Mining Complex* (QCoal, 2020)

- *Rehabilitation requirements for mining projects* (EHP, 2014)[1].
- *Groundwater Monitoring and Management Plan – Drake Coal Pty Ltd – Drake Coal Project* (QCoal, 2014)
- *Northern Hub Groundwater Assessment* (AGE, 2018)
- *Northern Hub Groundwater Assessment* (AGE, 2020)
- *Residual Void Hydrology Study QCoal Northern Hub Mines June 2020* (Engeny, 2020)
- *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland* (DME, 1995).

The QNH RMP presents the rehabilitation strategies and objectives for closure to achieve agreed post-mine land uses (PMLUs). Rehabilitation strategies have been developed for all relevant areas of disturbance (domains) across the QNH. These strategies have been developed to ensure the requirements of the four (4) QNH EAs have been satisfied.

A monitoring and reporting framework has been developed to demonstrate achievement of the relevant rehabilitation completion criteria.

[1] This guideline describes the policy framework and assessment process for determining the acceptability of rehabilitation outcomes and strategies. It provides EA holders with a clear structure for the development of objectives and targets that should be presented in approvals and mine management documents such as PoOs and rehabilitation plans.

2 Project Overview

2.1 Location

The QNH is located approximately 6 km south of the town of Collinsville, and 78 km southwest of the regional centre of Bowen (see **Figure 1**). Access to all four QNH sites is by the state-controlled Bowen Development Road.

2.2 Ownership

The QNH sites have ownership makeups as follows:

- SCM is a joint venture between QCoal Sonoma Pty Ltd, JS Sonoma Pty Ltd, CSC Sonoma Pty Ltd and Watami (Qld) Pty Ltd.
- DCM is owned by Northern Hub (Drake) Pty Ltd and Drake Coal Pty Ltd.
- CCM is owned by Bowen River Coal Pty Ltd.
- JCM is owned by Jax Coal Pty Ltd.

QCoal Sonoma Pty Ltd, Northern Hub (Drake) Pty Ltd, Drake Coal Pty Ltd, Bowen River Coal Pty Ltd and Jax Coal Pty Ltd, are wholly or majority owned subsidiaries of QCoal Pty Ltd. The owner and Managing Director of QCoal Pty Ltd is Mr Christopher Wallin.

2.3 Mining Tenures

The ML tenure details for the QNH mines are provided in **Table 1**, **Table 2**, **Table 3** and **Table 4**.

Table 1 – SCM Mining Lease Details

Details	ML10325	ML10326	ML10327
Permit Type	Mining Lease	Mining Lease	Mining Lease
Permit Status	Granted	Granted	Granted
Permit Sub-Status	None	None	None
Lodgment Date	21/11/2005	21/11/2005	21/11/2005
Grant Date	12/4/2007	13/09/2007	13/09/2007
Expiry Date	30/04/2037	30/09/2037	30/09/2037
Authorised Holder Name	QCoal Sonoma Pty Ltd	QCoal Sonoma Pty Ltd	QCoal Sonoma Pty Ltd
Area	716.7 ha	1,063 ha	360.4 ha
Permit ID	108618	108619	108620
Native Title Category	Exclusive Land	Exclusive Land	Exclusive Land

Table 2 – CCM Mining Lease Details

Details	ML10345
Permit Type	Mining Lease
Permit Status	Granted
Permit Sub-Status	None
Lodgment Date	11/04/2009
Grant Date	16/08/2012
Expiry Date	31/08/2027
Authorised Holder Name	Bowen River Coal Pty Ltd
Area	210.5 ha
Permit ID	108636
Native Title Category	Exclusive Land

Table 3 – DCM Mining Lease Details

Details	ML10349	ML10350	ML10351
Permit Type	Mining Lease	Mining Lease	Mining Lease
Permit Status	Granted	Granted	Granted
Permit Sub-Status	None	None	None
Lodgment Date	21/04/2010	21/04/2010	21/04/2010
Grant Date	2/11/2014	2/11/2014	2/11/2014
Expiry Date	29/02/2044	29/02/2044	29/02/2044
Authorised Holder Name	Northern Hub (Drake) Pty Ltd	Northern Hub (Drake) Pty Ltd	Northern Hub (Drake) Pty Ltd
Area	3,982 ha	4,805 ha	427.9
Permit ID	108640	108641	108642
Native Title Category	Right To Negotiate Agreement	Right to Negotiate Agreement	Right to Negotiate Agreement

Table 4 – JCM Mining Lease Details

Details	ML10346
Permit Type	Mining Lease
Permit Status	Granted
Permit Sub-Status	None
Lodgment Date	11/12/2009
Grant Date	20/12/2013
Expiry Date	31/12/2034
Authorised Holder Name	Jax Coal Pty Ltd
Area	1,943 hectares
Permit ID	108637
Native Title Category	Right to Negotiate Agreement

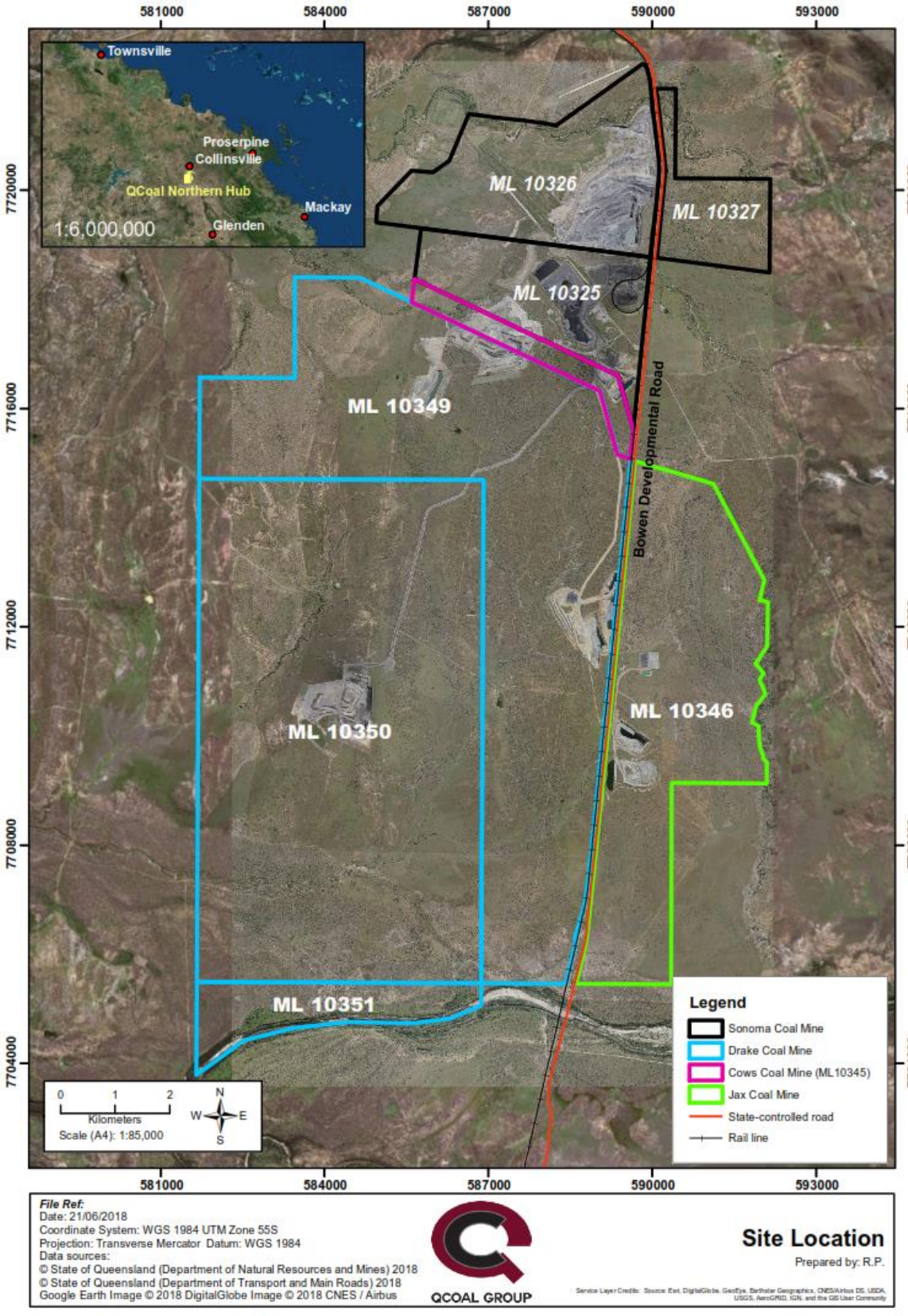


Figure 1 – QCoal Northern Hub Location

2.4 Underlying Landholders

The QNH spans eight (8) MLs, as described in **Section 2.3**. The MLs are located on land with several landholders, as summarised below and presented in **Figure 2**:

- SCM:
  - ML10325: The land underlying ML10325 is owned by Mr Christopher Wallin.
  - ML 10326: The land underlying ML10326 is "Sonoma" station, which is privately owned by a third party, apart from the land underlying the SCM rail spur, which is owned by Mr Christopher Wallin.
  - ML10327: The land underlying ML10327 is "Sonoma" station, which is privately owned by a third party.
- CCM:
  - ML10345: the land underlying ML10345 is a historic stock route which is no longer declared for that purpose. The land is held under a permit to occupy by Mr Christopher Wallin.
- DCM:
  - ML10349, ML10350, and ML10351: The land underlying these MLs is "Birralee" station, owned by Mr Christopher Wallin.
- JCM:
  - ML10346: The land underlying ML10346 is "Birralee" station, owned by Mr Christopher Wallin.

2.5 Environmental Authorities

EA numbers and primary holders for the QNH mines are provided in **Table 5**.

Table 5 – QCoal Northern Hub Environmental Authorities

Mine	MLs	EA Number	Grant	Primary EA Holder	Current version
SCM	ML10325, ML10326, ML10327	EPML00707713	13/9/2007	QCoal Sonoma Pty Ltd	6/03/2020
CCM	ML10345	EPML00334613	16/8/2012	Bowen River Coal Pty Ltd	9/03/2020
DCM	ML10349, ML10350, ML10351	EPML00393013	2/11/2014	Northern Hub (Drake) Pty Ltd	6/03/2020
JCM	ML10346	EPML00337613	20/12/2013	Jax Coal Pty Ltd	14/04/2020

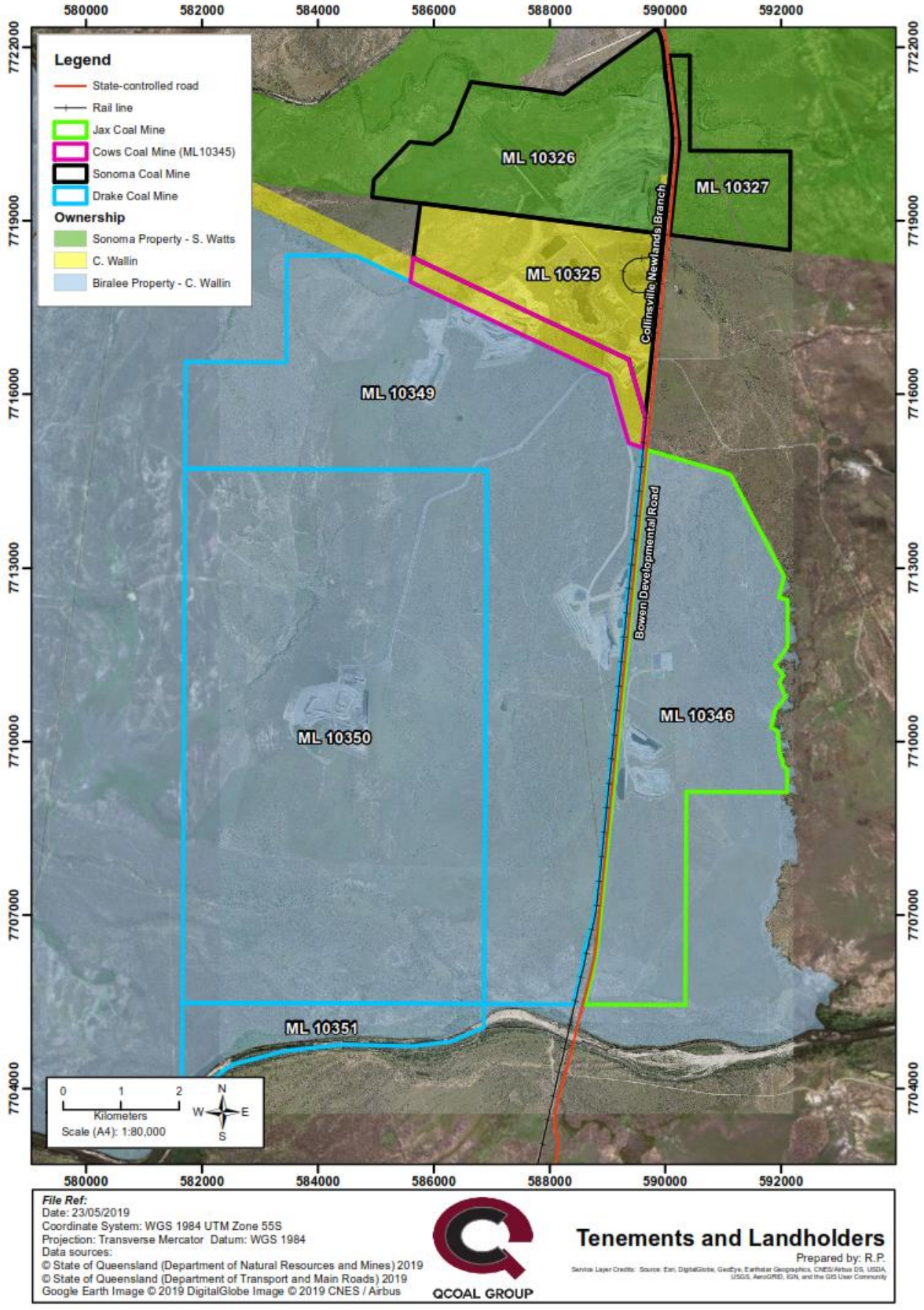


Figure 2 – Tenements and Underlying Landholders

2.6 Activities and Mining Methods

Mining operations on the QNH involve extraction of Run of Mine (ROM) coal using conventional drill and blast, and excavator and truck methodology. ROM coal is then processed and shipped as product coal (coking and thermal).

Topsoil stripped ahead of mine-related activities is either stockpiled for later use in rehabilitation or placed directly on areas already prepared for rehabilitation works. Waste rock materials are placed in either out-of-pit dumps or in-pit dumps.

The QNH mines share water management infrastructure, haul roads, equipment, resources, and other infrastructure. ROM coal from all four QNH mines is sent to the Coal Handling and Processing Plant (CHPP) and train load-out facility located on the SCM. Processed coal is transported to Abbot Point Coal Terminal for shipment to customers.

Coal rejects material generated during processing at the CHPP are placed into co-disposal facilities located on the SCM.

3 Environmental Values

3.1 Climate

The region is characterised by distinct wet and dry seasons, with the majority of rainfall occurring during the summer months, along with higher temperatures and evaporation rates. Average monthly temperature, rainfall and evaporation statistics, as collected at the Bureau of Meteorology's (BoM) Collinsville Post Office Station (no. 033013) are presented in **Figure 3**.

The average annual rainfall for the QNH is 701.6 mm and the average annual evaporation is 1,861.5 mm (BoM, 2019). As such, the region is subject to net annual evaporation, and is dry for much of the year. Predominant winds are south-easterly for the majority of the year.

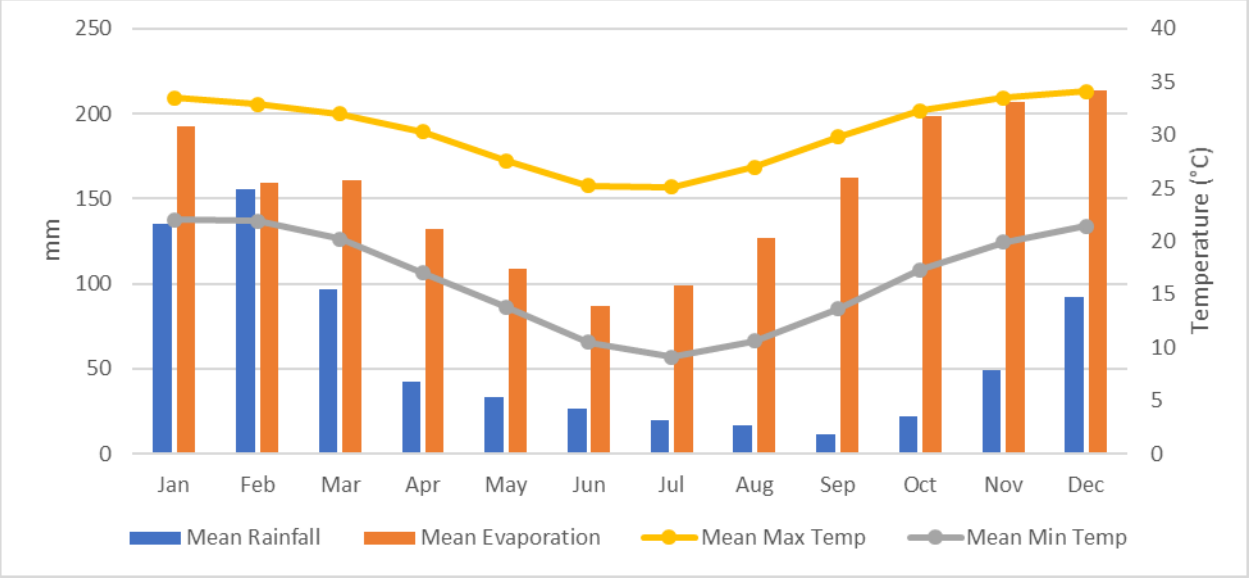


Figure 3 – QCoal Northern Hub Climate Averages

3.2 Topography

The QNH is situated in a flat-to-undulating landscape between the Bowen River (which curves to the south and west of the QNH), Pelican Creek to the north, and the northern sections of the Clarke Ranges to the east. Pre-mining topography in the region was described by GSSE (2005) as alluvial plains and terraces bordering Coral Creek in the north and the Bowen River in the south, and plains and low hills bordered by Two Mile Creek in the middle of the area. Pre-mining elevations ranged from 200 mAHD in the east to 160 mAHD in the west. Undisturbed areas of the QNH MLs typically have a slope of less than 10%.

3.3 Land Use and Suitability

Land suitability classification is assessed based on the *Guidelines for Agricultural Land Evaluation in Queensland* (DSITI & DNRM, 2015). The majority of the land on which the QNH MLs are held has been historically cleared for grazing activities; however, there are scattered areas of remnant vegetation. Current land use in the region is predominantly low intensity grazing on native and improved pastures, with other land uses including coal mining (including exploration), quarrying, and power generation (coal-fired and solar).

Previous land suitability assessments undertaken during the SCM and DCM EIS processes noted that:

- Large areas of the QNH were cleared historically for grazing;
- Logging and ringbarking have been undertaken historically in riparian zones, and mixed woodlands have been thinned, with understories removed to facilitate grazing;
- Soils and landforms are generally suitable for cattle grazing.
- Ongoing pastoral activities by landholders across the QNH MLs and the surrounding region have included agistment/grazing, clearing, regrowth and weed control, and control of feral animals (dogs, pigs, etc.).

The land underlying the SCM, and, by extension, the CCM was characterised as Class 2 for beef cattle grazing prior to the commencement of operations, and it has been concluded that the land was typically not suited to cultivation due to limitations of slope, soil, erosion and climate (GSSE, 2005).

The land underlying the DCM was assessed during the DCM EIS process and typically found to be Class 3 suitability for beef cattle grazing, with limitations to its suitability for broad acre cropping, typically due to water availability, workability, erosion and dissected topography (GHD, 2012).

The *State Rural Leasehold Land Strategy* (NRM, 2013) provides a framework for the management of leasehold land used for agricultural or pastoral pursuits, with a focus on managing land condition and sustaining productive use of leased land. Although mining activities are outside this land use, the rehabilitation strategies and post-mine land use targets for mined land must consider the impacts of rehabilitation on the condition of surrounding pastoral land and any obligations as a lessee.

The *Land Act 1994* obliges leaseholders to take all reasonable actions to:

- Maintain pastures dominated by perennial and productive species
- Maintain native grasslands free of encroachment
- Protect riparian vegetation
- Manage declared pests
- Avoid causing or contributing to salinity that reduces the productivity of leased land, or causes damage to surrounding land
- Conserve soil, water resources, and biodiversity.

3.4 Soils and Geology

The DCM EIS (GHD, 2012) describes the soil profile and geology of the land underlying the DCM and the broader QNH area and has been used to inform this section.

The QNH is located in the northern Bowen Basin. The regional geology documented by the 1:250,000 Geological Series (Bowen, Sheet SF55-3) indicates the QNH is underlain by the Later Permian Blackwater Group consisting of lithic sandstone, siltstone, shale, conglomerate, dolomite and tuff, and minor coal. This is surrounded and underlain by the Early to Late Permian Bienheim Sub-group described as a succession of siltstone, sandstone, coquinite, and limestone.

Overburden and reject materials generated by the QNH are likely to be relatively benign and are expected to generate slightly alkaline and low-to-moderately saline runoff and seepage following surface exposure (see **Section 3.5**).

The majority of the soil and subsoil materials tested were characterised as sodic and alkaline, which is typical of the region. Sodic soils are typically observed at 0.3 m below surface soils. The topsoil horizon depth varies between 0.2m and 1.0m in depth.

3.5 Mine Waste Characteristics

The geochemical characteristics of mine waste materials inform their placement during operations. Materials that have potential geochemical risks are to be encapsulated within materials categorised as lower risk. A number of geochemical investigations have been undertaken on the QNH, including, but not limited to, the following:

- *Sonoma Coal Project – Overburden Assessment Report* (Parsons Brinckerhoff, 2006)
- *Drake Coal Mine EIS – Chapter 7 Mining Waste* (2012)
- *Geochemical Assessment of Mining Waste and Coal Reject Materials, Sonoma Coal Mine* (Terrenus, 2012)
- *Mining Waste and Coal Rejects Management Plan – Sonoma Coal Mine* (Terrenus, 2013)

The findings of these assessments have provided an understanding of the nature of mining waste on the QNH, as detailed in the following sub-sections.

3.5.1 Mine Waste Risk Categories

Based on the geochemical analysis of spoils and coal rejects, a *Mining Waste and Coal Reject Management Plan* (Terrenus, 2013), was developed for the SCM. This plan establishes spoil categories for management of waste rock materials across the QNH. These categories have been visualised in **Figure 4**.

- **Topsoil and subsoil (low risk).** Topsoil (and subsoil) to nominal depth of 1 m below natural surface. Three types of topsoil are defined: Grey uniform clay, brown gradational sandy loam and red duplex sandy loam. Of these types, grey uniform clay is the most prevalent within the existing and future disturbance areas of the mine. This material is defined as Non-Acid Forming (NAF).

- **Category 1 (low risk).** Includes non-coal and non-carbonaceous material above C Seam, not including topsoil/sub-soil, and not within 1 m above and below ROM coal. Typically weathered or moderately weathered. This material is defined as NAF.
- **Category 2 (low to medium risk).** Includes non-coal and non-carbonaceous material below C Seam and not within 1 m above and below ROM coal. Generally fresh or slightly weathered and is defined as material with some capacity to generate Acid and Metalliferous Drainage (AMD). This material is classified as Potentially Acid Forming – Low Capacity (PAF-LC).
- **Category 3 (medium risk).** Includes coal and carbonaceous material, including material within 1 m above and below ROM coal seams, sub-economic coal, intruded coal and heat-affected coal. This material is defined as having some capacity to generate AMD, and is classified as PAF-LC.

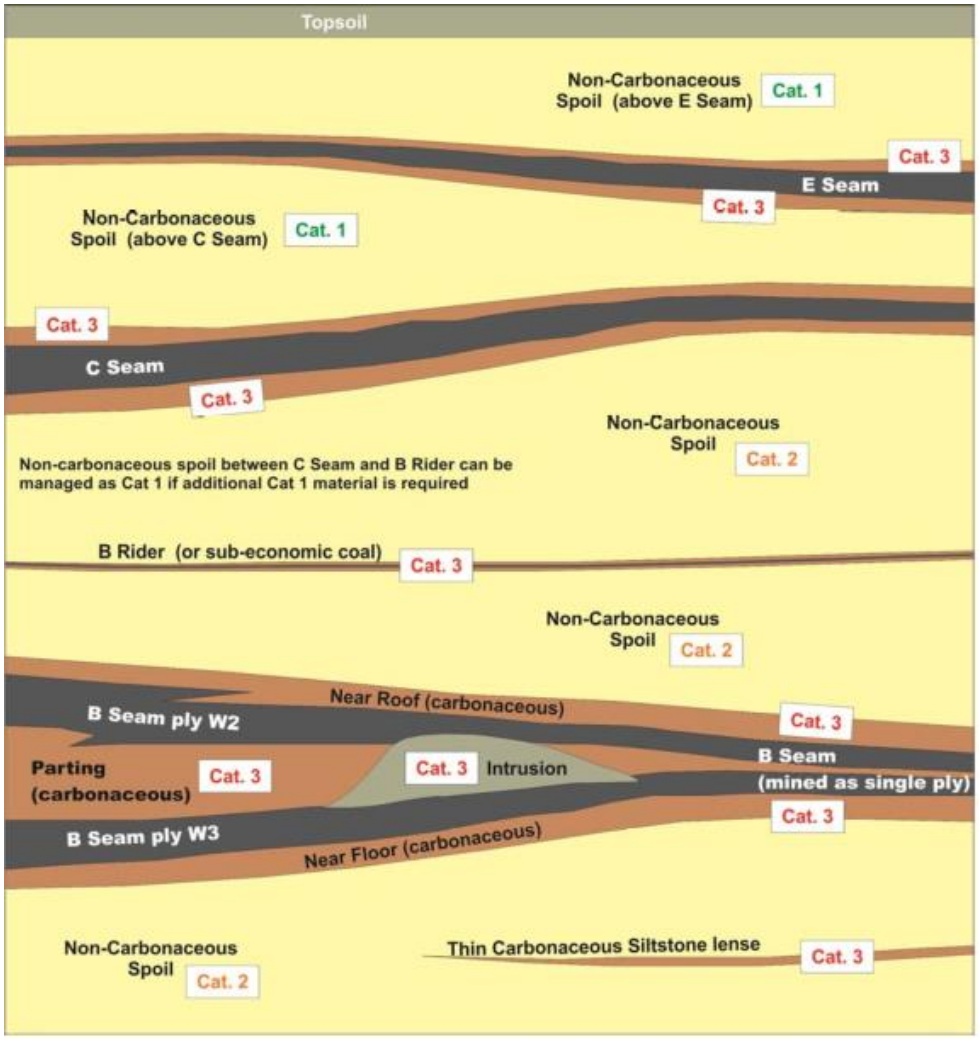


Figure 4 – Conceptual Representation of Spoil Categories (Terrenus, 2013)

3.5.2 QNH Waste Rock Characterisation

A summary of the findings of PB (2006) has been presented below:

- Waste rock was typically non-acid forming (NAF); however, rocks within 5m of coal seams should not be concentrated near the surface of waste rock dumps.
- Tertiary/Quaternary soils were generally slightly alkaline (pH between 7.8 and 8.6) and had low salinity (electrical conductivity (EC1:5) of 200 µS/cm) to moderate salinity (EC1:5 of 675 µS/cm). A single sample returned moderately high salinity (EC1:5 of 924 µS/cm).
- Alluvial soils were found to have low to moderate salinity.
- Weathered Permian rocks were found to have similar salinity, sodicity and alkalinity characteristics to the overlying alluvial soils. This material is considered suitable for capping.
- Fresh Permian rocks had moderately high alkalinity levels and low-to-moderate salinity. This material is considered unsuitable for capping.

A summary of the Terrenus (2013) waste rock findings is presented below:

- Spoil is likely to generate alkaline, low-salinity runoff and seepage following surface exposure.
- The total sulphur concentration of spoil is generally very low, and almost negligible. The majority of spoil materials are classified as NAF, with most spoil further classified as 'barren' (i.e. <0.1% sulphur) with respect to sulfuret content.
- Total metal and metalloid concentrations in spoils are low.
- There is potential for spoil to produce leachate containing slightly elevated soluble molybdenum and selenium concentrations, which is common for materials from the Moranbah Coal Measures.
- Spoil materials are expected to be moderately to highly sodic; however, they are not expected to be dispersive in their current condition. Following weathering or exposure, dispersion may occur.
- Waste rock at the QNH is anticipated to be mostly low risk.

3.5.3 Coal Rejects

Findings of the Terrenus (2013) investigation into the properties of coal rejects likely to be generated at the QNH are summarised below:

- Coal rejects are expected to generate low salinity, neutral to alkaline pH run-off and seepage following surface exposure.
- The total sulphur and sulphide concentrations are generally low. Fine rejects generally have higher sulphur and sulphide concentrations compared to coarse rejects.
- The coal reject materials as a whole are expected to have little capacity to generate acid.
- Total metal and metalloid concentrations are generally low.
- Some coal reject materials *may* produce leachate containing slightly elevated concentrations of soluble elements (particularly aluminium and arsenic).

3.6 Flora

The QNH is located in the northern section of the Brigalow Belt Bioregion. A desktop analysis of flora was undertaken as part of the Drake EIS (GHD, 2012), and a targeted survey was undertaken by GHD in April 2010, identifying 192 plant species from 50 families.

In the northern section of the QNH, the Coral Creek Riparian Management Zone has been established to protect a population of Black ironbox (*Eucalyptus raveretiana*), which is listed in the *Environmental Protection and Biodiversity Conservation Act 1999* (Commonwealth) as vulnerable.

3.7 Weeds

Weeds identified during surveys at the QNH (formerly covered by exploration permit EPC586) have been provided in **Table 6** below (TECSol, 2011). The *QCoal Northern Hub Weed Management Plan* has been developed as per the relevant conditions within the QNH EAs; however, general weed management practices on the QNH are also addressed in **Section 7.3.3** of this document.

Weed species are classified at the state level by the *Land Protection (Pest and Stock Route Management) Act 2002*, and regionally by the *Whitsunday Regional Council Biosecurity Plan 2016-2020* (WRC, 2016).

Table 6 – Significant Weeds identified on EPC 586 (TECSol, 2011)

Family	Species	Common Name	Biosecurity QLD Declared (Class)	Whitsunday Regional Council Biosecurity Plan Class
Amaranthaceae	*Gomphrena celosioides*	Gromphrena Weed	No	No
Apocynaceae	*Cryptostegia grandiflora*	Rubber Vine	Yes (2)	Yes (2)
Asteraceae	*Parthenium hysterophorus*	Parthenium	Yes (2)	Yes (2), WoNS
Asteraceae	*Xanthium pungens*	Noogoora Burr	No	No
Cactaceae	*Eriocereus spp.*	Harrisia Cactus	Yes (2)	Yes (2)
Cactaceae	*Opuntia stricta*	Prickly Pear	Yes (2)	No
Mimosaceae	*Acacia farnesiana*	Prickly Mimosa	No	No
Mimosaceae	*Acacia nilotica*	Prickly Acacia	Yes (1)	Yes (2); WoNS
Papaveraceae	*Aremone ochraluca*	Prickly Poppy	No	No
Poaceae	*Cenchrus cillaris*	Buffel Grass	No	No
Rhamnaceae	*Ziziphus mauritiana*	Chinee Apple	Yes (2)	Yes (2)

3.8 Surface Water

A detailed description and general characterisation of the receiving waters of the QNH can be found in the *QCoal Northern Hub Receiving Environment Monitoring Program* (REMP) (Freshwater Ecology, 2016) and the current version of the *QNH Water Management Plan* (WMP) (Engeny, 2020). The REMP outlines the requirements for ongoing collection of baseline monitoring results, including water quality and macroinvertebrate surveys within the

watercourses surrounding the QNH. The WMP outlines the requirements for water quality monitoring within watercourses, creeks and drainage channels in and surrounding the QNH, and describes the catchments, water storage and movement infrastructure on the sites. The WMP is updated annually to reflect changes in water management across the site and contains the Erosion and Sediment Control Plan for the QNH sites.

The QNH is located within the Bowen Broken Bogie Basin, in the upper reaches of the broader Burdekin River catchment. The QNH MLs extend over two sub-catchments, namely the Bowen River sub-catchment and the Pelican Creek sub-catchment. There are twenty-five (25) release points in the various site EAs; however, many of these have not been established and are not currently being used.

Apart from the Bowen River, the majority of waterways in the region are highly ephemeral, with flow typically only associated with significant regional rainfall events.

Two Mile Creek, which previously flowed through the middle of the SCM, was diverted in 2012 to allow for ongoing mining activities in the southern extent of the Sonoma Main Pit. Coral Creek, north of SCM, was diverted in 2018 to allow for the extraction of coal from Sonoma North Pit, the northern extension of the Sonoma Main Pit.

Priority actions for sub-catchments have been defined in the *Burdekin Water Quality Improvement Plan 2016* for both the Bowen River and Pelican Creek sub-catchments. These include the management of grazing, mining, industry, and other infrastructure, and they have been addressed as part of the management of rehabilitation activities.

The defined environmental values (EVs) for both the Bowen River and Pelican Creek are based on the *Environment Protection Policy (Water and Wetlands)* (DES). These EVs have their own associated set of water quality monitoring criteria based on the ANZECC (Australian and New Zealand Environment and Conservation Council) *Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000); however, the sites have prescribed monitoring parameters.

Bowen River EVs

- Aquatic Ecosystems
- Irrigation
- Farm Supply
- Stock Watering
- Human Consumer
- Primary, Secondary and Visual Recreation
- Drinking Water
- Industrial Use
- Cultural and Spiritual Values

Pelican Creek EVs

- Aquatic Ecosystems
- Irrigation
- Farm Supply
- Stock Watering
- Human Consumer
- Secondary and Visual Recreation
- Drinking Water
- Industrial Use
- Cultural and Spiritual Values

Routine surface water monitoring is undertaken to satisfy conditions of the four (4) QNH EAs and the REMP. Material impacts to water quality or aquatic ecology have not been identified in association with QNH activities to date. Final landforms are not anticipated to impact adjacent surface water EVs once the rehabilitation criteria are achieved.

3.9 Groundwater

Numerous groundwater studies have been undertaken across the QNH, including *Groundwater Monitoring and Management Plan – Drake Coal Pty Ltd – Drake Coal Project* (QCoal, October 2014), *Northern Hub Groundwater Assessment* (AGE, 2018) and *Northern Hub Groundwater Assessment* (AGE, 2020).

Findings of these studies indicate the following:

- Groundwater values:
  - There are no known groundwater springs or seeps in the QNH area.
  - Stygofauna have not been identified in the area.
  - Groundwater Dependent Ecosystems (GDEs) are not considered likely to exist in the QNH area.
  - Based on searches of registered licensed groundwater bores and a landholder bore survey, groundwater use (including, but not limited to pastoral, irrigation, mining, stock, domestic, and town water) is not considered a groundwater value across or in the immediate vicinity of the QNH.
  - The quality of groundwater is generally described as marginal, with typically poorer quality groundwater encountered within coal-bearing strata.
- Hydrogeological regime (see **Appendix A** for further detail)
  - Groundwater has been found to be present intermittently within alluvial strata and within the Permian coal measures.
  - There is limited connectivity between surface water, alluvium and the Permian coal measures (as evidenced by hydrograph data and major ion chemistry)
  - No significant interactions are expected between ephemeral creeks or the Bowen River and the Permian Coal measures.
  - Some direct interaction between the Bowen River and groundwater within the immediate alluvial banks is likely and would be associated with flooding/receding cycles.

Impact on groundwater from the QNH, once rehabilitated, can only occur through two mechanisms: 1) direct infiltration of contaminated runoff or leachate into groundwater, and/or 2) drawdown associated with voids reducing groundwater levels, which can have a secondary effect on quality under specific geochemical conditions.

Waste rock (including reject material) has been shown to be generally low risk (see **Section 3.5**) and is considered unlikely to generate poor quality runoff or leachate. Rehabilitation (includes capping for co-disposal facilities) and revegetation further reduces leachate and runoff risks.

Drawdown of water associated with the QNH voids is specifically addressed in the *Investigation into Residual Void Sonoma Coal Mine* (QCoal, 2020) report (see **Appendix A**), supported by Engeny, 2020 and AGE, 2020, which determined that the QNH voids will either remain perpetual groundwater sinks or groundwater sources which do not feed surrounding aquifers, but rather the other QNH void sinks, and, therefore, no migration of water from the voids into the surround groundwater aquifers is likely.

Based on the nature of regional groundwater characteristics, and its current level of use, the QNH is assumed to have minimal impact on groundwater values following rehabilitation.

Routine groundwater monitoring is undertaken across the QNH to identify fluctuations in water level or quality. To date, monitoring has shown the operations have not had a materially effect on groundwater level or quality. Accordingly, final landforms are not anticipated to affect the surrounding regional groundwater levels or EVs.

4 Environmental Authority Rehabilitation Conditions

The QNH EAs are the primary approval documents that stipulate rehabilitation requirements. The conditions related to rehabilitation in each of the four (4) QNH EAs are identical, apart from void outcomes. As such, the rehabilitation conditions for all four (4) QNH mines are presented in **Table 7** and the rehabilitation requirements for the QNH final voids (as detailed in **Table H1** of each of the EAs) has been summarised as **Table 8**.

Table 7 – QNH EA Rehabilitation Conditions

Condition	Condition Wording
H1	All areas significantly disturbed by mining activities must be rehabilitated to achieve the following rehabilitation goals: a) safe to humans and wildlife; b) stable; c) non-polluting; and d) self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids
H2	Rehabilitation must commence progressively in accordance with the Plan of Operations.
H3	A Rehabilitation Plan must be developed by **24 April 2020** by a suitably qualified person and submitted for approval prior to implementing.
H4	Within **20 business days** of the receipt of comments from the administering authority, the updated Rehabilitation Plan must be submitted to the department for approval.
H5	The Rehabilitation Plan must include: a) Rehabilitation objectives to achieve the rehabilitation goals for all disturbed areas; b) Detailed rehabilitation methods for each disturbed area; c) Rehabilitation indicators to measure the success of the rehabilitation against the rehabilitation objectives; d) Final completion criteria that will achieve the rehabilitation goals and objectives; e) Details of appropriate monitoring and maintenance of rehabilitation; f) Identify 3 reference sites to be used to develop rehabilitation success criteria for each disturbance domain; and g) Include a description of monitoring of reference sites inclusive of statistical design. h) For rehabilitation of watercourse diversion, details of the required methods of rehabilitation stated in the relevant approved Design Plans
H6	All areas significantly disturbed by mining activities must be rehabilitated in accordance with the Rehabilitation Plan to achieve the final completion criteria.
H7	The environmental authority holder must notify the administering authority of any changes to the Rehabilitation Plan and submit the updated document to the administering authority.
H10	**Contaminated Land** Before applying for surrender of a mining lease, the holder must (if applicable) provide to the administering authority a site investigation report under the Act, in relation to any part of the mining lease which has been used for notifiable activities or which the holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use.
H11	Before applying for progressive rehabilitation certification for an area, the holder must (if applicable) provide to the administering authority a site investigation report under the Act, in relation to any part of the area the subject of the application which has been used for notifiable activities or which the holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use under the approved Rehabilitation Plan as per **Condition H3**.

H15	**Residual void outcome** Residual voids must comply with the following outcomes: a) Residual voids must not cause any serious environmental harm to land, surface waters or any recognized groundwater aquifers, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority; b) Residual voids must comply with **Table H1 – Residual void outcomes**; and c) At the completion of decommissioning and rehabilitation, all residual voids must demonstrably have the appropriate level of flood protection from nearby watercourses as approved by the administering authority, such that the protection is sustainable for the foreseeable future.
H16	All reasonable and practical measure must be taken to minimize the size of the void remaining after mining activities cease.
H18	**Exploration** Land subject to exploration activities previously approved under EPC586 that subsequently became… (QCoal Comment: relevant site-specific MLs) must be rehabilitated in accordance with the *Code of Environmental Compliance for Exploration and Mineral Development Projects*.
H19	Land subject to exploration activities carried out on… (QCoal Comment: relevant site-specific MLs) subsequent to the grant of the relevant mining lease, must be rehabilitated in accordance with the *Code of Environmental Compliance for Exploration and Mineral Development Projects*.

Table 8 – EA Table H1 Summary

Site	Residual Void	Void Area	Void Outcome	Maximum Slope
Sonoma Coal Mine	Sonoma Main Pit	120 ha	*Unspecified in SCM EA Table H1*	High wall – 70° with top 10m max 45° including a 1m bund
	Sonoma East Pit 1	14 ha		
	Sonoma East Pit 2	15 ha		
	Sonoma Q-Pit	n/a backfilled		n/a backfilled
	Sonoma B-Pit	n/a backfilled		n/a backfilled
Drake Coal Mine	Drake Pit 5	59 ha	*Unspecified in DCM EA Table H1*	High Wall – 65° Low wall – 45°
	Drake Pit 1	258 ha		
	Drake Pit 2			
	Drake Pit 2 Expansion			
	Central Pit 3	50 ha		
	Central Pit 4	16 ha		
	East Pit 1	14 ha		
	Drake Pit 3-Q	61 ha		
	Drake Pit 3-R			
Jax Coal Mine	Jax Main Pit	70 ha	Residual void unable to sustain a post-mining land use	High wall – 60°
	Jax East Pit	27 ha		Low wall – 32°
Cows Coal Mine	B Seam Pit	Backfilled	*Unspecified in CCM EA Table H1-*	N/A
	Q Seam Pit	Backfilled	*Unspecified in CCM EA Table H1-*	

5 Rehabilitation Objectives and Targets

5.1 Domains of Disturbance

Disturbance by mining activities at the QNH has been split into eight (8) domains, each with individual rehabilitation requirements, as detailed in **Table 9**.

Table 9 – Rehabilitation Domains

Domain	Description	Applicable Mine
1	Residual voids	SCM, DCM, JCM
2	Overburden dumps	SCM, CCM, DCM, JCM
3	Mine Infrastructure	SCM, DCM, JCM
4a	Co-disposal dams	SCM
4b	In-Pit Co-disposal	SCM
5	ROM and product stockpiles	SCM, DCM, JCM
6	Haul roads and access tracks	SCM, CCM, DCM, JCM
7	Sediment dams and water management infrastructure	SCM, DCM, JCM
8	Creek diversions	SCM

5.2 Rehabilitation Goals

Broad rehabilitation goals for the QNH sites are defined in **Condition H1** of the QNH EAs. These rehabilitation goals generally align with the rehabilitation goals summarised in the *Rehabilitation Requirements for Mining Projects* (EHP, 2014), and are as follows:

- Safe to humans and wildlife
- Stable
- Non-polluting
- Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids.

EHP (2014) also includes a range of suggested strategies to aid in achieving the rehabilitation goals, which have informed the development of the rehabilitation strategies presented in this RMP (see **Section 7**).

5.3 Agreed Post-Mining Land Use

The post-mining land use is agreed between the mining company and the administering authority. Generally, the agreed post-mining land use considers both the historical use(s) of the land underlying the operations and the current use(s) of the land surrounding the operations.

Post-mining land use in the context of the Progressive Rehabilitation and Closure Plan (PRC Plan) for transitional sites is determined by Land Outcome Documents (LODs), as defined in the EP Act as follows:

***land outcome document**, for land, means the following documents relating to the land—*

(a) an environmental authority for a resource activity on the land;

(b) a document made under a condition of an environmental authority mentioned in paragraph (a), if—

(i) the document relates to the management of a void within the meaning of section 126D on the land, or the rehabilitation of the land; and

(ii) the document was received by the administering authority before the assent date; and

(iii) the administering authority has not, within 20 business days after the assent date, given notice to the holder of the environmental authority that the document is insufficient in a material particular relevant to a matter mentioned in subparagraph (i); and

(iv) before the assent date, the document had not been superseded;

(c) a document made under a condition of an environmental authority mentioned in paragraph (a), if—

(i) the document relates to the management of a void within the meaning of section 126D on the land, or the rehabilitation of the land; and

(ii) the environmental authority requires the document to be given to the administering authority on a stated day that is on or after the assent date, or does not state a day when the document must be given; and

(iii) the document is received by the administering authority within 3 years after the assent date; and

(iv) the administering authority does not, within 20 business days after receiving the document, give the holder of the environmental authority notice that the document is insufficient in a material particular relevant to a mater mentioned in subparagraph (i);

(d) a report evaluating a EIS under the State Development and Public Works Organisation Act 1971, section 34D;

(e) an EIS assessment report;

(f) a written agreement between the holder of an environmental authority mentioned in paragraph (a) and the State that is in force on the assent date.

Post mining land use by domain and the relevant LOD to that post-mining land use has been presented in **Table 10**.

Table 10 – Post Mining Land Use by Domain

	Sonoma Coal Mine		Drake Coal Mine		Jax Coal Mine		Cows Coal Mine	
Domain	PMLU	LOD	PMLU	LOD	PMLU	LOD	PMLU	LOD
Residual voids	Residual void unable to sustain a post-mining land use.	QNH RMP	Residual void unable to sustain a post-mining land use.	QNH RMP	Residual void unable to sustain a post-mining land use.	QNH RMP and EA	-	-
Overburden Dumps	Grazing pasture	EA	Grazing pasture	EA	Grazing pasture	EA	Grazing pasture	EA
Mine Infrastructure	Grazing pasture or retained*	EA	Grazing pasture or retained*	EA	Grazing pasture or retained*	EA	-	-
Co-disposal dams	Grazing pasture	EA	-	-	-	-	-	-
In-pit co-disposal	Part of the Sonoma Main Pit Void complex	-	-	-	-	-	-	-
ROM and product stockpiles	Grazing pasture	EA	Grazing Pasture	EA	Grazing Pasture	EA	-	-
Haul Roads and Access tracks	Grazing pasture or retained*	EA	Grazing pasture or retained*	EA	Grazing pasture or retained*	EA	Grazing pasture or retained*	EA
Sediment dams and water management infrastructure	Grazing pasture or retained*	EA	Grazing pasture or retained*	EA	Grazing pasture or retained*	EA	-	-
Creek diversions	Grazing Pasture and Permanent Watercourse	EA and Diversion Design Documents	-	-	-	-	-	-

* These domains may be retained by the landholder only in the presence of written agreement

The agreed post-mining land use for all QNH mines, as per **Condition H1** in each of the QNH EAs (considered in the legislation as the highest Land Outcome Document) , is self-sustaining grazing pasture for all domains with the exception of residual voids, creek diversions, and any infrastructure retained by the landholder (such as dams, hardstand areas, buildings, haul roads/access tracks, etc.) which will have a post-mining land use specific to the landholder.

When mine pits are backfilled, no residual void remains, and those areas no longer classified as Domain 1 (residual voids). Areas of backfilled pit (i.e. in-pit waste rock dumps) are classified as Domain 2 (overburden dump), and sediment control structures constructed within areas of backfilled pit are captured by Domain 7 (sediment dams and water management infrastructure). The PMLU for these landforms is identified in the relevant sections of **Table 10** above.

The residual voids permitted on the QNH are stated in the QNH EA's (presented in **Table 8**). The JCM EA stipulates a void outcome for the JCM voids as "Residual unable to sustain a post mining land use"; however, the DCM and SCM EAs do not stipulate a post-mining land use. As the DCM and SCM voids are not sources of groundwater to surrounding aquifers, and have perpetually degrading void lake water quality, they are also considered to be unable to sustain a post-mining land use (see **Appendix A**).

For rehabilitation to have been considered successful, the land must be returned to a "stable condition" as defined in Section 111A of the EP Act:

111A Meaning of stable condition

*Land is in a **stable condition** if –*

(a) the land is safe and structurally stable; and
(b) there is no environmental harm being caused by anything on or in the land; and
(c) the land can sustain a post-mining land use.

As the residual voids on the QNH have degrading lake water quality, and are therefore unable to sustain a PMLU, they cannot be rehabilitated to a stable condition as per the EP Act. As per the definitions in section 112 of the EP Act, land that cannot be rehabilitated to a stable condition is considered a non-use management area (NUMA):

***non-use management area** means an area of land the subject of a PRC plan that can not be rehabilitated to a stable condition after all relevant activities for the PRC plan carried out on the land have ended.*

As the QNH mines transition into to the Progressive Rehabilitation and Closure Plan (PRC Plan) framework, residual voids will be managed as NUMAs. The primary LOD for this land outcome will be the QNH RMP; however, for JCM, these void outcomes are presented in the EA (see **Appendix A** for further detail).

5.3.1 Requirements for Grazing Pasture

QNH land to be rehabilitated to a grazing post mining land-use is to be returned to Class 4 suitability or better, based on the *Guidelines for Agricultural Land Evaluation in Queensland* (DSITI & DNRM, 2015). The acceptance criteria for Class 4 land are presented in **Table 11**.

Table 11 – Acceptance criteria – Class 4 Land Suitability

Parameter	Acceptance criteria
Plant Available Water Capacity (PAWC)	>50 mm
Salinity	$EC_{1:5}$ <1.2 mS/cm or $Cl_{1:5}$ <1,500 ppm in the root zone (60 cm depth)
Rockiness	<100% (% coarse fragments at soil surface)
Soil pH	<10 and >4 as measured at any part of the root zone.
Exchangeable Sodium Percentage (ESP %)	<30% (0-10 cm depth)
Water erosion (a function of slope % and ESP %)	Mean Slope <15% on cracking clay soils Mean Slope <12% on sodic soils (ESP >15% within 500 mm of surface) rigid soils Mean Slope <45% on non-sodic (ESP <15% within 500 mm of surface) rigid soils
Grazing Criteria	≥70% of the productivity (or carrying capacity) of non-mined land in the lease area or, Carrying capacity within the range of values reported for the region, taken as 15 ha/head
Groundcover	Mean groundcover ≥50% or > than the reference site mean minus one standard deviation.
Grazing Trials	Undertaken following groundcover establishment to confirm carrying capacity.
Species Mix and Composition	Proportion of non-preferred species not increasing Proportion class will not be more than one class* greater than the grazed reference sites. Proportion of declared plant pest species not increasing, and proportion class* will not be more than one class greater than the grazed reference sites.

* - Classes based on *State Rural Leasehold Land Strategy: Guidelines for determining land condition* prepared by DNRM (2013): Class 1 = 0%, Class 2 = 0-10%, Class 3 = 10-30%, Class 4 = >30% for declared plant pest (weed) species. Class 1 = >80%, Class 2 = 61-80%, Class3 = 10-60%, Class 4 = <10% for preferred species composition.

In order to achieve these acceptance criteria, a range of rehabilitation strategies have been developed for site personnel to assist in the planning and execution of rehabilitation activities (see **Section 7**).

5.4 Landform Design

The design of rehabilitated landforms (other than voids or infrastructure retained by the landholder) is to be consistent with Class 4 suitability grazing, and the surrounding topography of the land. The rehabilitation process may include shaping of the landform to the designed slope, encouraging groundcover and any required works for drainage, and erosion control. Scheduling of works is discussed in **Section 7.4**.

Landform stability is typically achieved by achieving a desired slope length and angle, correct material selection and establishment of groundcover to improve erosion resistance. Mining operational requirements, particularly for waste rock dumps and co-disposal facilities, inform the size (footprint), height, and operational slopes, and other parameters related to the final landform. These operational requirements consider the need to leave domains in a state that

minimises the bulk earthwork requirements to achieve the desired landform design (i.e. geotechnical stability as a function of slope design) once they are released from operational use. Landform design plans are produced commensurate with the operational requirements to ensure as much of the bulk earthworks can be undertaken during regular operation as is possible. Slope ranges are detailed in **Table 12**.

5.5 Completion Criteria

Completion criteria for rehabilitation of the QNH mine domains have been developed to enable measurable/quantifiable criteria, which once achieved demonstrate that rehabilitation is complete and that the rehabilitated final landforms are (1) safe to humans and wildlife, (2) stable, (3) non-polluting, and (4) able to self-sustain the agreed post-mining land use. The criteria have been presented in **Table 12**.

Table 12 – QCoal Northern Hub Rehabilitation Completion Criteria

<table>
<tr><th>Domain</th><th>Objective</th><th>Completion Criteria</th><th>Performance Verification</th></tr>
<tr><td rowspan="4">Domain 1 - Residual Voids</td><td>Safe to humans and wildlife</td><td>Access to the high wall will be restricted by bunds and/or fencing.
Appropriate remediation of slope failures or rock falls.</td><td>Photographic evidence of bunding/fencing.
If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure.</td></tr>
<tr><td>Stable</td><td>Maximum slope:
<table>
<tr><th>Site</th><th>EA reference</th><th>Highwall / Competent Rock</th><th>Low wall / Incompetent Rock</th></tr>
<tr><td>SCM</td><td>Table H1</td><td>Top 10m = 45°
Thereafter = 70°</td><td>17° to 37°</td></tr>
<tr><td>DCM</td><td>Table H1</td><td>65°</td><td>45°</td></tr>
<tr><td>JCM</td><td>Table H1</td><td>60°</td><td>45°</td></tr>
</table>
Appropriate remediation of slope failures or rock falls.
Appropriate remediation of rill and gully erosion.</td><td>Slope measurements retained with rehabilitation documentation.
If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure.
If rill or gully erosion is identified, it is rectified, and additional erosion controls implemented as appropriate.</td></tr>
<tr><td>Non-polluting</td><td>Hydrogeological assessment completed.
Void water balance completed and confirms ‘no overtopping’ in final design.
Void water quality will not diminish the EVs of the surrounding groundwater.</td><td>Hydrogeology and water balance report.
Groundwater monitoring/modelling shows no risk to local aquifer EVs.</td></tr>
<tr><td>Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids</td><td>Not applicable to residual voids that are groundwater sinks, which are classified as “Residual void unable to sustain a post mining land use”. See Appendix A.</td><td>Not applicable to residual voids that are groundwater sinks. See Appendix A.</td></tr>
<tr><td>Domain 2 - Overburden dumps</td><td>Safe to humans and wildlife</td><td>Appropriate remediation of slope failures or rock falls.</td><td>If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure.</td></tr>
</table>

Domain	Objective	Completion Criteria	Performance Verification
	Stable	The nominated maximum slope on dumps is 20% (11.5°), unless otherwise advised by an RPEQ. Mean groundcover ≥50%, or > the reference site mean minus one standard deviation. Appropriate remediation of slope failures or rock falls. Appropriate remediation of rill and gully erosion.	As-built/survey information retained with rehabilitation documentation. Rehabilitation monitoring reports to verify groundcover. If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure If rill or gully erosion is identified, it is rectified, and additional erosion controls implemented as appropriate.
	Non-polluting	Spoil is to be dumped in accordance with the *QNH Mining Waste and Coal Rejects Management Plan* (Terrenus, 2013). Run-off or seepage water is not to diminish the EVs of the receiving environment including surrounding groundwater.	*Mining Waste and Coal Rejects Management Plan* (Terrenus, 2013) to be retained with rehabilitation documentation. As-built/survey information to be retained with rehabilitation documentation. REMP reporting during operations. Post-closure surface and groundwater quality monitoring reports.
	Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids	Class 4 land suitability and light cattle grazing target (see **Section 5.3**)	Rehabilitation monitoring reports verify soil/land suitability standards are met. Rehabilitation monitoring reports verify productivity standards are met. Rehabilitation monitoring reports verify species mix and community composition standards are met.
Domain 3 - Mine Infrastructure including CHPP, Train Load out facility and rail loop.	Safe to humans and wildlife	Hazardous material is identified and managed Only infrastructure remaining on-site is as per an agreement with the landholder and the State. Appropriate remediation of slope failures or rock falls	Remediation of identified contaminated areas is verified and/or approved Site Management Plan is in place. All unwanted infrastructure is removed. Evidence of agreement is held with rehabilitation documentation. If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure.
	Stable	For all infrastructure on the QNH the adopted maximum slope completion criteria will be 20% (11.5°), unless otherwise advised by an RPEQ. Mean groundcover ≥50%, or > the reference site mean minus one standard deviation. Appropriate remediation of slope failures or rock falls. Appropriate remediation of rill and gully erosion.	As-built/survey information retained with rehabilitation documentation. Rehabilitation monitoring reports to verify groundcover. If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure. If rill or gully erosion is identified, it is rectified, and additional erosion controls implemented as appropriate.
	Non-polluting	Hazardous material is identified and managed. Run-off or seepage water is not to diminish the EVs of the receiving environment and local aquifers.	REMP reporting during operations. Post-closure surface and groundwater quality monitoring reports.
	Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids	Class 4 land suitability and light cattle grazing target (see **Section 5.3**)	Rehabilitation monitoring reports verify soil/land suitability standards are met. Rehabilitation monitoring reports verify productivity standards are met. Rehabilitation monitoring reports verify species mix and community composition standards are met.
Domain 4a - Co-disposal	Safe to humans and wildlife	Appropriate remediation of slope failures or rock falls.	If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure.

Domain	Objective	Completion Criteria	Performance Verification
dams (out-of-pit)	Stable	For all co-disposal facilities on the QNH the adopted slope completion criteria will be 11.5°, unless otherwise advised by an RPEQ. Mean groundcover ≥50%, or > the reference site mean minus one standard deviation. Appropriate remediation of rill and gully erosion.	Approved Site Management Plan is in place. Remediation of identified contaminated areas is verified and/or approved Site Management Plan is in place. As-built/survey information retained with rehabilitation documentation. Rehabilitation monitoring reports to verify groundcover. If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure. If rill or gully erosion is identified, it is rectified, and additional erosion controls implemented as appropriate.
	Non-polluting	Hazardous material is identified and managed. Run-off or seepage water is not to diminish the EVs of the receiving environment and local aquifers.	Remediation of potentially contaminated areas is verified. REMP reporting during operations. Post-closure surface and groundwater quality monitoring reports.
	Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids	Class 4 land suitability and light cattle grazing target (see **Section 5.3**)	Rehabilitation monitoring reports verify soil/land suitability standards are met. Rehabilitation monitoring reports verify productivity standards are met. Rehabilitation monitoring reports verify species mix and community composition standards are met.
Domain 4b - Co-disposal dams (in-pit)	Safe to humans and wildlife	Pit access is restricted as part of Void rehabilitation actions; therefore, no further action is required to make the in-pit co-disposal safe.	Residual void acceptance criteria met.
	Stable	As there are no batters associated with the in-pit co-disposal, there is no risk of slope failures or rock falls. The in-pit co-disposal is to be capped with appropriate waste material.	Residual void acceptance criteria met.
	Non-polluting	The in-pit co-disposal makes up a part of the SCM Main Pit complex, which is a groundwater sink, and will not have any impacts on groundwater or surface water EVs.	Residual void acceptance criteria met.
	Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids	As the in-pit co-disposal becomes part of the residual void floor, and the Sonoma Main Pit is a groundwater sink, there will be no PMLU, and the in-pit co-disposal will make up part of the void NUMA.	N/A
Domain 5 - ROM and Product stockpile areas	Safe to humans and wildlife	Hazardous material is identified and managed. Appropriate remediation of slope failures or rock falls.	Remediation of identified contaminated areas is verified and/or approved Site Management Plan is in place. If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure.

Domain	Objective	Completion Criteria	Performance Verification
	Stable	For all ROM/Product Stockpiles on the QNH the adopted slope completion criteria will be 11.5° (20%), unless otherwise advised by an RPEQ. Mean groundcover ≥50%, or > the reference site mean minus one standard deviation. Appropriate remediation of slope failures or rock falls. Appropriate remediation of rill and gully erosion.	As-built/survey information retained with rehabilitation documentation. Rehabilitation monitoring reports to verify groundcover. If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure. If rill or gully erosion is identified, it is rectified, and additional erosion controls implemented as appropriate.
	Non-polluting	Hazardous material is identified and managed. Run-off or seepage water is not to diminish the EVs of the receiving environment and local aquifers.	REMP reporting during operations. Post-closure surface and groundwater quality monitoring reports.
	Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids	Class 4 land suitability and light cattle grazing target (see **Section 5.3**)	Rehabilitation monitoring reports verify soil/land suitability standards are met. Rehabilitation monitoring reports verify productivity standards are met. Rehabilitation monitoring reports verify species mix and community composition standards are met.
Domain 6 - Haul roads and tracks not being retained for post-mining use	Safe to humans and wildlife	Appropriate remediation of slope failures or rock falls.	If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure.
	Stable	Agreement from landholder regarding infrastructure allowed to remain on site For all roads and tracks not being retained the adopted slope completion criteria will be 11.5° (20%), unless otherwise advised by an RPEQ. Mean groundcover ≥50%, or > the reference site mean minus one standard deviation. Appropriate remediation of slope failures or rock falls. Appropriate remediation of rill and gully erosion.	Evidence of landholder agreement. As-built/survey information retained with rehabilitation documentation. Rehabilitation monitoring reports to verify groundcover. If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure. If rill or gully erosion is identified, it is rectified, and additional erosion controls implemented as appropriate.
	Non-polluting	Run-off or seepage water is not to diminish the EVs of the receiving environment and local aquifers.	REMP reporting during operations. Post-closure surface and groundwater quality monitoring reports.
	Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids	Class 4 land suitability and light cattle grazing target (see **Section 5.3**)	Rehabilitation monitoring reports verify soil/land suitability standards are met. Rehabilitation monitoring reports verify productivity standards are met. Ongoing pasture management measures documented in the PMCP. Rehabilitation monitoring reports verify species mix and community composition standards are met.
Domain 7 - Sediment dams and other water	Safe to humans and wildlife	Appropriate remediation of slope failures or rock falls.	If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure.

Domain	Objective	Completion Criteria	Performance Verification
management infrastructure not retained for post-mining use	Stable	Agreement from landholder regarding infrastructure allowed to remain on site For all dams and water management infrastructure on the QNH the adopted slope completion criteria will be advised by an RPEQ. Mean groundcover ≥50%, or > the reference site mean minus one standard deviation. Appropriate remediation of slope failures or rock falls. Appropriate remediation of rill and gully erosion.	Evidence of landholder agreement Remediation of identified contaminated areas is verified and/or approved Site Management Plan is in place. As-built/survey information retained with rehabilitation documentation. Rehabilitation monitoring reports to verify groundcover. If slope failure has occurred, it is rectified and ongoing design accounts for the previous failure. If rill or gully erosion is identified, it is rectified, and additional erosion controls implemented as appropriate.
	Non-polluting	Hazardous material is identified and managed Run-off or seepage water is not to diminish the EVs of the receiving environment and local aquifers.	REMP reporting during operations. Post-closure surface and groundwater quality monitoring reports.
	Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids	Class 4 land suitability and light cattle grazing target (see **Section 5.3**)	Rehabilitation monitoring reports verify soil/land suitability standards are met. Rehabilitation monitoring reports verify productivity standards are met. Ongoing pasture management measures documented in the PMCP. Rehabilitation monitoring reports verify species mix and community composition standards are met.
Domain 8 - Creek diversions	Safe to humans and wildlife	RPEQ designed and certified	As-built drawings and ongoing monitoring show no safety issues.
	Stable	Total ground cover on the creek banks is sufficient to minimize erosion (70% protective foliage cover in the absence of rock or armouring at the surface) Maximum bank slope: ≤25% (*Design of Two Mile Creek Diversion* (BSM, 2012) and *North Sonoma Creek Diversion Design Plan* (Engeny, 2018)) RPEQ designed and certified Revegetation works completed using the species lists found in the relevant design documents Appropriate remediation of rill and gully erosion.	As-built/survey information retained with rehabilitation documentation. Rehabilitation monitoring reports to verify groundcover. If rill or gully erosion is identified, it is rectified, and additional erosion controls implemented as appropriate.
	Non-polluting	Creek diversions do not impact the EVs of the receiving environment and local aquifers.	REMP reporting during operations. Post-closure surface and groundwater monitoring reports.
	Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids	At least 50% of tree and shrub species located in analogue areas are growing in the diversion area. Abundance of tree species are at least 80% of analogue species abundance. Plant cover is stable or increasing. Class 4 land suitability and light cattle grazing target (see **Section 5.3**) for at least 60% of the land area. Index of Diversion Condition (IDC) score of the diversion is consistent with the creek control reaches.	Rehabilitation monitoring reports verify soil/land suitability standards are met. Rehabilitation monitoring reports verify productivity standards are met. Ongoing pasture management measures documented in the PMCP. Rehabilitation monitoring reports verify species mix and community composition standards are met. Annual monitoring reports show that diversion reaches score equally or better than reference reaches based on the methodology of IDA, 2001. *Monitoring and evaluation program for Bowen Basin river diversion*, ID&A Pty Ltd. Australian Coal association Research Program C9068 (IDA 2001).

6 Required Assessments and Certifications

In order to determine the efficacy of rehabilitation and compliance with various EA conditions, the tasks presented in **Table 13** are to be undertaken by an Appropriately Qualified Person (AQP) (as defined in the QNH EAs) relevant to each task.

Table 13 – Assessments, Designs, and Certifications

Task	Description	Timing
Contaminated Land Assessment	Requirement for a Phase 1 for all sites, using ERC to inform the Phase 1. Phase 1 informs any required Phase 2, which in turn informs any remediation and verification. Remediation of identified contaminated areas is verified and/or approved Site Management Plan is in place. Certification that any identified contaminated land has been managed appropriately and in accordance with the relevant administering authority guideline/s.	Prior to rehabilitation of relevant areas (e.g. MIAs, Infrastructure areas, CHPPs etc.).
Geotechnical studies	Certification that the final landforms are stable/geotechnically sound, and there is a low risk of rock falls with serious environmental or safety consequences.	Following completion of all rehabilitation works with associated geotechnical or rock-fall related risks.
Surface and groundwater monitoring	Monitoring is to be undertaken to identify occurrence of any downstream impacts.	During rehabilitation works and following completion of works until rehabilitation is certified.
Capping material assessment	Assessment of suitable materials and depth for capping of co-disposal facilities	As part of capping of the co-disposal facilities
Soils Assessment	Monitoring of topsoil is to be undertaken in order to determine chemical, physical and biological properties remain appropriate for the proposed land use.	Following completion of rehabilitation works and 5-yearly until certification of rehabilitation completion.
Final Rehabilitation Report	Report outlining compliance with conditions of the EA, achievement against completion criteria, the extent and success of the rehabilitation, ongoing environmental management and monitoring requirements, and residual risk.	Following completion of rehabilitation works, to be submitted in order to discharge Financial Assurance.
Compliance Statement	Details compliance with EA conditions and confirms the accuracy of the Final Rehabilitation Report.	To be submitted with the Final Rehabilitation Report.
Diversion Monitoring Reports	A report on monitoring of diversion stretches to assess Index of Diversion Condition (IDC) and process towards revegetation goals.	Annually during operations. The requirement to continue following relinquishment will be assessed based on operational monitoring.

7 Rehabilitation Strategies

Strategies for undertaking rehabilitation to achieve the completion criteria provided in **Section 5.5** are provided in the following sections, with the general objective to achieve a post-mining land suitability of Class 4 for grazing.

7.1 Mining Domains

7.1.1 Residual Voids (Domain 1)

The design of operational mining pits is such that they are generally geotechnically stable and meet slope requirements prior to being released for rehabilitation works. A number of pits on the QNH have been and will be backfilled during normal mining operations; however, the majority of pits will not be backfilled and will remain as final voids.

It is critical to note that although residual voids on the QNH are unable to sustain a PMLU, this does not remove the requirement for them to be safe, structurally stable and non-polluting.

The rehabilitation process for residual voids is as follows:

- The final landform is to be shaped and graded to be geotechnically stable. Re-profiling (including blasting of void walls) may be required.
- Establish drainage and erosion controls.
- Final slope (completion criteria) as per **Section 5.5**.
- Signage, fencing, and/or safety bunds (specification based on DME (1995)) are to be placed as required to limit access to the void lakes for people, stock and fauna.

QNH voids are to have the following characteristics based on a final hydrogeological assessment:

- Acceptable (low) risk of overtopping.
- Isolated from surface water flows (non-flushing).
- Void water is unlikely to impact the EVs of any surrounding groundwater.
- Voids are to have no intended or planned access for livestock or any other uses.

7.1.2 Overburden Dumps (Domain 2)

Waste Rock Management

The waste rock categories and characteristics for the QNH are detailed in **Section 3.5**. Placement of waste rock in overburden dumps is to be undertaken in accordance with the current version of the *QCoal Northern Hub Mine Waste Management Plan*.

Waste Rock Dump Landforms

The general strategy to be followed when rehabilitating waste rock dumps is as follows:

- Shape and grade the final landform to be geotechnically stable. Final slope completion criteria as per **Section 5.5**.
- Rip surface material on the contour at a spacing of 1 m to between 0.5 and 1.0 metres as required.
- Establish drainage and erosion controls through ripping, profiling and/or construction of control structures.
- Apply topsoil to a minimum depth of 100 mm.
- Scarify the surface immediately prior to any required seeding.
- Seed with an appropriate species mix (see **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
- Control weeds and pest animals.
- Exclude livestock during establishment of groundcover.

Note that waste rock dumps are typically designed to be geotechnically stable and safe during the operation of the mine, which minimises the need for major stabilisation works during rehabilitation.

Topsoil Stockpiles

During routine mine operations, topsoil will be stripped, typically to a depth of 300 mm, and either used immediately on rehabilitation works (stripped and then placed) or stockpiled separately for use in future rehabilitation. These stockpiles will be tracked, inventoried and seeded where required to minimise erosion.

Topsoil will be recovered from stockpiles and spread during rehabilitation works, with depth of spreading based on the nature/condition of the surface on which the topsoil is spread.

Areas where topsoil was previously stockpiled will be rehabilitated once the stockpiled topsoil has been recovered for use, with the following methodology:

- Recover topsoil for use in rehabilitation elsewhere, leaving a minimum of 100 mm of topsoil.
- Establish drainage and erosion controls as required.
- Rip/scarify any compacted topsoil material.
- Final slope completion criteria as per **Section 5.5**.
- Scarify the surface immediately prior to any required seeding.
- Seed with an appropriate seed mix (see **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
- Control weeds and pest animals.
- Exclude livestock during establishment of groundcover.

7.1.3 Mine Infrastructure (Domain 3)

Constructed infrastructure is typically to be removed from site when the infrastructure areas are decommissioned and demolished. This includes, but is not limited to, demountable offices, CHPPs, sewage treatment systems, etc. However, any infrastructure (or components of infrastructure) considered beneficial to the subsequent landholder or the final land use, may be retained upon formal agreement. Examples of constructed infrastructure that could be retained include hardstand areas, concrete pads, shipping containers, sheds, workshops, tanks, etc.

A contaminated land assessment (see **Section 6**) is to be undertaken to determine the requirement for any remediation activities prior to the commencement of rehabilitation activities.

Below are rehabilitation strategies for infrastructure areas where infrastructure is not to be retained, and assumes that physical structures including foundations and concrete slabs have been removed:

- Contaminated land assessment completed as per **Section 6**.
- Final slope completion criteria as per **Section 5.5**.
- Rip compacted surface material on the contour at a spacing of 1 m to between 0.5 and 1.0 metres as required.
- Establish drainage and erosion controls as required.
- Apply topsoil to a minimum depth of 100 mm.
- Scarify the surface immediately prior to seeding
- Seed with an appropriate seed mix (see **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
- Control weeds and pest animals.
- Exclude livestock during establishment of groundcover.

7.1.4 Co-disposal Facilities (Domain 4)

Out-of-Pit

The general strategy for decommissioning and rehabilitating out-of-pit co-disposal facilities on the QNH involves capping of the facility followed by rehabilitation activities. The top and upper slopes would be capped first (reducing ongoing infiltration) in order to allow the co-disposal to drain residual leachate prior to capping the lower slopes and shaping.

The capping materials for co-disposal dams should consider the following elements:

- *Trafficability* – If the dams are not suitable for direct vehicle access at the time of decommissioning, a layer of stable material is required to allow heavy vehicles to access the dams safely when undertaking rehabilitation works (nominal thickness of 0.5-1m).
- *Impeding infiltration* – To reduce the infiltration of surface water into the body of the co-disposal and reduce capillary rise should that be identified as a likely issue (nominal thickness of 0.5 – 1 m).

- *Growth* – Provide a suitable substrate for revegetation and be constructed of non-dispersive material with a nominal thickness of 0.5 – 1 m. Topsoil should be spread to a minimum of 0.1m above this.

The geochemical and geotechnical properties required for capping material, as well as the depth and any compaction requirements are to be determined by an SQP (see **Section 6**), and, where necessary, materials on-site that can be used in this application should be stockpiled for this use during normal operations. Shaping and capping is necessary to reduce rainwater infiltration into the body of the co-disposal, which reduces minimises the phreatic surface within the decommissioned co-disposal facilities and reduces the potential for leaching of water from the body of the co-disposal through the rehabilitated slopes

Monitoring of shaped slopes is required to determine whether seepage is reporting through the capping material, which can a) affect geotechnical stability, and b) in the case of acidic leachate, pose a potential environmental risk. Therefore, geotechnical stability should be assessed to identify any slippage risks, and with regard to the potential for acid leachate, the rejects material is non-acid forming (see **Section 3.5**).

Rehabilitation works for co-disposal facilities following capping are as follows:

- Final slope completion criteria as per **Section 5.5**.
- Establish drainage and erosion controls.
- Apply topsoil to a minimum depth of 100 mm.
- Scarify the surface immediately prior to seeding (if seeding is required).
- Seed with an appropriate seed mix (see **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
- Control weeds and pest animals.
- Exclude livestock during establishment of groundcover.

In-Pit

Currently, one in-pit co-disposal facility is proposed on the QNH, being the SCM Main Pit in-pit co-disposal. Similar to out-of-pit co-disposal facilities, the general strategy for decommissioning and rehabilitation in-pit co-disposal facilities on the QNH involves capping of the facility followed by rehabilitation activities; however, as there are no outer batters associated with the in-pit facility, only the top needs to be capped. As this facility is completely within the Sonoma Main Pit void, and will ultimately be inundated, no further rehabilitation actions are required, and the in-pit co-disposal will make up part of the Sonoma Main Pit residual void.

7.1.5 ROM and Product Stockpile Areas (Domain 5)

Rehabilitation of ROM and product stockpile areas is similar to other infrastructure areas and is subject to the contaminated land assessment outcomes discussed in **Section 6**.

A contaminated land assessment (see **Section 6)** is to be undertaken to determine the requirement for any remediation activities prior to the commencement of rehabilitation activities.

Rehabilitation works are as follows:

- Final slope completion criteria as per **Section 5.5**.
- Rip surface material on the contour at a spacing of 1 m to between 0.5 and 1.0 metres as required.
- Establish drainage and erosion controls as required.
- Apply topsoil to a minimum depth of 100 mm.
- Scarify the surface immediately prior to seeding (if seeding is required).
- Seed with an appropriate species mix (see **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
- Control weeds and pest animals.
- Exclude livestock during establishment of groundcover.

7.1.6 Haul Roads and Tracks (Domain 6)

Constructed haul roads, access roads and tracks (including paved and dirt roads) are typically rehabilitated; however, any roads or tracks which are considered beneficial to the underlying landholder or the final land use may be retained upon formal agreement. Haul roads used for moving coal are subject to contaminated land investigations and potential associated remediation works.

A contaminated land assessment (see **Section 6)** is to be undertaken to determine the requirement for any remediation activities prior to the commencement of rehabilitation activities. As haul roads are routinely graded, it is considered likely that the only areas of potential contamination are the haul road drains, and therefore only these areas require assessment.

The rehabilitation strategy for haul roads and tracks below only applies in instances where they are not being retained, and assumes that physical components such as pavement and culverts etc., have been lifted and removed:

- Final slope completion criteria as per **Section 5.5**.
- Rip surface material on the contour at a spacing of 1 m to between 0.5 and 1.0 metres as required.
- Establish drainage and erosion controls as required.
- Apply topsoil to a minimum depth of 100 mm.
- Scarify the surface immediately prior to seeding (if seeding is required).
- Seed with an appropriate species mix (see **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
- Control weeds and pest animals.
- Exclude livestock during establishment of groundcover.

7.1.7 Water Management Infrastructure (Domain 7)

Sediment Dams

Dams (mine affected, sediment affected, or raw water) can be decommissioned, demolished and rehabilitated; however, any dams considered beneficial to the underlying landholder, or

would be necessary or beneficial to the final land use, may be retained based on formal agreement with the landholder.

For mine-affected sediment dams (i.e. those dams that have come into contact with coal) or dams which have contained other contaminated water (such as hydrocarbons), a contaminated land assessment is to be undertaken to determine the requirement for any remediation (see **Section 6**) prior to the commencement of rehabilitation activities.

For those dams being retained, some minor rehabilitation works may be required prior to hand-over to the landholder. As such, the rehabilitation strategy has been split into two categories: (1) retained or (2) demolished then rehabilitated. The rehabilitation strategy assumes that dams are dry (or drained) prior to commencing rehabilitation works, as inflows will be restricted to rainfall once production ceases, and water from dams will be used for dust suppression during rehabilitation works.

Dams retained:

- Sediment within drained mine affected dams are subject to a contaminated land assessment (as per **Section 6**), and any contaminated material removed is to be encapsulated within a waste rock dump. This does not apply to sediment affected or raw water dams.
- Embankments, dam walls and spillways should be repaired where required (i.e. where rill erosion is observed). Following any repairs:
    - Apply topsoil to a minimum depth of 100 mm.
    - Scarify the surface immediately prior seeding (if seeding is required)..
    - Seed with an appropriate species mix (see **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
    - Control weeds and pest animals.
    - Exclude livestock during establishment of groundcover.

Dams demolished and rehabilitated:

- Sediment within drained mine affected dams are subject to a contaminated land assessment (as per **Section 6**), and any contaminated material removed is to be encapsulated within a waste rock dump. This does not apply to sediment affected or raw water dams.
- Final slope completion criteria as per **Section 5.5**.
- The final landform must not retain water.
- Rip surface material on the contour at a spacing of 1 m to between 0.5 and 1.0 metres as required.
- Establish drainage and erosion controls.
- Apply topsoil to a minimum depth of 100 mm.
- Scarify the surface immediately prior to seeding (if seeding is required).
- Seed with an appropriate species mix (see **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
- Control weeds and pest animals.
- Exclude livestock during establishment of groundcover.

Levees and Drains

Levees and drains are in place on a mine site to manage surface water runoff and, in the specific case of a co-disposal facility, the decant water cycle. More specifically, they are in place to manage surface water runoff from mine-affected areas, sediment-affected areas, and unaffected areas (clean run-off) in a controlled/designed manner. This avoids adverse impacts on pits/dumps/roads/dams or any other infrastructure. Accordingly, the decision whether a drain or levee is retained post-closure (and therefore the level of rehabilitation required for that drain or levee) depends on a number of factors including:

- What infrastructure the landholder is retaining. If the landholder requests that infrastructure be retained, then any drain or levee associated with that infrastructure should also be retained to ensure its ongoing functionality and safety.
- The specific design of rehabilitated final landforms. For example, during operation, waste rock dumps have drains to collect and manage runoff, so the post-closure design of drainage must consider:
    - whether the runoff from a rehabilitated waste rock dump would flow down the slopes to the toe and then onto the surrounding land without control (thereby carving its own flow path ultimately into a local watercourse); or
    - whether the drain should be retained to control the runoff post-closure along a designated flow path into a designated watercourse.
- How the removal of some drains or levees might affect the hydraulic functionality of those that are retained.

In addition, any drains or levees not associated with retained infrastructure, but which are considered directly beneficial to the subsequent landholder or would be directly necessary/beneficial to the final land use, may be retained upon formal agreement.

For drains or levees being retained, some minor rehabilitation works may be required prior to hand-over to the landholder. As such, the below rehabilitation strategy is separated into those being retained and those being demolished and rehabilitated.

Drains or levees retained:

- Mine affected drains (co-disposal decant, ROM/Product pad drains, etc.): Sediment within mine-affected drains is subject to a contaminated land assessment (as per **Section 6**), with any contaminated material removed encapsulated within a waste rock dump. This does not apply to sediment affected or un-affected drains/levees.
- All drains: where required, remove sediment build-up and/or reeds to ensure hydraulic functionality.
- Drain or levee walls should be repaired where required (e.g. where rill erosion is observed).
- Drain beds should be repaired where required (e.g. where scouring is observed)
- Following any required repair works:
    - Apply topsoil to external drain batters and levee walls to a minimum depth of 100 mm and where required.
    - Scarify the surface immediately prior seeding (if seeding is required).

  - Seed with an appropriate species mix (see **Section 0.0.0**) where natural seedbanks have been identified as unsuitable.
  - Control weeds and pest animals.
  - Exclude livestock during establishment of groundcover.

Drains or levees being demolished:

- Mine affected drains (co-disposal decant, ROM/Product pad drains, etc.): Sediment within mine-affected drains is subject to a contaminated land assessment (as per **Section 6**), with any contaminated material removed encapsulated within a waste rock dump. This does not apply to sediment affected or un-affected drains/levees.
- Drains backfilled.
- Drain walls and levees graded to final slope (completion criteria) as per **Section 5.5**.
- Rip surface material on the contour at a spacing of 1 m to between 0.5 and 1.0 metres as required.
- Establish drainage and erosion controls.
- Apply topsoil to a minimum depth of 100 mm.
- Scarify the surface immediately prior seeding (if seeding is required).
- Seed with an appropriate species mix (See **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
- Control weeds and pest animals.
- Exclude livestock during establishment of groundcover.

7.1.8 Creek Diversions (Domain 8)

Creek diversions are to be permanent landforms following mine closure. Rehabilitation works (particularly along the banks) may be required to achieve the requirements of the diversion design (i.e. stable, non-polluting and ecologically functional).

As at the time of this RMP, there are two creek diversions as follows:

- Two Mile Creek diversion:
  - Design: Design of Two Mile Creek Diversion (BSM, 2012)
  - Construction completed in 2013
- Coral Creek diversion
  - Design: North Sonoma Creek Diversion Design Plan (Engeny, 2018)
  - Construction completed in 2018

Any other creek diversion works undertaken on the QNH will be subject to the revegetation and rehabilitation requirements presented in their relevant design plans.

Diversions become non-polluting and able to sustain their agreed post-mining land use through appropriate design, material selection, construction methods and revegetation. Low-flow channels in both diversions are designed with rock lining and therefore, revegetation within the low flow channel is not required. Any imported or native rock material should be geochemically inert to ensure that no pollution to the surrounding environment occurs. Revegetation of benches above the low flow channel or on the upper banks is required, as they are not rock lined. Revegetation strategies vary between creek diversions, as the nature of the flow regime and vegetation diversity/abundance are specific to each creek.

Two Mile Creek Diversion Revegetation

Construction of the Two Mile Creek Diversion was completed in 2013. The natural seedbank present in the topsoil spread has continued to support a self-sustaining population of groundcover species (such as grasses), shrubs, and small and large trees. The requirement for future revegetation works is assessed during annual creek diversion inspections (see **Section 6**).

Coral Creek Diversion Revegetation

Construction of the Coral Creek Diversion was completed in 2018. After construction activities were completed, the bench above the low flow channel and adjacent batters of the diversion were hydromulched with a seed mix comprising grasses, shrubs and trees as per Engeny, 2018. The requirement for potential future revegetation works is assessed during annual creek diversion inspections (see **Section 6**).

7.2 Supporting Activities

7.2.1 Exploration

Exploration activities undertaken on the granted mining leases are not considered a mining domain, and they do not represent a significant area of disturbance. Exploration areas generally comprise an access track, a small cleared drill pad (e.g. 50m by 50m), a sump, drill cuttings and the drill hole. Disturbance associated with exploration is to be rehabilitated as follows:

- Boreholes are to be backfilled with cuttings, sealed and capped.
- Shape and grade the drill pads to match the grade of the surrounding area.
- If required, rip any compacted surface material to between 0.5 and 1.0 metres.
- Establish drainage and erosion controls as required.
- Any stripped topsoil is to be replaced to a minimum depth of 100 mm.
- Scarify the surface immediately prior seeding (if seeding is required).
- Seed with an appropriate species mix (See **Section 7.3.2**) where natural seedbanks have been identified as unsuitable.
- Control weeds and pest animals.
- Exclude livestock during establishment of groundcover.

Under the relevant conditions of the QNH EAs, lands previous subject to exploration under Exploration Permit Coal (EPC) 586 are to be rehabilitated in general accordance with Conditions B24 to B31 of ESR/2016/1985 *Eligibility criteria and standard conditions for exploration and mineral development projects – Version 2* (EHP, 2016). The rehabilitation status of legacy boreholes will assessed on a case by case to prioritise a program of rehabilitation based on environmental risk.

The conditions of the Code also apply to any additional exploration activities undertaken on the now granted mining leases. These criteria have been extracted and presented in **Table 14**.

Table 14 – Rehabilitation Conditions for Exploration

Condition	Description
B24	In Riverine Areas, the holder of the environmental authority must complete the Rehabilitation Processes on all areas disturbed by mining activities, apart from those areas currently being utilised for mining activities, as soon as practical and prior to the onset of the wet season
B25	For all other areas on the mining tenement, the holder of the environmental authority must complete the rehabilitation processes on all areas disturbed by mining activities, apart from those areas currently being utilised for mining activities, as soon as practical and at least within six months of the completion of works in those areas.
B26	The holder of the environmental authority must backfill all excavations, drill holes or sampling sites as soon as practical following the completion of exploration activities.
B27	**Condition B26** does not apply to any excavations, drill holes or sampling sites that are to remain after the completion of exploration activities, by agreement with the land owner.
B28	The holder of the environmental authority must rehabilitate areas disturbed by mining activities to a stable landform similar to that of surrounding undisturbed areas.
B29	The holder of the environmental authority must spread seeds or plant species that will promote vegetation of a similar species and density of cover to that of the surrounding undisturbed areas or vegetation that is appropriate for providing erosion control and stabilisation of the disturbed areas.
B30	For any Mine Infrastructure to remain after all mining activities have ceased, the holder of the environmental authority must obtain the written agreement of the land owner stating they will take over responsibility for that infrastructure.
B31	The holder of the environmental authority must complete rehabilitation of disturbed areas to the satisfaction of the administering authority.

7.3 General Rehabilitation Strategies

7.3.1 Establishing Drainage and Erosion Controls

Final landform surfaces are to be contoured, and the final drainage features installed, along with permanent sediment control structures.

The most effective way to control surface flow in rehabilitated areas is to construct contour furrows or contour banks at regular intervals down the slope, effectively dividing a long slope into a series of short slopes. As slope angle increases, these banks or furrows must be spaced closer together. Contour banks are typically the preferred erosion control option for relevant domains (e.g. waste rock dumps, out-of-pit co-disposal facilities, etc.). Construction plant required to establish contour banks is a small dozer (civil scale) with a multi-tined, rear-mounted ripper and a front angle-and-tilt blade.

7.3.2 Establishing Vegetation

Establishment of vegetation is required to ensure a stable and productive landform following rehabilitation activities. Vegetation is to be established by either a reliance on a viable seedbank existing within previously stripped and stockpiled topsoil, or direct seeded if the seedbank found to not be viable.

Natural Seedbank

The stripped and stockpiled topsoils on the QNH have shown to be laden with viable seed, and minimising the maximum height of stockpiles ensures that the seedbank remains viable until it is respread on rehabilitated areas. The natural seedbank contains a representative

diversity of the dominant grass, shrub and tree species present on the land prior to disturbance and is therefore inherently suitable for the rehabilitated use.

To ensure the greatest potential for rehabilitation success when using the existing seedbank in the topsoil, the subsoils are ripped to between 0.5 and 1 metres immediately prior to spreading topsoil (see the **Soil Preparation** subsection for further detail). This breaks up any potential soil compaction and allows the roots of newly sprouted plants to penetrate the subsoils more readily.

Direct Seeding

Where topsoil stockpiles have been observed to have unsuitable seedbanks rom previous rehabilitation works, or where the topsoil seedbank has failed to produce an appropriate level of groundcover or species mix, direct seeding may be required.

Sourcing Seed and Suitable Species

Seed can be purchased from a commercial supplier or collected from the local area. Collection of seed may only take place where the collector has the relevant permission and/or permits for the area from which they are collecting. Any seeds requiring storage prior to planting should be maintained in cool, dry conditions and protected from insects.

Based on surrounding pasture, native grass and pasture species composition should consider, but not necessarily be limited to, the list of species in **Table 15**. These species have been observed in paddocks either surrounding the QNH, or within undisturbed areas of the QNH, and will help facilitate the final land use of cattle grazing. Other suitable improved pasture and native grass species may also be used in seeding mixes.

Table 15 – Suitable Grass Species

Species Name	Common Name
Preferred grazing species	
Urochloa mosambicensis	Sabi Grass
Cenchrus ciliaris	Buffel Grass
Heteropogon contortus	Black Speargrass
Dichanthlum sp.	Bluegrass
Rhynchosia minima	Rhynchosia
Macroptilium lathyroides	Phasey Bean
Clitoria ternatea	Butterfly Pea
Sorghum halepense	Johnson Grass
Intermediate grazing species	
Neptunia gracilis	Native Sensitive Plant
Chloris inflate	Purple-top Rhodes Grass
Legumes	
Chamaechrista rotundifolia	Wynn Cassia
Macroptilium astropurpureum	Siratro
Stylosanthes humilis	Stylo
Stylosanthes scabra	Seca Stylo

Soil preparation

Where compaction of subsoil has occurred, such as in infrastructure areas, roads, and other heavily trafficked areas, the surface will need to be ripped to between 0.5 and 1 metres prior to topsoiling and seeding. This will break up the compaction and allow vegetation to establish more easily. In order to prevent degradation of soils with high clay content, ripping should be undertaken after a dry period. In areas where compaction has not been identified, scarification could still be undertaken on a case-by-case basis to assist in establishing a soil bed.

The need for fertilisation will be informally assessed prior to the commencement of rehabilitation, or following any failed rehabilitation, where the cause of the failure is assessed as being due to poor nutrient loading. Typically, a low phosphate fertiliser at a nominal application rate of up to 250 kg per hectare is appropriate. Care should be taken when using fertilisers to minimise runoff into drainage channels. Fertilisers can also promote weed growth.

Seed Application

Seeding, where required, should ideally be undertaken immediately prior to the onset of the wet season (i.e. December or January). This gives seeds the best chance of taking hold, as soil moisture will be at its highest in the late wet season.

Establishment period

Regardless of reliance on the seedbank or direct seeding, the establishment period for species can vary, so progress should be regularly monitored following spreading of topsoil or any seeding undertaken. Monitoring typically commences one month from spreading of topsoil (reliance on seedbank) or from application of seed (direct seeding), in order to assess germination. Reseeding may be required if germination does not occur; however, it should not be undertaken outside of the wet season unless suitably wet weather is forecast.

Weed management may be required during the establishment period (see **Section 7.3.3**).

7.3.3 Weed Control and Pest Management

Weeds

Weeds that pose the highest risk to sustaining cattle grazing productivity are those that limit stocking rate, are toxic to animals and/or may potentially outcompete pasture grasses. These include, but are not limited to Parthenium, Lantana, Chinee Apple, and Prickly Mimosa. As light cattle grazing is the agreed post-mining land use, the control of these weeds should be prioritised. See **Section 3.7** for a complete list of expected weed species.

Weed management is to be undertaken as per the Thiess *Weed Management Plan QCoal Northern Hub* (Thiess, 2016), the *Sonoma Coral Creek Weed Management Plan* (NRA, 2013), and any other relevant QNH weed management document, or any updates thereof.

Where weed control is required, a licenced and qualified professional should undertake herbicide treatment (including selection of appropriate herbicides and application) with a focus on priority weed species (see **Section 3.7**). Weed control is an ongoing process and will likely require repeated treatments.

Weed prevention is more effective and economical than weed treatment; therefore, efforts should be made to prevent the spread of weeds into rehabilitation areas. These include:

- Limiting the area of soil disturbed at any one time to minimise exposure of bare ground.
- Use mulches and establish preferred groundcover as quickly as practicable
- Avoid importing or using soils where their origins and seedbanks are unknown.
- Avoid re-using weed infested topsoils if possible
- Ensure that any seed mixes used for rehabilitation are weed free
- Ensure stockpiled topsoil material is weed-free prior to use.

Pest Animals

Pest animals considered relevant to rehabilitation efforts at the QNH include feral pigs, rabbits, and goats. During rehabilitation activities, active pest management should be undertaken where impacts are observed during routine monitoring of rehabilitation works. Methods of control should consider how the QNH manages pest species during active mining operation, as well as how the underlying landholder manages pest species in the area.

7.4 Scheduling of Rehabilitation

Rehabilitation activities undertaken during active mining is referred to as progressive rehabilitation.

During mining activities, works on sections of disturbed land may be completed to a point where there is no further potential operational use for that section of disturbed land. The domain is then considered available to be rehabilitated. The most common example is sections of a waste rock dump face which have received their final dumping sequence and therefore have no further operational use. Rehabilitation can then be undertaken on that face in isolation, without having to rehabilitate the entire dump at the time.

By undertaking progressive rehabilitation, the actual amount of rehabilitation required at the completion of mining is minimised. Progressive rehabilitation is scheduled considering the following factors:

- Progressive rehabilitation is to be undertaken in line with the relevant PRCPs for each QNH mine as they are approved;
- The potential for future operational use of the area;
- The progressive rehabilitation is not to conflict with mining/production priorities:
- Required plant must not be currently needed for mining/production operations.
- Opportunities to minimise double handling of topsoil, such as applying topsoil stripped directly to areas of rehabilitation is preferred. This also prevents degradation of the natural seedbank during stockpiling.

Additionally, there is an economic benefit to completing progressive rehabilitation as soon as practicable. This includes a reduction in Estimated Rehabilitation Cost (ERC) held, and reduced area requiring erosion control and dust suppression during operations. As such, while there are currently no requirements to achieve a target rate of rehabilitation (such as timeframes, areas, or outcomes) in the absence of established PRCPs, QNH will undertake progressive rehabilitation when areas and schedules become available to do so.

8 Monitoring, Maintenance and Reporting

8.1 Monitoring

8.1.1 Timing

General rehabilitation monitoring is to be undertaken annually following the wet season, or at a suitable frequency based on recommendations from the SQP undertaking the monitoring.

Soil assessments at both monitoring and reference sites (to allow comparison) are to be undertaken five (5) yearly; however, an SQP may recommend an increase or decrease in the frequency of these assessments.

Monitoring of progressive rehabilitation areas will only commence after at least one wet season has passed following completion of rehabilitation works. This will allow monitoring to better assess the performance of the seedbank, rates of growth, areas of erosion, and other issues.

8.1.2 Survey Intensity

A 1:15,000 monitoring scale (or approximately one (1) observation per nine (9) hectares) is to be used initially, as this allows for a detailed assessment of the land (McKenzie *et al.* 2008). This may be scaled up or down upon review, depending on the level of detail required as per the recommendations of an SQP.

Rehabilitation areas are to be broken into discrete management units to facilitate data management and planning for rehabilitation monitoring. Management units should be delineated based on the age of the rehabilitation, waste type, and rehabilitation methodology.

8.1.3 Reference Sites

Reference sites are used as a non-mine affected point of comparison to assess performance of the rehabilitated areas with regard to groundcover, carrying capacity (productivity), weed proportion, and species mix and composition.

Monitoring reference sites are to be chosen to be appropriate analogues to the areas being monitored and on-the-ground assessments are required to select the most appropriate locations. The land use of the reference site should align with the intended post-mining land use of the rehabilitation area(s) being monitored. The location of reference sites are to be determined during monitoring works and can be altered based on the dynamic nature of ephemeral landscapes that are, and have historically been, used for cattle grazing. The location of reference sites may also change based on landholder access restrictions.

Current reference sites used for monitoring of progressive rehabilitation on the QNH are presented in **Table 16**. The location or number locations may change based on the recommendations of an SQP undertaking the monitoring.

Table 16 – QNH Rehabilitation Reference Sites

Reference Site	Start		End	
	Latitude	Longitude	Latitude	Longitude
V19	-20.6168	147.8346	-20.6164	147.8346
V20	-20.6187	147.8352	-20.6182	147.8351
V21	-20.6143	147.8323	-20.6139	147.8324
V33	-20.6157	147.8336	-20.6153	147.8335

8.1.4 Parameters

Soils

Where soil monitoring is undertaken, profiles will be excavated to a depth of at least 1 m below the soil surface, with samples collected at intervals of 10 cm, except where an SQP recommends that sampling be undertaken to a different depth or at different intervals. The following parameters are to be assessed:

- Plant Available Water Capacity (PAWC)
- Exchangeable Sodium Percentage (ESP)
- Soil Salinity (1:5)
- Soil pH (1:5)
- Water erosion, calculated as a function of slope % and ESP
- Rockiness

Analysis is to be undertaken by a laboratory that is NATA-accredited for the given parameter.

The following information should also be gathered in accordance with the methods and categories in the *Australian Soil and Land Survey Field Handbook* (NCST, 2009):

- Slope
- Surface condition
- Depth of topsoil and other horizons
- Soil colour per horizon (as per the Munsell Soil Colour Charts)
- Soil structure per horizon
- Coarse fragment content at the soil surface and in each horizon
- Root depth
- Presence of waterlogging features
- Presence of free carbonate and other segregations.

Land Suitability and Vegetation

Vegetation assessments are to be conducted using 50 m transects to confirm land suitability has been achieved. Sites will be chosen through a random selection process by the SQP undertaking the work and is landform dependent. Any photographs taken during vegetation assessment are to follow the methodology found in the *Pasture photo standards* (DPIF, 2003). The following parameters are to be measured:

- Species list for each transect to determine species composition and proportion of preferred species
- Groundcover to be measured within 1 m square quadrats and the average will be used to assess compliance with the groundcover completion criteria (see **Section 5.5**). This measurement is also to include characterisation of the groundcover (e.g. vegetation, woody debris, rock, etc.).
- Stock carrying capacity as head/ha based on grass load.
- Vegetation structure.
- Species showing evidence of fruiting or flowering are to be noted.
- Prescribed weed species are to be noted.

Carrying capacity is to be calculated as per advice from Bob Shepard, Principal Extension Officer, Queensland Department of Agriculture Fisheries and Forestry (NRA, 2015), as follows:

- One adult equivalent (450 kg beast) requires 2.2% of live body weight of dry biomass per day (3,650 kg per annum).
- A utilisation rate of 25% to 30% should be applied to prevent degradation.
- Therefore, one beast requires between 12,167 and 14,600 kg of dry biomass per annum.

The number of hectares required per beast is to be calculated by dividing the dry biomass required per annum by the measured mean pasture biomass (in kg/ha) of each management unit. To determine the carrying capacity, the number of hectares per beast is then converted to head/ha.

Other

Other data to be collected during monitoring is as follows:

- Evidence of any slope failure or rock falls
- Evidence of any rill or gully erosion
- Evidence of pest animals
- Note any leachate observed originating from rehabilitated co-disposal facilities.

8.1.5 Creek Diversions

Diversions are present on the SCM and require specific administering authority approval based on RPEQ designs. Those designs include requirements for rehabilitation of the landform as part of construction activities.

In addition, the designs require annual monitoring and reporting (by an RPEQ) of diversion stretches as per **Condition J7** of the SCM EA. The monitoring and reporting program includes annual assessment of the progress of the rehabilitation of the diversion. As such, diversion rehabilitation monitoring is separate from other rehabilitation monitoring works and is subject to the approved diversion design.

8.2 Reporting

Following annual monitoring (or any other frequency as proposed by an SQP), a report is to be prepared providing a summary of data collected and an update on the progress towards meeting completion criteria. These reports do not need to be submitted to the administering authority; however, they should be retained and reviewed internally to determine the readiness of the rehabilitated domains for certification. Monitoring reports are also to be used to identify the need to amend rehabilitation practices, or the RMP itself, prior to future works.

A separate report related to creek diversions is also be generated by an RPEQ annually and must be submitted to the administering authority.

8.3 Rehabilitation Maintenance and Potential Issues

Ongoing monitoring of progressive rehabilitation will inform any required maintenance and identify any issues requiring corrective action. Potential issues, which could occur following rehabilitation, have been identified and include, but are not limited to, those presented in **Table 17**.

Table 17 – Potential Issues and Remedial Action

Issue	Remedial Action
Seedbank fails to germinate or groundcover dies following early establishment when using the seedbank present in topsoil.	Investigate topsoil quality. Considering supplementary seeding of future rehabilitation using this topsoil. Reseed rehabilitated areas as required.
Rapid die-off of groundcover.	Investigate cause, and reseed rehabilitation as required.
Groundcover species are failing to thrive.	Investigate soil quality, consider the suitability of applying fertilisers
Water stress – wilting foliage, heavy insect damage, die back.	Apply water to the rehabilitation area until signs of stress have been alleviated.
Water logging – stem rot, fungal infection	Ensure that drainage features are installed correctly. Where additional drainage is required, instate drainage features. Cease, or cut back, any watering regime being undertaken. Reassess the use of fertiliser (if it had been applied)
Extensive exotic weed cover	Assess the viability of undertaking additional weed management actions in order to ensure that the groundcover seedbank can undertake secondary succession.
No germination or die-off of direct seeding	Assess the seed being used and consider reseeding with a different stock. Assess soil quality and consider the requirement for fertilisation.
Erosion or Slippage in rehabilitation areas	Investigate for failures in drainage features and reinstate or add additional drainage as required. Repair rill erosion by ripping and re-contouring. Repair gully erosion by filling and recontouring.

8.4 Rehabilitation Completion

Rehabilitation is considered functionally complete once the completion criteria set out in **Section 5.5** have been achieved, and the associated performance verification works have been undertaken.

Once completion criteria have been met to a satisfactory level and the performance verification has been completed, a final rehabilitation report (see **Section 6**) must be provided to the administering authority. The final rehabilitation report outlines compliance with conditions of the EA and completion criteria, the extent and success of the rehabilitation, any ongoing environmental management and monitoring requirements, and any residual risk. A compliance statement drafted by a third party must also be provided with the final rehabilitation report, detailing compliance of the report against the requirements of the EA, as well as the accuracy of the report itself.

Additionally, any land that has previously been on the environmental management register (such as contaminated land) must be removed or have an appropriate Site Management Plan approved and in place (see **Section 6**).

Upon receipt of the final rehabilitation report, the administering authority can certify the rehabilitation and subsequent allow for the surrender of the site EAs.

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Appendix A Residual Voids on the QCoal Northern Hub Mining Complex

QCOAL GROUP

Residual Voids on the QCoal Northern Hub Mining Complex

Sonoma, Cows, Drake and Jax Coal Mines



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Submitter information	
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Project	Sonoma Coal Mine Cows Coal Mine Drake Coal Mine Jax Coal Mine
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Revision summary

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1 Introduction

QCoal Pty Ltd (QCoal) manages four (4) adjacent open cut coal mines located between six (6) and fifteen (15) km south of the town of Collinsville in Central Queensland. The four mines are Sonoma Coal Mine (SCM), Cows Coal Mine (CCM), Drake Coal Mine (DCM) and Jax Coal Mine (JCM). Mining pits, waste rock dumps, roads and water management infrastructure span mining lease (ML) boundaries. As such the four (4) mines are collectively managed and operated as a single multi-pit operation referred to as the QCoal Northern Hub (QNH). Each mine has its own environmental authority (EA), however, operational and environmental management and resources are integrated across the four mines.

1.1 Ownership

The QNH sites have ownership makeups as follows:

- SCM is owned by the Sonoma Coal Joint Venture (SCJV) in which QCoal Sonoma Pty Ltd is the majority interest holder;
- DCM is owned by Northern Hub (Drake) Pty Ltd and Drake Coal Pty Ltd;
- CCM is owned by Bowen River Coal Pty Ltd; and
- JCM is owned by Jax Coal Pty Ltd.

QCoal Sonoma Pty Ltd, Northern Hub (Drake) Pty Ltd, Drake Coal Pty Ltd, Bowen River Coal Pty Ltd and Jax Coal Pty Ltd, are wholly or majority owned subsidiaries of QCoal Pty Ltd. The owner and Managing Director of QCoal Pty Ltd is Mr Christopher Wallin.

1.2 Environmental authorities

EA numbers and primary holders for the QNH mines are provided in **Table 1**.

Table 1 – QNH EAs

Mine	MLs	EA Number	Grant	Primary EA Holder	Current version
SCM	ML10325, ML10326, ML10327	EPML00707713	13/9/2007	QCoal Sonoma Pty Ltd	6/3/2020
CCM	ML10345	EPML00334613	16/8/2012	Bowen River Coal Pty Ltd	9/3/2020
DCM	ML10349, ML10350, ML10351	EPML00393013	2/11/2014	Northern Hub (Drake) Pty Ltd	6/3/2020
JCM	ML10346	EPML00337613	20/12/2013	Jax Coal Pty Ltd	14/4/2020

1.3 Objectives

The SCM, DCM and JCM include final voids as part of their rehabilitated final landforms, while the CCM does not have approved voids (pits having previously been backfilled. The voids are approved by the Department of Environment and Science (DES) within the respective EAs. Specifically, the EAs provide the required rehabilitated landform design criteria for each void, being size (area), location and wall angles (high-wall and low-wall). The other consideration for final void rehabilitation is the approved void outcome (whether or not a final void can sustain a post mining land use and if so what type).

The JCM EA stipulates a post-mining land use (PMLU) of "residual void unable to sustain a post mining land use", while the DCM and SCM EAs do not provide a PMLU for residual voids. Void outcomes are discussed in detail within the relevant sections of this document.

A key objective of this investigation is to determine appropriate void outcomes for the voids on the SCM and the DCM for inclusion in the respective EAs. This objective allows for the DCM and SCM EAs to align and be consistent with the JCM EA, which:

- allows for constancy in regulation of voids across the QNH;
- allows for catchment-wide cumulative consideration of all final voids collectively on the QNH rather than on a site by site basis; and
- informs the "*QCoal Northern Hub Rehabilitation Management Plan"* – April 2020 (QNH RMP) which is a single plan addressing rehabilitation of all four (4) QNH mines (including voids) cumulatively rather than in isolation.

1.4 Methodology

To achieve the above objective, this investigation addresses the following:

- Location and size of all voids on the QNH;
- Surrounding land uses (pre and post mining);
- Geology of the QNH;
- Hydrogeological and hydrological modelling of voids to determine interaction with surrounding groundwater, potential for overtopping and void water quality;
- Based on the above modelling, determine whether any DCM or SCM voids can sustain a PMLU and, if so, what that PMLU should be, and confirm the appropriateness of the approved PMLU for the JCM residual voids as "residual voids unable to sustain a post mining land use"; and
- Demonstrate that for each void, regardless of void outcome, the final landform will be safe, structurally stable, and will not cause environmental harm, including assessment of relevant surrounding values (human and environmental) and the suitability of the approved final landform wall angles for each void.

1.5 Previously submitted void studies

This investigation relies upon previously completed waste rock, rehabilitation, geochemical, geotechnical, hydrological and hydrogeological assessments undertaken across the QNH, which are referenced in the relevant sections. Two previous void studies have been completed on the QNH and submitted to DES, the conclusions of which are referenced in the relevant sections:

- *"Investigation into Residual Void Sonoma Coal Mine – QCoal January 2016"* (submitted to DES 29 January 2016), which included the technical study "*Sonoma Coal Mine Final Void Hydrology Study Main Pit – Engeny Water Management 2015*" (Engeny 2015a); and
- *"Investigation into Residual Void Jax Coal Mine – QCoal October 2018"* (submitted to DES 12 October 2018), which included the technical study "*Jax Coal Mine Final Void Hydrology Study Main Pit – Engeny Water Management 2018*" (Engeny 2018) and "*Long Term Water Quality of Jax Coal Mine Residual Voids - 2 April 2019*" ((Engeny (2018) Supplementary Memo).

1.6 Technical studies for this assessment

QCoal engaged technical consultants to undertake specific studies for this assessment as follows:

- Engeny had previously undertaken a specific final void study for the Jax Main Pit and Jax East Pit final voids "*JCM Final Void Hydrology Study Main Pit – Engeny Water Management 2018*" (Engeny 2018) which was appended to "*Investigation into Residual Void Jax Coal Mine – QCoal October 2018"* (submitted to DES 12 October 2018). Engeny (2018) is relied upon for the Jax Main Pit and Jax East Pit final voids and is appended to this assessment as **Appendix A**.
    - A supplementary memo was prepared by Engeny "*Long Term Water Quality of Jax Coal Mine Residual Voids - 2 April 2019*", to present an extended prediction length for water quality beyond what was presented in Engeny (2018) The results of this memo were provided to DES in person (Emerald Coal Hub) on 4 April 2019. The memo is referred to as "Engeny (2018) Supplementary Memo" and has been included in Appendix A of this assessment for completeness.
- Engeny Water Management Pty Ltd (Engeny) was engaged to undertake water balance modelling of the remaining QNH final voids, which is reported in "*Residual Void Hydrology Study QCoal Northern Hub Mines April 2020*", Engeny (2020). Engeny (2020) is appended as **Appendix B** to this assessment.
- The key objectives of both Engeny (2018) and Engeny (2020) void modelling included:
    - model the equilibrated (steady state) water level in QNH final voids, allowing an assessment of interaction with surrounding groundwater and the potential for overtopping into surface waterways; and
    - determine the rate of change and make predictions on the water quality within final voids.
- Australasian Groundwater and Environmental Consultants Pty LTD (AGE) was engaged to undertake hydrogeological modelling of the QNH final voids. A specific report title was not available for reference at the time of submission of this assessment; however, the results of the AGE study are referred to in this assessment as AGE (2020) and outputs have been inserted into this assessment in the relevant sections.

2 Description of QNH

2.1 Location

The QNH is between six (6) and fifteen (15) km south of the town of Collinsville in Central Queensland. Access to all four QNH sites is by the state-controlled Bowen Development Road. The location of the QNH (SCM, CCM, DCM and JCM) is presented in **Figure 1**, which also presents the four (4) individual QNH mines.

The mines that make up the QNH are directly adjacent to one another on the western side of Bowen Development Road and the parallel Newlands rail line, apart from JCM, which is on the eastern side.

2.2 Mining tenures

The ML tenures for the QNH mines are provided in **Table 2**, for each respective mine.

Table 2 – QNH MLs

Details	Sonoma			Cows	Jax	Drake		
Lease	ML10325	ML10326	ML10327	ML10345	ML10346	ML10349	ML10350	ML10351
Status	Granted	Granted	Granted	Granted	Granted	Granted	Granted	Granted
Lodgment	21/11/2005	21/11/2005	21/11/2005	11/04/2009	11/12/2009	21/04/2010	21/04/2010	21/04/2010
Grant	12/4/2007	13/09/2007	13/09/2007	16/08/2012	20/12/2013	2/11/2014	2/11/2014	2/11/2014
Expiry	30/04/2037	30/09/2037	30/09/2037	31/08/2027	31/12/2034	29/02/2044	29/02/2044	29/02/2044
Holder	QCoal Sonoma Pty Ltd	QCoal Sonoma Pty Ltd	QCoal Sonoma Pty Ltd	Bowen River Coal Pty Ltd	Jax Coal Pty Ltd	Northern Hub (Drake) Pty Ltd	Northern Hub (Drake) Pty Ltd	Northern Hub (Drake) Pty Ltd
Area (ha)	716.7	1,063	360.4	210.5	1,943	3,982	4,805	427.9
Permit ID	108618	108619	108620	108636	108637	108640	108641	108642
Native Title	Exclusive Land	Exclusive Land	Exclusive Land	Exclusive Land	Right to Negotiate Agreement	Right to Negotiate Agreement	Right to Negotiate Agreement	Right to Negotiate Agreement

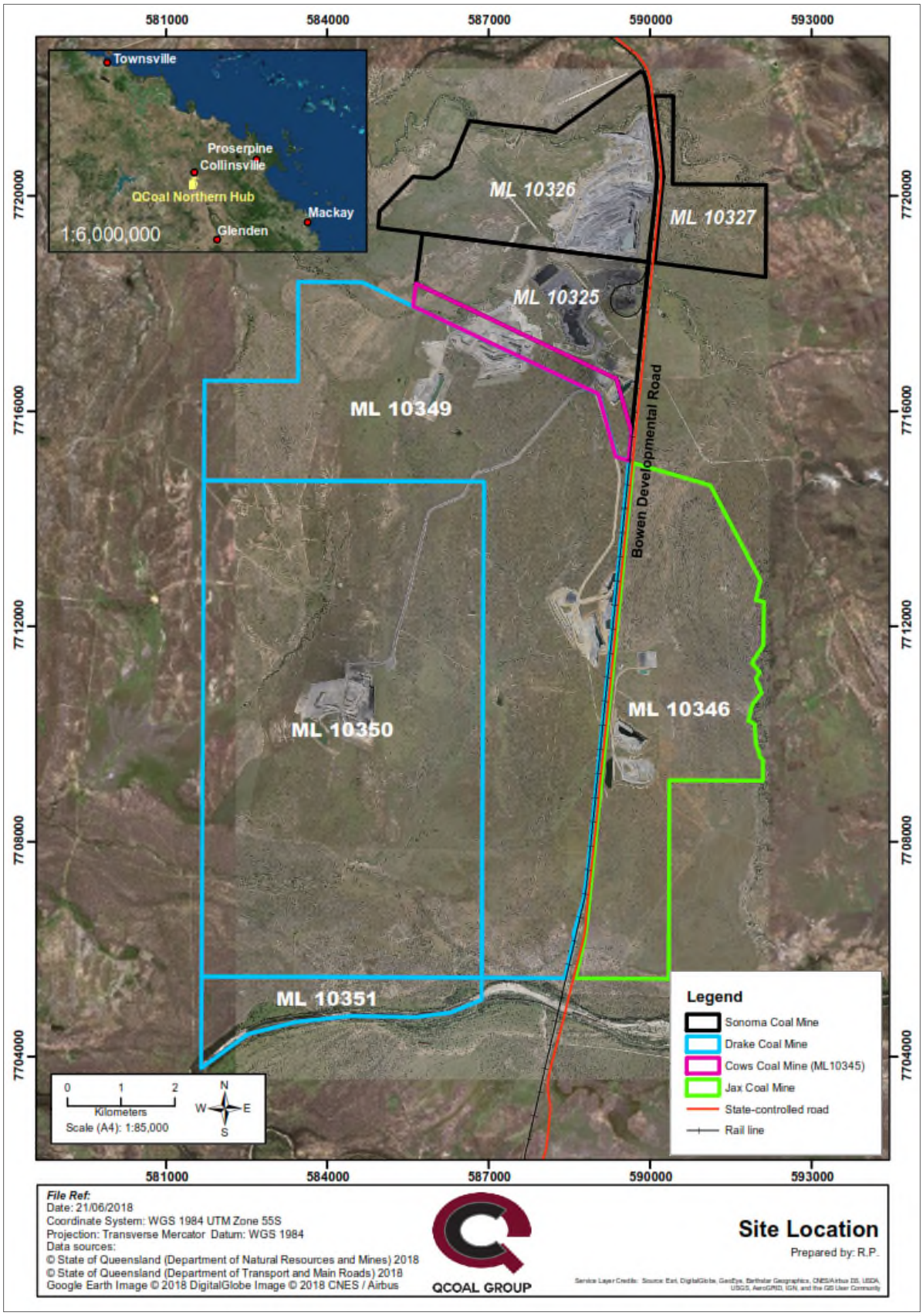


Figure 1 – QNH location and MLs

2.3 Underlying landholders

The QNH spans eight (8) MLs (see **Table 2**) located on land with several landholders, as summarised below and presented in **Figure 2**:

- SCM:
  - ML10325: The land underlying ML10325 is owned by Mr Christopher Wallin.
  - ML 10326: The land underlying ML10326 is “Sonoma” station, which is privately owned by a third party, with the exception of the land underlying the SCM rail spur and loop, which is owned by Mr Christopher Wallin.
  - ML10327: The land underlying ML10327 is “Sonoma” station, which is privately owned by a third party.
- CCM:
  - ML10345: the land underlying ML10345 is a historic stock route which is no longer declared for that purpose. The land is held under a permit to occupy by Mr Christopher Wallin.
- DCM:
  - ML10349, ML10350, and ML10351: The land underlying these MLS is “Birralee” station, owned by Mr Christopher Wallin.
- JCM:
  - ML10346: The land underlying ML10346 is “Birralee” station, owned by Mr Christopher Wallin.

2.4 Mining methods

Mining operations on the QNH involve extraction of Run of Mine (ROM) coal with conventional advancing highwall (mining face) open cut mining methods, utilising drill and blast, and, excavator and truck. As the high wall of an active pit progresses forwards (following the coal seam) to allow continued mining, dumping of waste rock occurs at the low wall (rear of the pit) behind the mining areas, progressively backfilling the pit.

ROM coal is hauled from active pits on the QNH (i.e. all the four QNH mines) to the SCM for processing and shipping. Processing is undertaken at the SCM Coal Handling and Processing Plant (CHPP) after which the product coal is loaded onto trains at the SCM train load-out facility located for transport to Abbot Point Coal Terminal. Coal rejects materials generated during processing at the CHPP are placed into a co-disposal facility located on the SCM.

Topsoil stripped ahead of mine-related activities is either stockpiled for later use in rehabilitation or placed directly on areas already shaped and prepared for rehabilitation works. Waste rock materials are placed in either out-of-pit dumps or in-pit dumps.

The QNH mines share water management infrastructure, haul roads, equipment, resources, and other infrastructure.

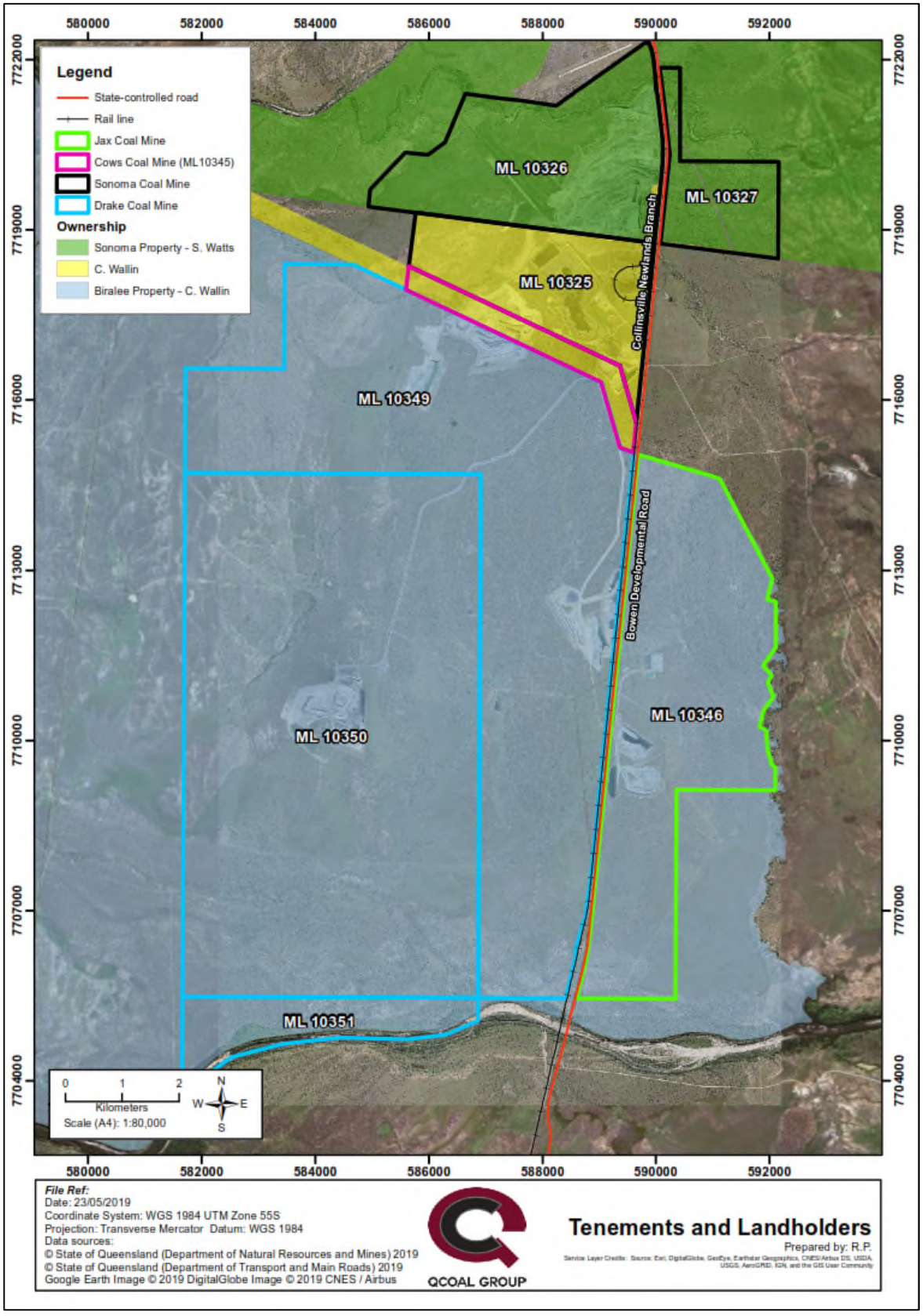


Figure 2 – QNH underlying landholders

3 Regional and Local Geology

A geological understanding of the QNH is required for both the groundwater model (**Section 6**) and water balance model (**Section 7**).

The QNH is located in the northern Bowen Basin, where active subsidence and deposition during the Permo-Triassic was centred within an extensional terrain known as the Taroom Trough. This deposition centre was situated marginal to the Collinsville Shelf in the west, which typically behaved as a stable platform throughout. The deformed Taroom Trough of the north Bowen Basin is defined by the Nebo Synclinorium, where contained sediments and volcanics of the western two-thirds dip gently toward the major synclinal axis in the east. Post-depositional compression has resulted in a fold-and-thrust style of deformation, particularly on the eastern side of the basin where sediments along this margin tend to dip steeply westward.

The QNH is underlain by the late Permian Blackwater Group consisting of lithic sandstone, siltstone, shale, conglomerate, dolomite and tuff and minor coal. This is surrounded and underlain by the low to upper Permian Blenheim Subgroup described as a succession of siltstone, sandstone, conquite and limestone (i.e. the Blackwater Group is an outlier surrounded by the Blenheim Subgroups). The Collinsville Coal Measures underlie the Blenheim Group.

Regionally, the stratigraphic sequence is summarised as follows: the Permo-Triassic sediments of the Bowen Basin are overlain by a veneer of unconsolidated Quaternary alluvium and colluvium, poorly consolidated Tertiary sediments and, in places, remnants of Tertiary basalt flows. The stratigraphy comprises basal Lizzie Creek Volcanics and overlying marine Back Creek Group, non-marine Blackwater Group, and Tertiary sediments of the Suttor Formation.

QNH geology is presented in **Figure 3**, in which the coal measures targeted by the QNH (the Fort Cooper and the Moranbah Coal Measures) are highlighted.

Geological detail in the QNH area is intermittently obscured by alluvium and gravel, especially adjacent to creeks and watercourses. This recent (Cainozoic) cover comprises unconsolidated fine to very coarse-grained sand, along with occasional irregularly interbedded silt, clay and gravel lenses. The most persistent gravel bed occurs at the base of the unit and generally comprises markedly rounded pebble to cobble-sized clasts of predominantly andesitic to basaltic composition set in a silt to clay-rich matrix. Generally the alluvial unit is a thin veneer but becomes thicker along rivers and watercourses in the region.

An example of typical QNH surficial strata is presented in **Figure 4**, which is a photo of the south-eastern wall of the current Jax Main Pit showing the surficial geological strata, in particular a thin veneer of alluvial material.

The QNH is well understood to comprise a consistent, contiguous geology and hydrogeology across the four mines. As such, geological, geochemical, and geotechnical findings are applicable across the QNH. Specific operational examples of geological continuity include (see **Figure 5**):

- the Drake 3 Pit complex and the Jax Main Pit complex target the same coal seams, with consistent overburden characteristics; and
- the SCM, CCM and DCM Q-Pit and B-Pit complexes target the same coal seams, with consistent overburden characteristics.

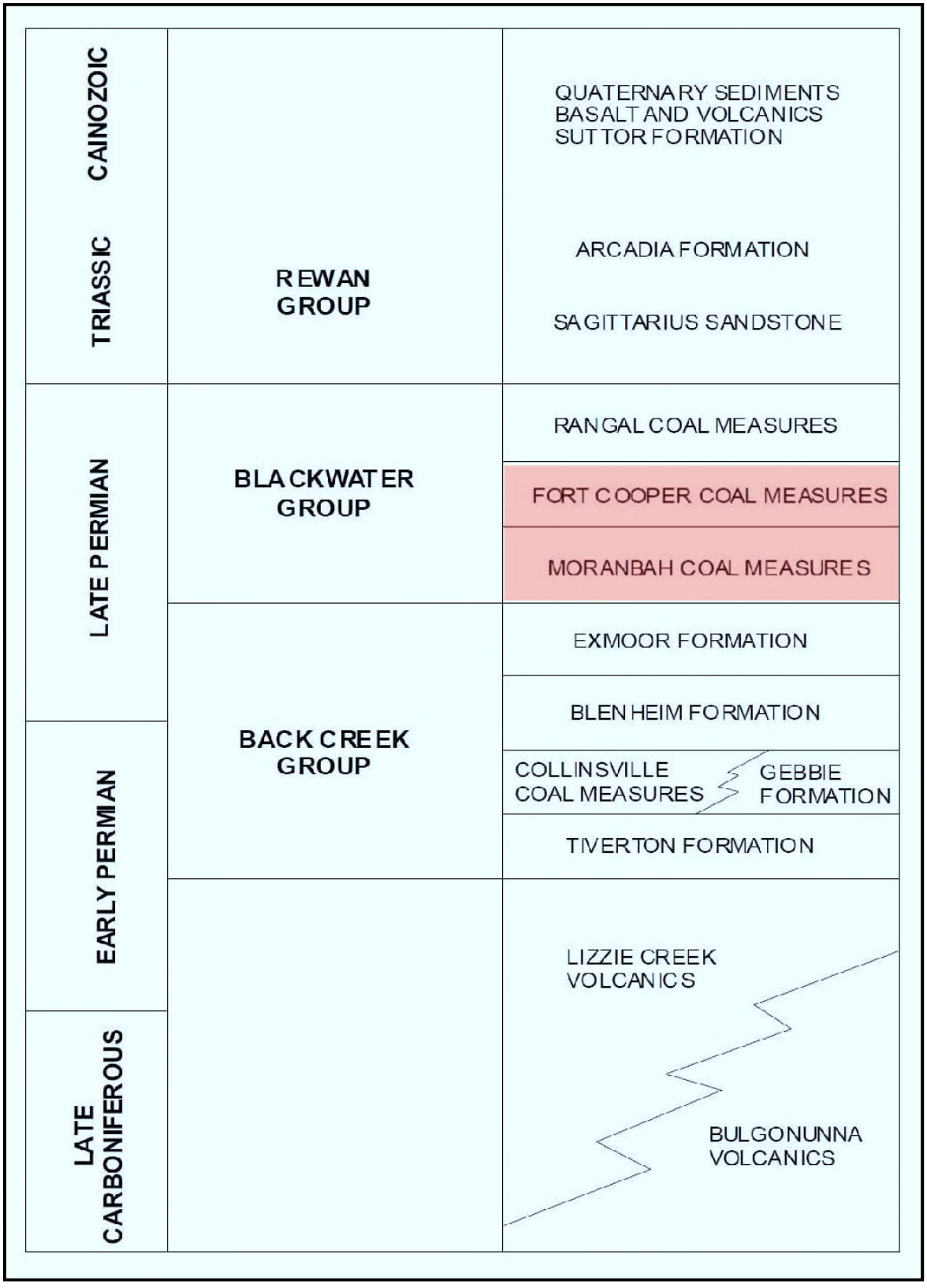


Figure 3 – Geological conceptualisation



Figure 4 – Example of surficial strata Jax Main Pit

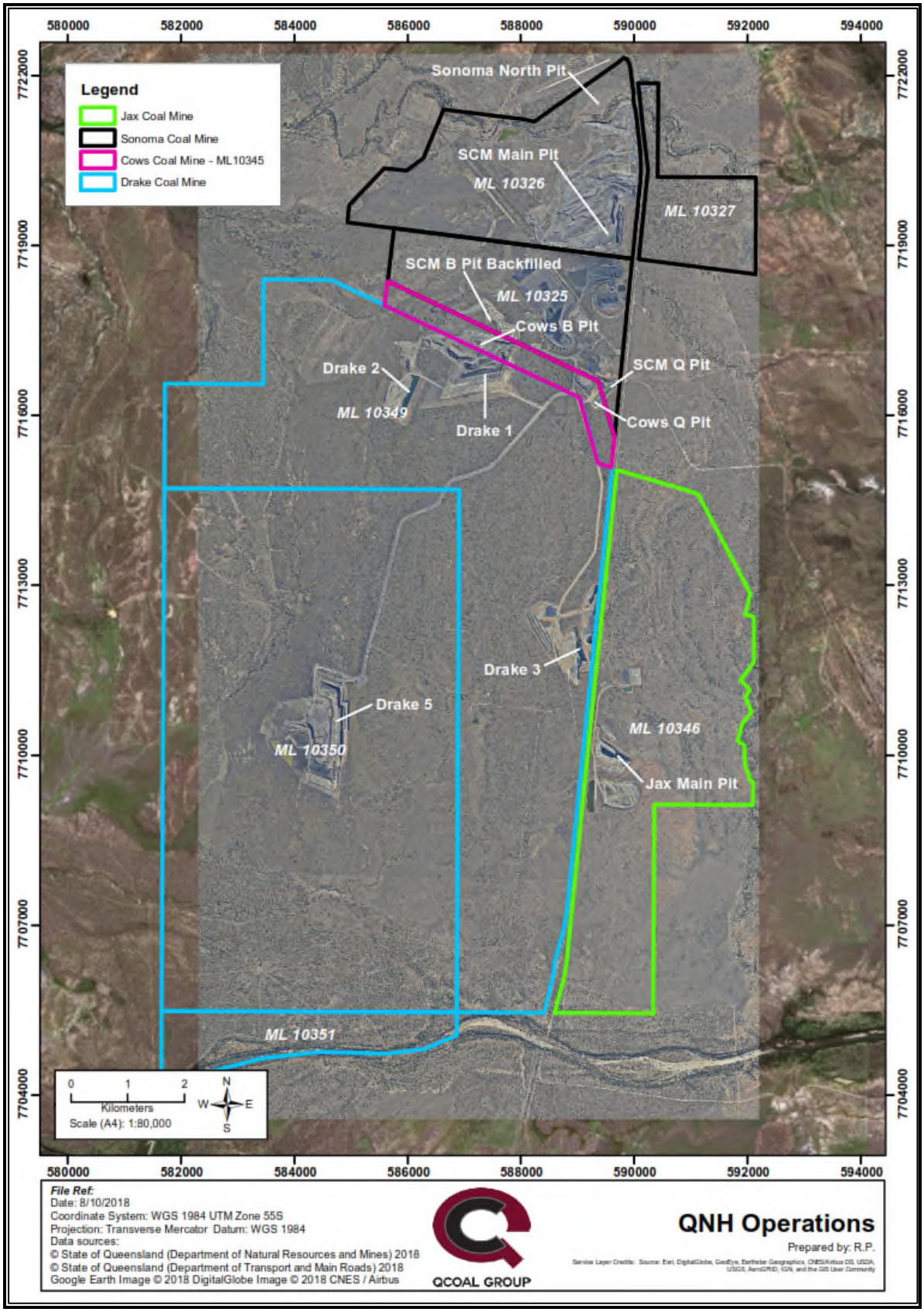


Figure 5 – QNH Operations

4 Regional and Local Groundwater

4.1 Groundwater studies

The hydrogeology across the QNH is well understood with numerous hydrological and hydrogeological studies previously completed for individual mines within the QNH (including specific void modelling for the JCM and SCM) and the QNH cumulatively. The relevant studies are listed below chronologically, and all documents have previously been submitted to DES:

- "*Sonoma Coal Environmental Impact Statement – November 2005*" (SCM EIS)
- "*Drake Coal Project Environmental Impact Statement – March 2012*" (DCM EIS)
- "*Groundwater Monitoring and Management Plan – Drake Coal Project*" (QCoal (2014))
- "*Drake Coal Project Groundwater Model – Australasian Groundwater and Environmental Consultants Pty Ltd 2015*" (AGE (2015))
- "*Sonoma Coal Mine Final Void Hydrology Study Main Pit – Engeny Water Management 2015*" (Engeny (2015a))
- "*Stygofauna Survey for the Drake Coal Mine Project (July 2016) – Freshwater Ecology Pty Ltd 2016*" (Freshwater Ecology (2016))
- "*QCoal Northern Hub Water Management Plan – Engeny Water Management 2017*" (Engeny (2017))
- "*QCoal Northern Hub Water Management Plan – Engeny Water Management 2018"* (Engeny (2018))
- "*Northern Hub Groundwater Assessment – Australasian Groundwater and Environmental Consultants Pty Ltd 2018*" (AGE (2018))
- "*JCM Final Void Hydrology Study Main Pit – Engeny Water Management 2018*" (Engeny (2018a))
- "*QCoal Northern Hub Water Management Plan – Engeny Water Management 2019*" (Engeny (2019))

4.2 Groundwater values (resources)

The actual groundwater values (the ways in which groundwater is relied upon by natural hydrological or ecological processes, or by humans) across the QNH area form the basis for any assessment of potential groundwater impact. A detailed review of the potential groundwater values surrounding the QNH was undertaken as part of QCoal (2014), which identified four main potential values that groundwater may have in that area:

1) connection to surface water as a source of baseflow for surface waterways, including the consideration of inter-aquifer hydraulic connectivity;
2) source water for springs, wetlands or groundwater dependent ecosystems (GDEs);
3) stygofauna habitat requirement; and/or
4) human groundwater users (irrigation, livestock, domestic, or industrial water supply).

4.2.1 Groundwater - surface water (baseflow) and inter-aquifer connectivity

As part of the DCM EIS and SCM EIS baseline studies, interaction between groundwater and surface water was considered, as well as any potential interaction between various identified groundwater-bearing units. Of particular note were the assessments of the potential for connection to exist between:

- between the groundwater underlying the QNH and the Bowen River (the only surface water body with permanent flow in the vicinity of the QNH);
- between the groundwater underlying the QNH and Twelve Mile Gully drainage channel in the central QNH area; and
- between the groundwater underlying the QNH and the Two Mile Creek/Coral Creek/Pelican Creek drainage channels in the northern QNH areas.

QCoal (2014) summarised the findings of the above in consideration of the geology of the area (further detailed in AGE (2015)), operational pit groundwater inflow data, and, importantly, ongoing groundwater monitoring of bores across the QNH since 2007.

DCM EIS, SCM EIS and QCoal (2014) concluded that there is limited connectivity between alluvium (where present) and the underlying Permian coal measures across the QNH. This observation is considered consistent with the expected low permeability of the majority of the coal measure's strata. In addition, the major ion chemistry results indicate a difference between groundwater sampled from the coal measures and surface water samples, further suggesting limited interaction between groundwater and surface water.

The groundwater level hydrographs, groundwater quality data, and expected permeabilities of the Permian coal measure aquitards suggest limited interaction between the alluvium and the underlying coal measures. Given that the Bowen River flows through strata of alluvial material, the DCM EIS concludes that there is limited connection between the coal measures and the Bowen River. Due to the observed and recorded highly ephemeral nature of Twelve Mile Gully, Two Mile Creek, Coral Creek and Pelican Creek (the channels for all of which run east west across the QNH), any alluvial deposits associated with these watercourses are well understood to be dry except as a result of rainfall, and therefore not fed by groundwater baseflow. No significant interaction between groundwater and surface water is therefore anticipated along these minor watercourses.

With specific regard to the Bowen River, AGE (2015) reports on numerical modelling of the Bowen River which was undertaken specifically for DCM approval purposes (as reported in QCoal (2014)). AGE (2015) concludes in the presentation of numerical modelling results, that drawdown extents would reach the Bowen River; however, as a result of the lack of direct hydraulic connection between groundwater and the Bowen River, the DCM voids would not have any direct interaction with baseflow in the Bowen River.

AGE (2018) builds on the modelling undertaken in AGE (2015), with updates to the QNH layout and final void locations, in addition to updated modelling software. The updates to the numerical modelling in AGE (2018) result in the cumulative QNH drawdown having a smaller southern extent than was previously modelled, mainly due to a change in the layout of the DCM. Results from AGE (2018) confirmed a lack notable surface water – groundwater connectivity in the QNH area and therefore a limited potential for changes in QNH groundwater to impact on surface water. The maximum extent of final void driven drawdown in AGE (2018) was >3 kilometres from the Bowen River, in both the coal measures and the alluvial modelling layers.

AGE (2020) was completed as a cumulative groundwater modelling study for final voids in the QNH for the specific purpose of informing this final void assessment. AGE (2020) included updated numerical modelling of steady state drawdown extents associated with the final voids on the QNH. Results and drawdown extents of AGE (2020) are presented in **Section 6**.

Conceptually, the above studies conclude that surface water channels across the QNH are losing-disconnected streams (see **Figure 6**) with no notable interconnection between the watercourses and the groundwater system.

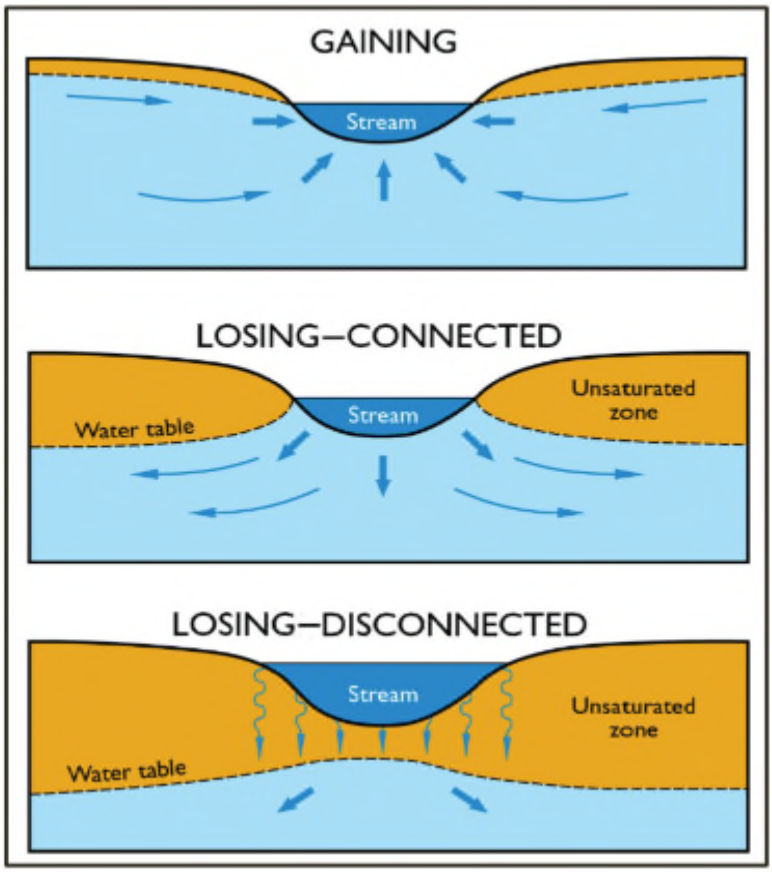


Figure 6 – Groundwater to surface water connectivity (NSW Government 2010)

As such, surface water in the vicinity of the QNH is not reliant on groundwater for baseflow; however, AGE (2018) does states there is potential for some surficial alluvial groundwater interaction with the Bowen River directly along the incised banks of the river channel. Such interaction is stated as being associated with periods of flooding in the river saturating the banks, which would then seep back into the channel after flood waters recede as opposed to any hydraulic connection to groundwater.

As such, surface water baseflow as a value for QNH groundwater is not considered further in this investigation other than in presentation of groundwater and water balance modelling results in **Section 6** and **Section 7** respectively.

4.2.2 Springs, wetlands and GDE

As part of the DCM EIS and SCM EIS baseline studies, a review of potential springs, swamps, wetlands and GDEs in the surrounding area was undertaken. Numerous environmental surveys, investigations and studies have been undertaken during ongoing QNH operations, including numerous receiving environment monitoring programs (REMPs) which specifically focus on aquatic ecology, groundwater reviews such as QCoal (2014) and stygofauna assessments such as Freshwater Ecology (2016). As a result of those EIS's, operational site observations and environmental studies, it is concluded that

- there are no notable groundwater springs or seeps in the QNH area;
- there are no notable wetlands in the QNH area; and
- GDEs are unlikely to exist in the vicinity of the QNH.

As such, springs, wetlands and GDEs are not considered groundwater values for the QNH and are therefore not considered further for impact assessment or associated mitigation.

4.2.3 Stygofauna

As part of the DCM EIS baseline survey assessments, a stygofauna pilot survey was undertaken in May 2011 (GHD (2011)) in accordance with *Guideline No. 54a: Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia* (the stygofauna guideline). The DCM EIS stygofauna pilot survey sampling was undertaken in ten (10) bores at varying depths across QNH area (predominantly across the DCM and JCM). Stygofauna were not recorded in any of the samples obtained during the pilot survey; however, it is noted that low abundances of terrestrial invertebrates including Diptera adults and Coleoptera larvae were recovered from some samples (these are typical of ingress from surface environments and are not obligate subterranean forms, i.e. are not stygofauna). As such, the DCM EIS determined that the absence of stygofauna from the sampled bores indicates a low likelihood of stygofauna occurrence in the groundwater across the area, and, as such, stygofauna was not identified as a QNH groundwater value in the DCM EIS.

Subsequently, a second stygofauna study was undertaken in July 2016 (Freshwater Ecology (2016)) at three DCM bores located along the Bowen River to focus on alluvial sequences in the QNH, which were identified by the Queensland Government Department of Natural Resources Mines and Energy (DNRME) as potential stygofauna habitat. The alluvial groundwater bores along the Bowen River were recorded as dry and as such the alluvial material along the Bowen River in the vicinity of the QNH is not a notable stygofauna habitat.

As per **Section 3**, the QNH spans a consistent contiguous geology and hydrogeology with consistent overburden characteristics. As such, stygofauna results from the DCM EIS and the Bowen River alluvium study are representative of the entire QNH. Accordingly, stygofauna is not a groundwater value on the QNH in the Permian groundwater or the Bowen River alluvium, and, as such, stygofauna is not considered further for impact assessment or associated mitigations.

4.2.4 Human groundwater use

Groundwater resource management in Queensland involves the identification of Groundwater Management Units (GMU) within heavily utilised areas and Unincorporated Areas (UA) where use and/or monitoring data is limited. GMUs are defined by the extent of aquifer systems while UAs are established by dividing the remaining area in Queensland based on geological region boundaries (ANRA (2007)). The QNH is located within the Bowen UA, which covers an area of 153,800 km^2. Average groundwater resource usage in the Bowen UA is estimated to be 14,900 ML/yr compared to an estimated sustainable yield of 260,000 ML/yr (National Land and Water Resources Audit, 2001).

The current low levels of groundwater use within the Bowen UA, may conservatively be considered to include pastoral, irrigation, mining, stock and domestic, and town water. The quality of the groundwater is generally described as marginal, with poorer quality groundwater typically encountered within coal bearing strata. According to the National Land and Water Resources Audit 2001, there are no priority issues for groundwater management within the Bowen UA and the current level of extraction within the Bowen UA is considered sustainable, given the relatively low level of groundwater utilisation.

As part of the previous hydrogeological investigations across the QNH (including the "*Investigation into Residual Void Sonoma Coal Mine – QCoal January 2016" and "Investigation into Residual Void Jax Coal Mine – QCoal October 2018"*), the Queensland Government Groundwater Database (GWDB) has been accessed and searched numerous times. The GWDB is a publicly available database of registered groundwater bores, administered by the Queensland Government Department of Natural Resources Mines and Energy (DNRME) via an online geospatial interface "The Queensland Globe". An updated search was undertaken in April 2020, the results of which are presented in **Figure 7,** which shows the raw GWDB data (as at 20 April 2020), for a search radius of approximately 10km from the external QNH ML boundaries.

For comparison, presented in **Figure 8** is the figure from the 2016 Sonoma Final Void assessment, in which the raw DNMRE GWDB data was reviewed and identified as either supply or other use. Between 2016 and the preparation of this investigation, no new registered supply bores have been installed within the respective search radius.

Of the over 50 registered bores within the area on **Figure 8**, only four (4) are identified as a potential water supply bores:

- RN25008 – located ~2.5 km north-east from the SCM East Pits 1 and 2 and Main Pit residual final voids;
- RN125696 – located ~8.5 km east-north-east from the JCM Main Pit residual voids and ~9 km from the SCM East Pit 1 and 2 residual voids;
- RN125698 – located ~6 km south-east from the SCM East Pits 1 and 2 final voids, ~7.5 km east of the DCM Drake 1 Pit final void and ~8 km north-east of the JCM Main Pit final void; and
- RN140020 –located ~6 km south-east from the SCM East Pit final voids and ~ 6.5 km north-east from the JCM Main Pit void.

This indicates that landholder groundwater use (including irrigation, livestock watering and domestic use) is not considered a groundwater value across or in the immediate vicinity of the QNH site. As such, groundwater use is not considered further for impact assessment or associated mitigation.

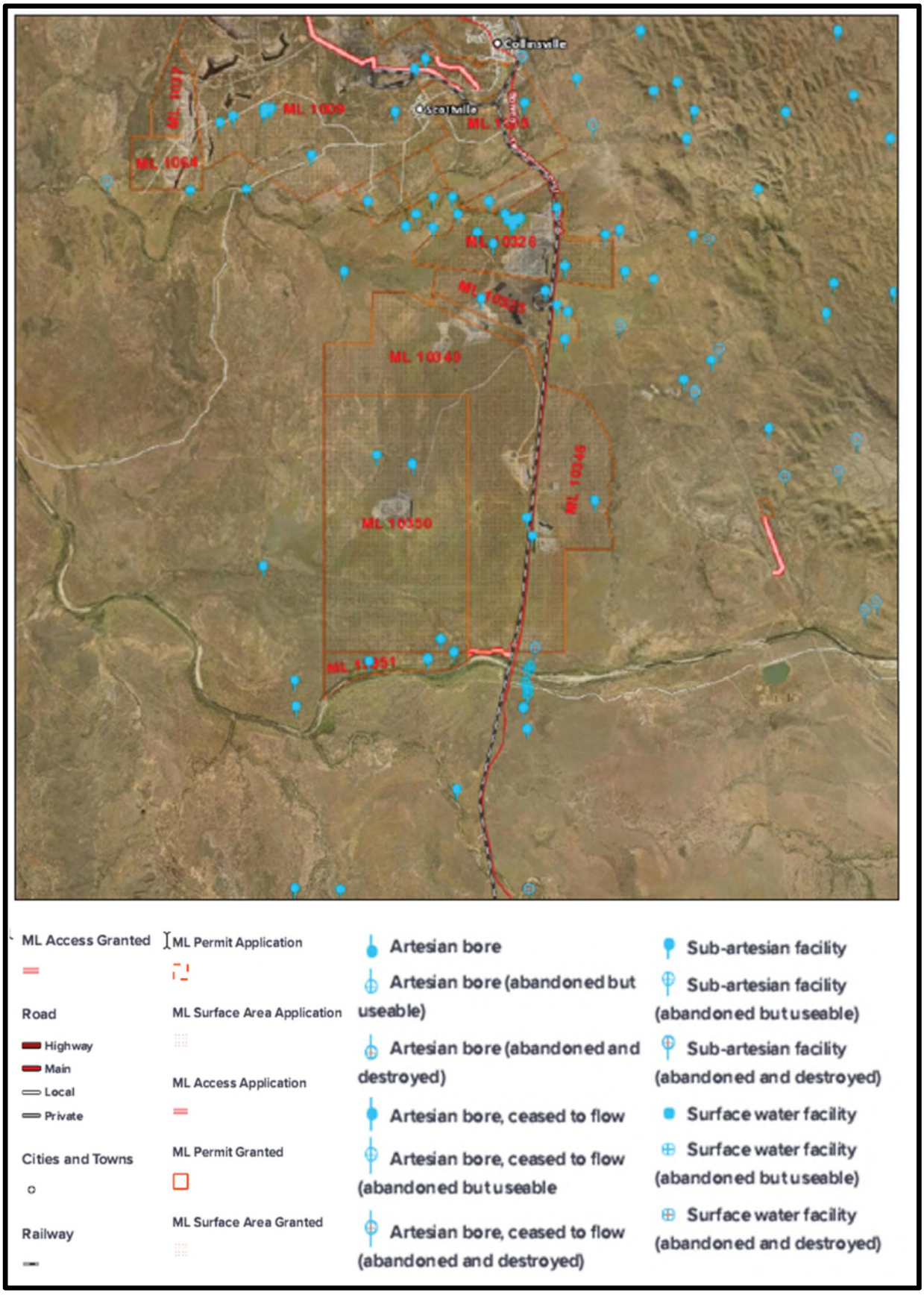


Figure 7 – DNRME GWDB April 2020 (no scale)

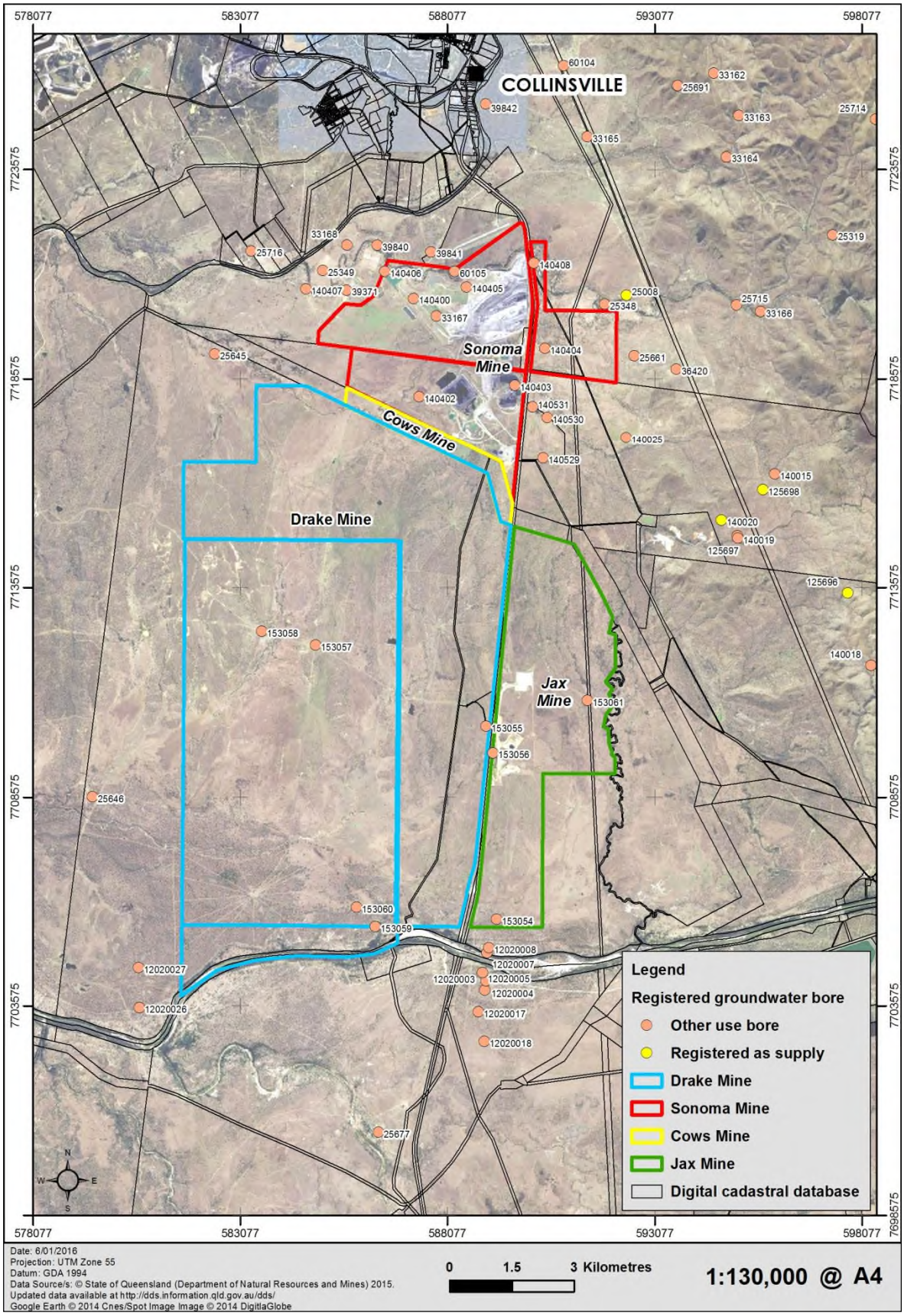


Figure 8 – DNRME GWDB figure from 2016 Sonoma Final Void Investigation

4.2.5 Summary

The four potential groundwater values of the northern QNH are listed in **Section 4.2** and discussed respectively in **Section 4.2.1** to **Section 4.2.4**. A summary of those findings is as follows:

- surface water in the vicinity of the QNH is not reliant on groundwater for baseflow and, as such, is not considered a groundwater value;
- springs, wetlands and GDEs are not considered a groundwater value for the QNH;
- stygofauna is not considered a groundwater value for the QNH; and
- groundwater use (conservatively including pastoral, irrigation, stock and domestic supply) is not considered a groundwater value across the QNH (CCM and SCM).

It has been concluded through a range of previously completed studies listed in **Section 4.1**, as well as operational environmental monitoring data (specifically groundwater monitoring), that groundwater in the QNH area has minimal value. Therefore, any changes in groundwater associated with drawdown resulting from the presence of the QNH final voids will not have notable impacts.

However, as a conservative measure, this investigation includes a modelling assessment of the potential level changes which may occur to the surrounding groundwater (e.g. modelled drawdown curve), and an associated void lake water balance (level and quality). The modelling assessments quantify the potential changes to groundwater resulting from QNH final voids.

5 QNH Final Voids

5.1 Definitions

With the advancing highwall – progressive backfilling method of open cut mining adopted at the QNH, a pit remains when mining of the highwall ceases and the waste rock recovered as part of active mining is no longer available to continue advancing the low wall (progressive backfilling). Such pits are then available to support ongoing mining related activities such as bulk water storage, in-pit rejects disposal or as a designated location for waste rock to be dumped from adjacent mining pits.

Assuming the residual pit was not backfilled by in-pit rejects disposal or waste rock from adjacent mining, the void that remains is then considered the final void, which requires rehabilitation to the final landform (shape, size, slopes etc) as discussed in **Section 9**.

5.2 Authorised final voids, locations and catchments

On the QNH, there are 14 approved final voids, which are located on the SCM, DCM and JCM, with pits on the CCM having been backfilled with waste rock from adjacent mining operations on the DCM.

The SCM, DCM and JCM EAs contain conditions relating to the size, location, slopes and post-mining land use of authorised final voids (Table H1 in each EA). It is noted that the approved size of selected final voids in the DCM EA is a cumulative total area across multiple final voids in close proximity (a “complex” of pits).

Presented in **Table 3** are the approved final voids, the operational complexes to which they belong, the approved size, void outcome and wall slopes. Also shown in **Table 3** is the status of the pit for each approved residual void, with seven of the 14 approved voids having commenced mining and the remainder yet to be developed as pits.

For the final void and the associated rehabilitated waste rock dump details required by the modelling (such as layouts, geometry, storage curves, depths, heights and precise locations), the current “life-of-mine planning” (LOMP) was used in combination with actual operational progression and observations for those pits and dumps which have commenced. For pits and dumps which have yet to commence the final void details were informed by the LOMP and by operations in adjacent pits. It is noted that the LOMP is updated and changes frequently during the life of a mine and, as such, for pits or dumps planned for commencement years into the future, the specific planning is likely to change.

Additionally, it is noted that:

- the DCM final voids “Central 3” and “Central 4”, as named in the DCM EA, are referred to in this assessment as “Drake Pit 4 North” and Drake Pit 4 South” respectively due to changes in naming conventions; and
- specific assessment of East Pit 1 (Drake) has been excluded from this assessment at this time due to its proximity to Drake 1 Pit (its hydrological processes would be dominated by Drake Pit 1 and East Pit 1 may potentially be amalgamated into Drake Pit 1 at a later date).

The locations of the final voids modelled as part of this assessment are presented in **Figure 9** along with the assumed areas of rehabilitated waste rock dumps from which runoff reports to the respective voids (the catchments). Catchment definition is required to quantify rainfall runoff inflow into a void as part of water balance modelling.

Table 3 – QNH approved final voids (as per SCM, DCM and JCM EAs)

Site	QNH Operational Complex	Approved Void Name	Approved Void Area	Approved Void Outcome	**Pit status**	Approved High Wall Slope	Approved Low Wall Slope
Jax	Jax	Jax Main Pit	70 ha	Residual void unable to sustain a post mining land use	Commenced	High wall – 60°	Low wall – 32°
		Jax East Pit	27 ha	Residual void unable to sustain a post mining land use	Planned		
Sonoma	Sonoma	Sonoma Main Pit	120 ha	*Not specified in EA*	Commenced	High wall – Maximum slope of 70° with the top 10m having a maximum of 45° including a 1m bund	Low wall – 17°-37°
		Sonoma East Pit 1	14 ha	*Not specified in EA*	Planned		
		Sonoma East Pit 2	15 ha	*Not specified in EA*	Planned		
Drake	Drake 5	Drake Pit 5	59 ha	*Not specified in EA*	Commenced	High wall – 65°	Low wall – 45°
	Drake 1-2	Drake Pit 1	258 ha	*Not specified in EA*	Commenced		
		Drake Pit 2		*Not specified in EA*	Commenced		
		Drake Pit 2 Expansion		*Not specified in EA*	Planned		
		East Pit 1	14 ha	*Not specified in EA*	Planned		
	Drake 3-4	Central Pit 3 (Drake Pit 4 North)	50 ha	*Not specified in EA*	Planned		
		Central Pit 4 (Drake Pit 4 South)	16 ha	*Not specified in EA*	Planned		
		Drake Pit 3-Q	61 ha	*Not specified in EA*	Commenced		
		Drake Pit 3-R		*Not specified in EA*	Commenced		

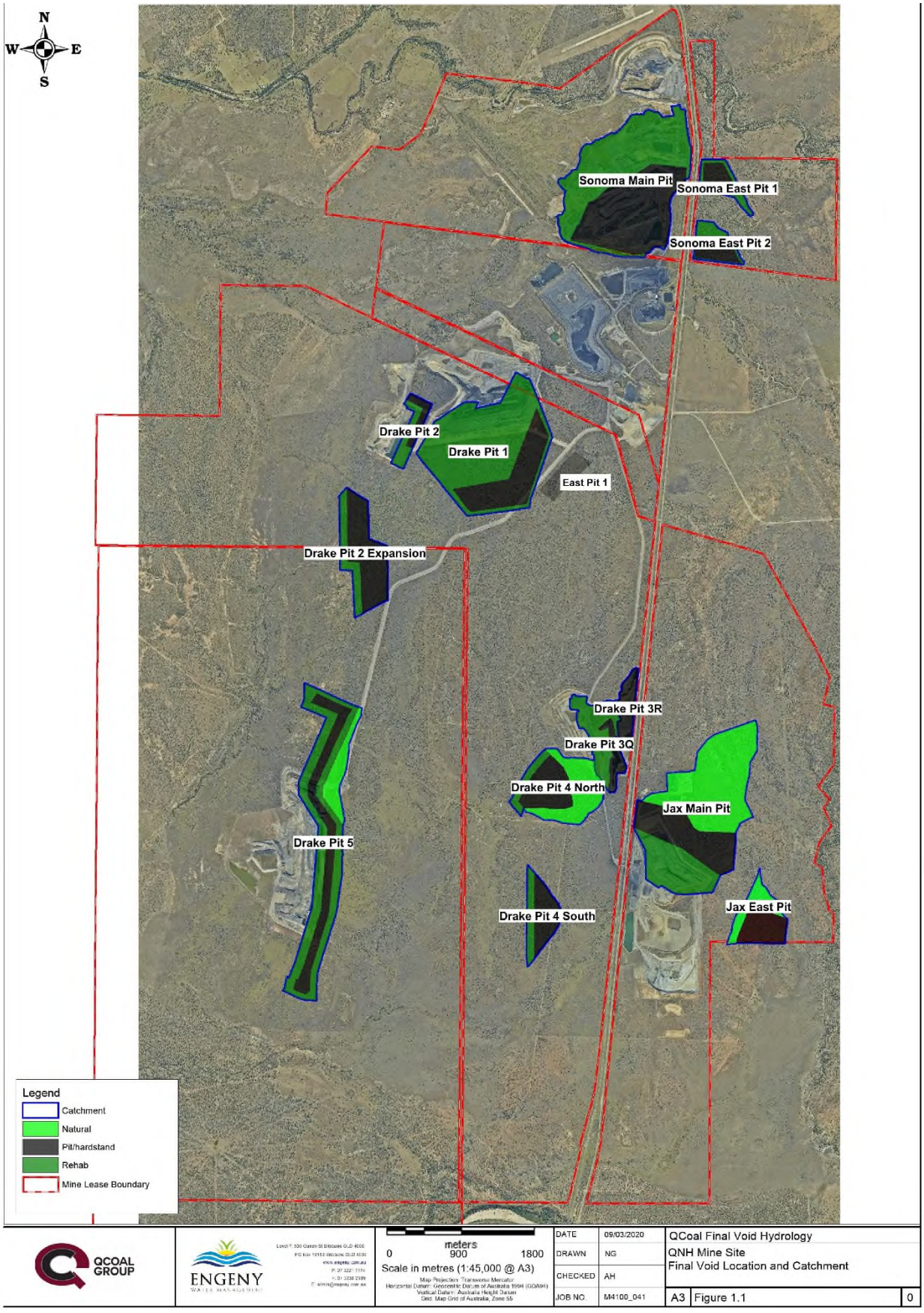


Figure 9 – QNH final void locations and catchments (adapted from Engeny (2020)

5.3 Final void storage curves

The storage curves of the final voids (i.e. the relationship between level, area and volume within a void) are a key input for the water balance and numerical groundwater modelling, and are derived from the geometry of the final voids.

Storage curves for the Jax Main Pit and Jax East Pit final voids are described and plotted in detail in Engeny (2108), provided as **Appendix A** to this assessment. Storage curves for all other QNH voids are described and plotted in detail in Engeny (2020), provided as **Appendix B** to this assessment.

The final void volumes extracted from the storage curves for all QNH voids are presented in **Table 4**.

Table 4 – Void capacity to crest (ML)

Void	Capacity to crest (ML)
Jax Main Pit	32,000 Engeny (2018)
Jax East Pit	11,000 Engeny (2018)
Sonoma Main Pit	45,151 Engeny (2020)
Sonoma East Pit 1	1,788 Engeny (2020)
Sonoma East Pit 2	2,009 Engeny (2020)
Drake Pit 5	13,996 Engeny (2020)
Drake Pit 1	18,323 Engeny (2020)
Drake Pit 2	1,711 Engeny (2020)
Drake Pit 2 Expansion	15,824 Engeny (2020)
East Pit 1	refer **Section 5.2**.
Central Pit 3 (Drake Pit 4 North)	6,160 Engeny (2020)
Central Pit 4 (Drake Pit 4 South)	3,708 Engeny (2020)
Drake Pit 3-Q	2,326 Engeny (2020)
Drake Pit 3-R	1,254 Engeny (2020)

6 Groundwater Model (hydrogeology)

6.1 Model Development

AGE (2020) is a numerical groundwater modelling scope, the results of which have been inserted into this assessment.

A 3D numerical groundwater model was developed that covers the QNH mining leases. The model represents the weathered regolith and underlying Permian strata. Each key coal seam is represented as an individual model layer, as well as the interburden units that separate the coal seams. Most coal seams simulated are within the Moranbah Coal Measures, but also include the lower seam of the Fort Cooper Coal Measures. The base model layer represents the Exmoor Formation.

The modelling uses the unstructured version of the industry standard MODFLOW model (MODFLOW-USG). MODFLOW-USG uses a control volume finite difference scheme to represent the groundwater flow equation. The model is transient and simulates pre mining water levels through a steady state timestep, followed by transient annual timesteps representing both historical and future mining. The model has been calibrated against historical groundwater monitoring data. The model also simulates recovery of the groundwater system post mining, where hydraulic properties are changed within the pits to represent spoil emplacement and final voids.

The open cut mining at QNH is represented in the model using the Drain package. The drains are applied to each model layer within the mined out areas and groundwater is removed to create the desaturated conditions within the open cut pits. This drawdown then propagates away from the pits as water from the surrounding groundwater system flows through the ground towards the pits due to the gradients created by the desaturated conditions. The coal seam (and model layer) that the pit floor is in varies across the site due to the basin shape and accessibility of seams in different areas.

The mining is conservatively represented in the model by maintaining the dewatering (leaving the drain boundary on) once mining has started. This is done also to simplify the model setup, with all pits changed to spoil / void properties at the same time. This means that for pits such as Drake 3Q and 3R, which have completed mining and recovered, they continue to be dewatered in the model until all other pits have completed mining.

6.2 Groundwater level predictions

Presented in **Figure 10**, is the predicted water level in layer 1 for the end of mining with all pits dewatered. This prediction is representative of the water table, with some areas across the model domain layer 1 being fully unsaturated, in which case the predicted level resides in lower model layers. Predicted water levels in lower layers reflect these contours, though any sharp changes in level in higher levels tend to be gradually muted with depth. Due to the low permeability of the geology, predicted (and observed) impacts to the surrounding groundwater system remain local to the pits. The water levels in this figure become the starting point for the recovery simulation.

The recovery process is simulated by assuming recharge to the spoil and voids, factoring in evaporative losses to the void lakes. The level of recovery is controlled by the balance of water coming in from rainfall derived recharge and groundwater inflow as inputs and the loss due to evaporation from the void lake.

Recharge rates into the void and into the in-pit spoil are much higher than the undisturbed recharge rate calibrated for the model, which is conceptually expected as backfilled spoil has higher porosity and permeability than undisturbed material.

Presented in **Figure 11** is the predicted groundwater in layer 1 at year 10 after end of mining, and presented in **Figure 12** is the predicted groundwater in layer 1 at equilibrium, which show the following:

- the extent of groundwater change is largest at equilibrium due to the continued dewatering offered by evaporation from void lakes that equilibrate below the pre mining water levels;
- some of the pits have been predicted to have a hydraulic gradient back into the surrounding geology (a net outflow) particularly where they have been completely backfilled or where the void footprint is small. Those pits are Drake 3Q, Drake 3R and Sonoma East 2:
    - A potential issue with such modelling outputs is the assumption that it indicates a migrating of water away from void. This assumption is not correct in the case of the QNH voids due to the proximity and influence of adjacent final voids. With this in mind, the predicted equilibrium water levels have been forensically interrogated to identify that all these potential sources are predicted to be intercepted by the larger and deeper voids (such as Drake 1, Drake 5, Sonoma East 1, and Jax 1), and will not migrate away from the site.
    - More broadly the model identifies some minor movement of water between some of the smaller voids towards adjacent voids, while all other voids remain as groundwater sinks. In summary, the QNH voids when assessed as complexes are all groundwater sinks and the QNH when assessed cumulatively is a groundwater sink with no migration away from the QNH. To illustrate this outcome groundwater flow directions have been added to **Figure 12**.

Presented in **Figure 13** is the predicted groundwater in layer 1 at equilibrium with the bores registered as supply bores (**Section 4.2.4**). All bores are located outside of the extent of the cone of depression.

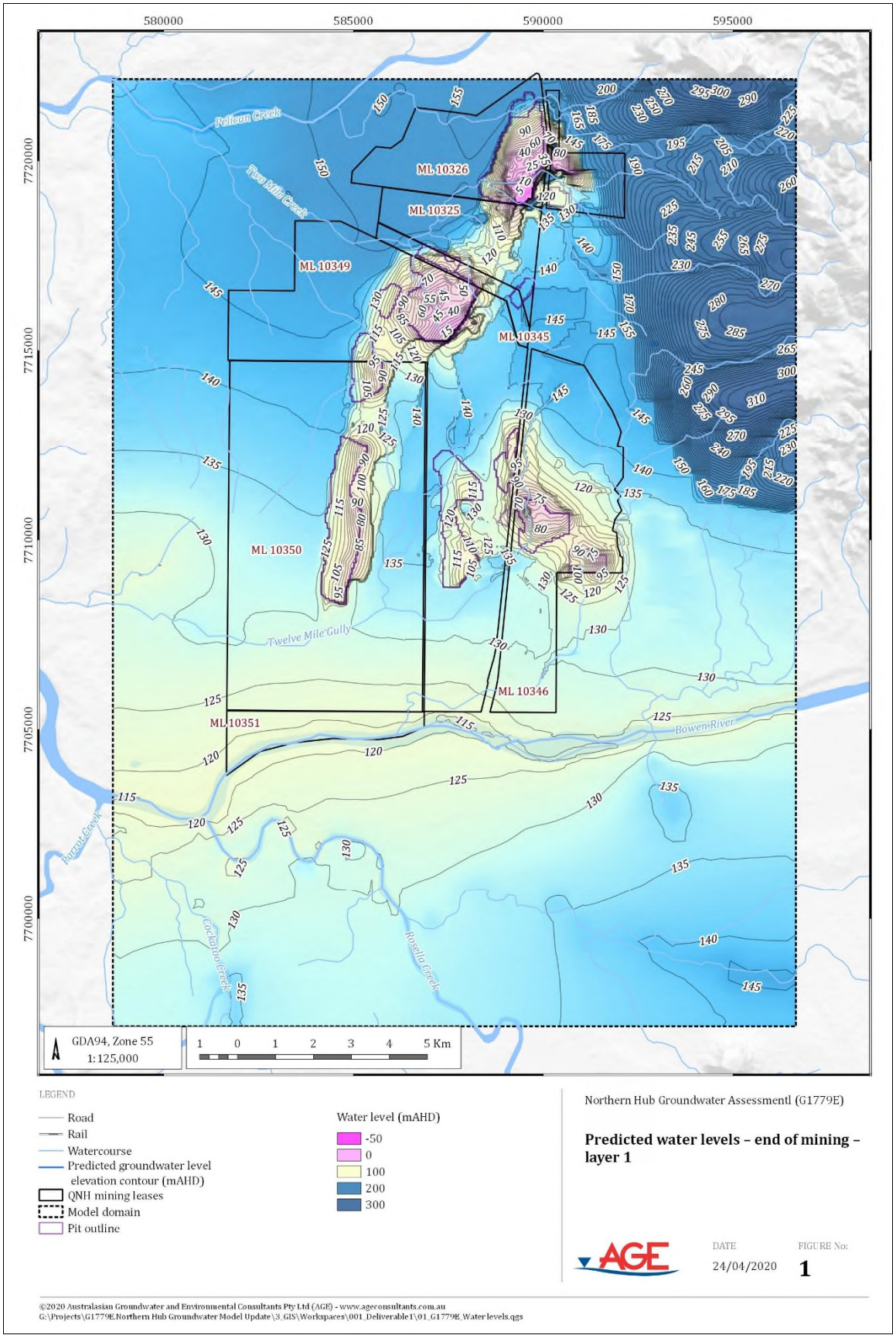


Figure 10 – Predicted groundwater levels end of mining – model layer 1

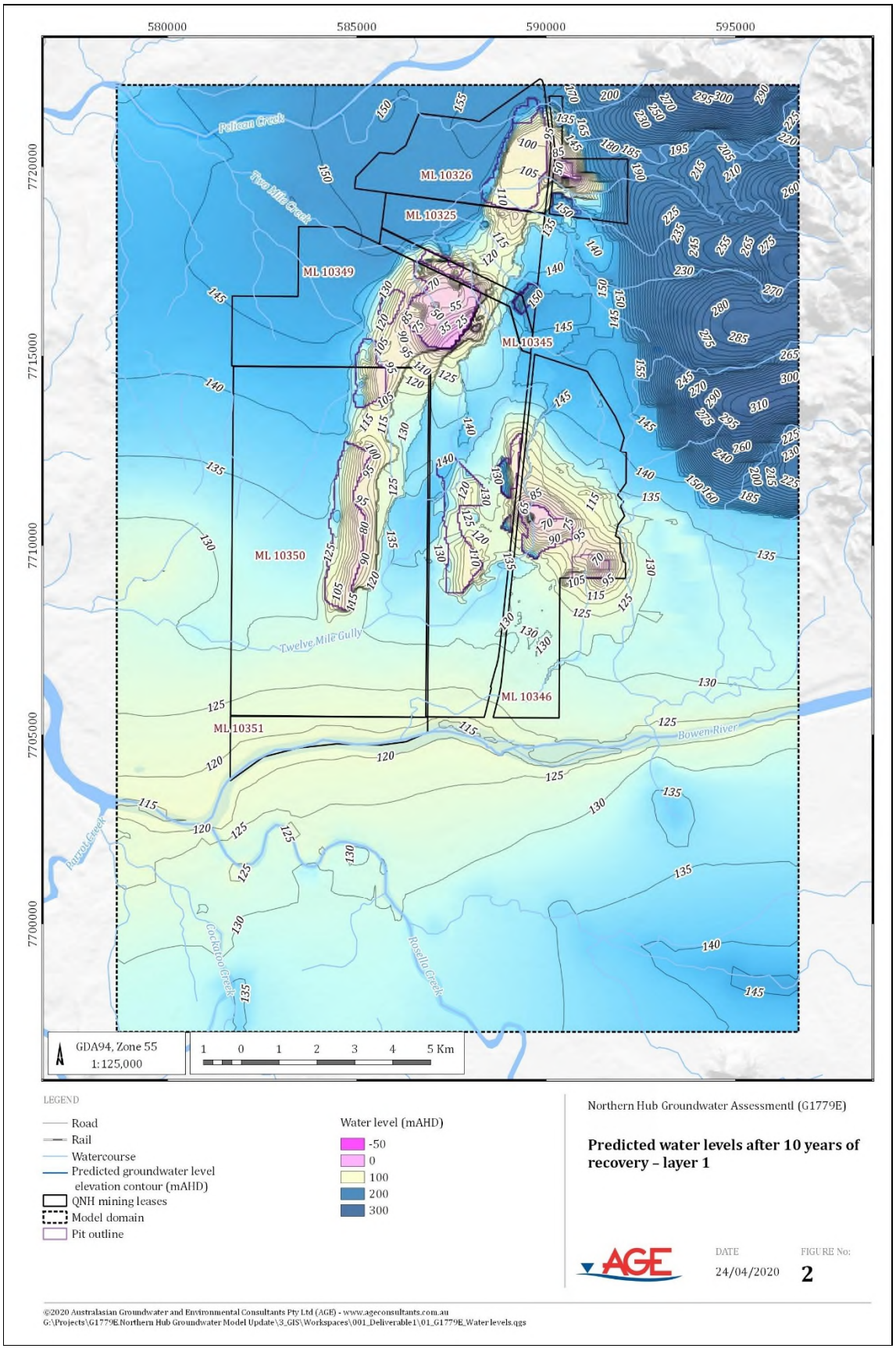


Figure 11 – Predicted groundwater levels year 10 after mining – model layer 1

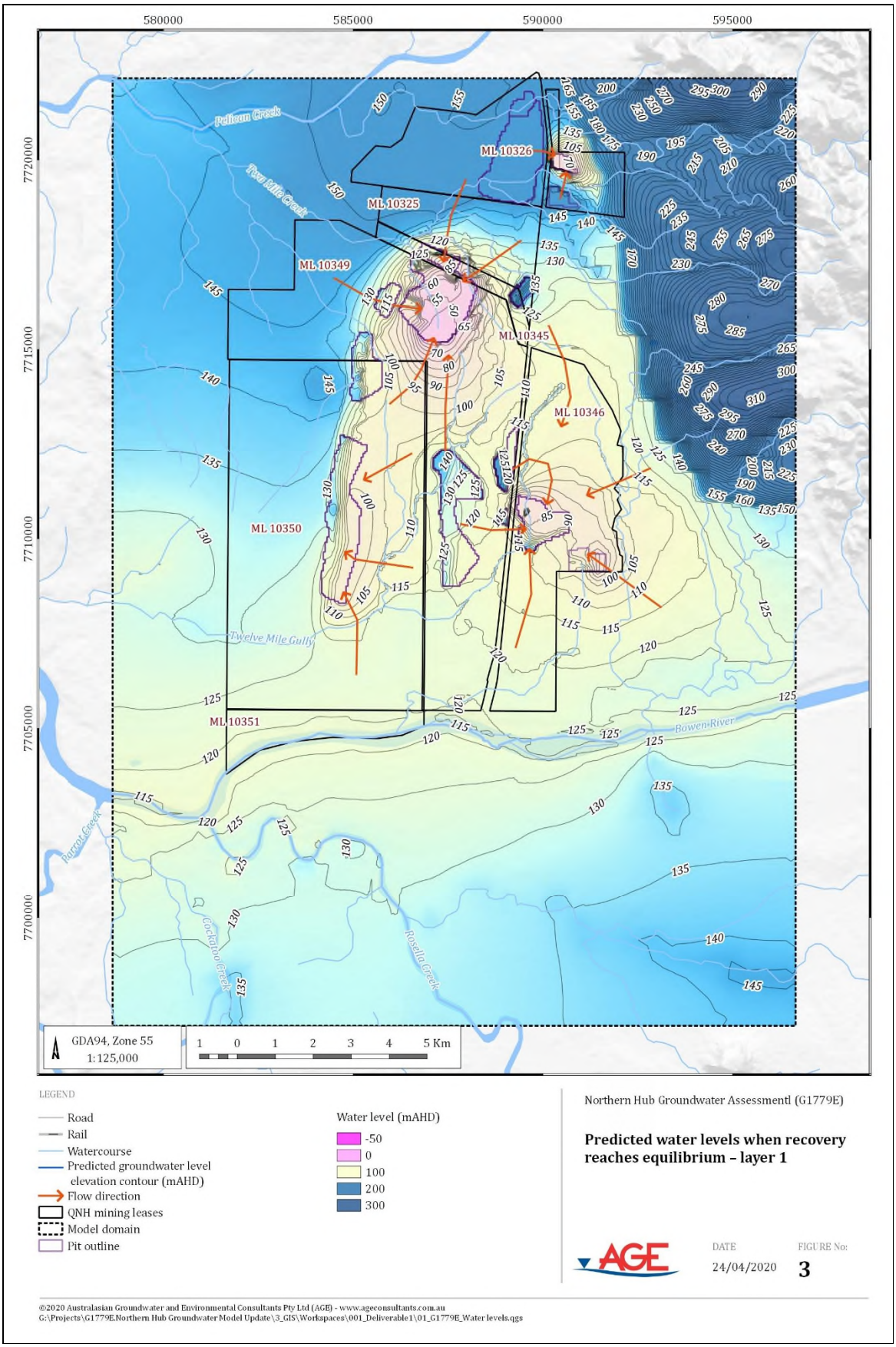


Figure 12 – Predicted groundwater levels equilibrium – model layer 1

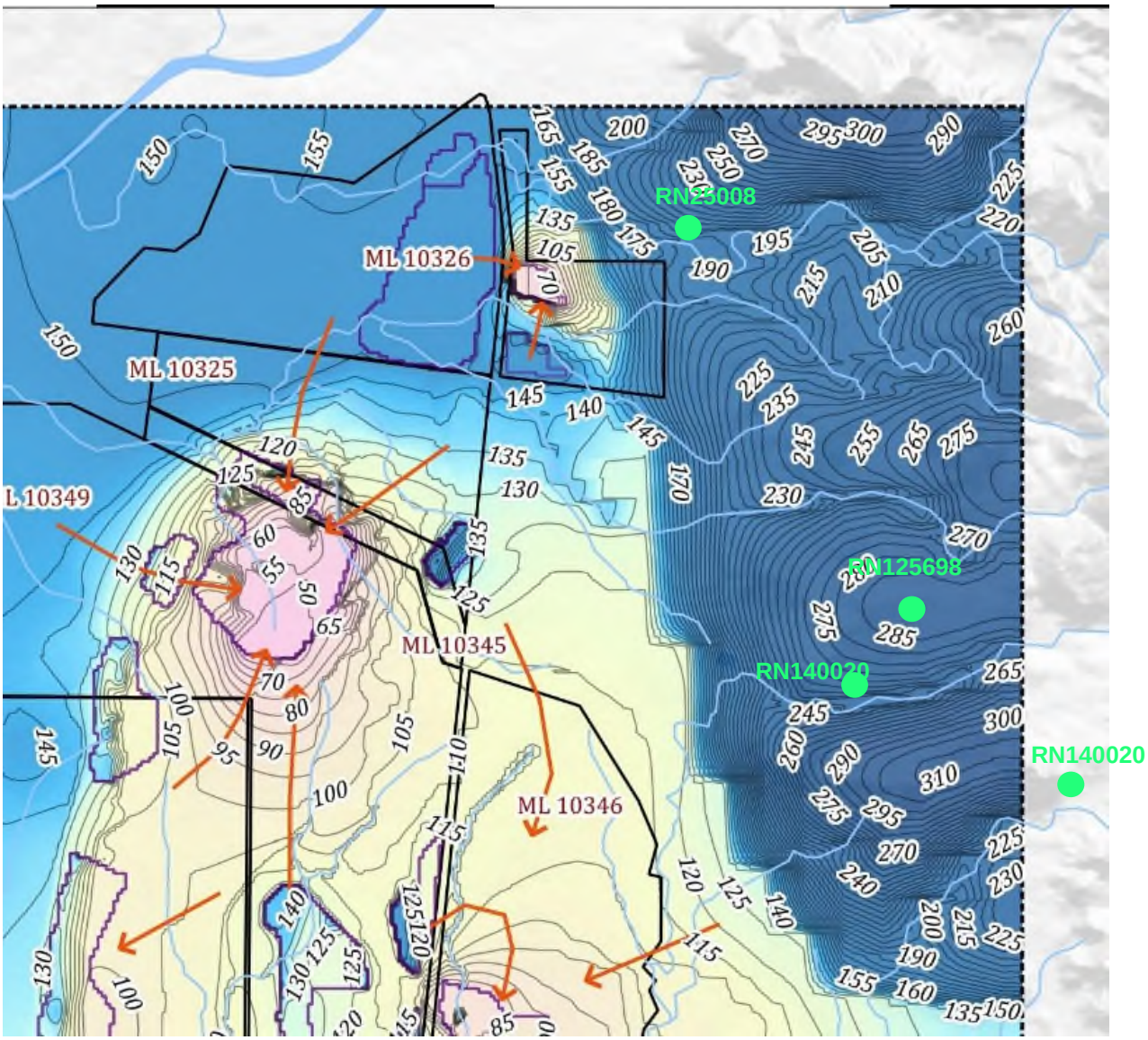


Figure 13 – Predicted groundwater levels equilibrium layer 1 and registered supply bores

7 Water Balance Model Inputs

7.1 Conceptual void hydrology

The water balance of the QNH final voids will be governed by the following water inflows and outflows:

- Inflows:
  - Surface runoff inflows from rehabilitated spoil areas that drain to the void.
  - Surface runoff inflows from the walls and ramps of the void.
  - Inflows from incident rainfall on the void lake.
  - Groundwater inflows to the void (nominally where void lake level is lower than regional groundwater).
- Continuous outflows:
  - Outflows due to evaporation losses from the surface area of the void lake.
- Hypothetical outflows (conditional on void lake level):
  - Seepage outflows from the void lake – potential to flow into an adjacent groundwater sink void or into the unsaturated low-wall waste rock dump or into the local groundwater system if not contained by the cumulative cone-of-depression surrounding the QNH voids.
  - Discharges to surface water (conditional on maximum void lake levels relative to crest height).

7.2 Groundwater recovery curves

Numerical groundwater modelling of the design residual voids was undertaken by AGE (2018) for Jax Main Pit and Jax East Pit, and by AGE (2020) for all other QNH voids, to predict groundwater recovery after the cessation of mining. From those modelling studies a rating curve of groundwater inflow versus pit water level for each residual void was developed which is required for the water balance modelling of the final voids.

Groundwater recovery curves for the Jax Main Pit and Jax East Pit final voids are described and plotted in detail in Engeny (2108), provided as **Appendix A** to this assessment. Groundwater recovery curves for all other QNH voids are described and plotted in detail in Engeny (2020), provided as **Appendix B** to this assessment.

It is noted that the range of the groundwater recovery curves is limited by the water levels simulated in the groundwater model. Where required, the final value of the groundwater recovery curves have been conservatively extrapolated for the remainder of the adopted void storage curve values.

Negative flows shown in the groundwater recovery curve figures indicate the elevation of water level within the lake is generating a hydraulic gradient out of the void lake, at which point a net outflow from the void lake can potentially occur. **Any modelled outflows from a void lake resulting from these portions of the groundwater recovery curves need to be interpreted with care and may not necessarily indicate flows to the surrounding regional groundwater system.** It is understood that the adopted groundwater recovery curves are impacted by the following processes:

- Interaction between residual void lakes located in close proximity, such as hydraulic gradients between void lakes resulting in flow from one void lake to another, which **is not considered flow into the surrounding regional groundwater** (e.g. as has been identified between Sonoma East 1 and Sonoma East 2 and between Drake 3Q and Drake 3R). It is noted that the modelled flow rates in these situations are generally of very small magnitude.
- Outflows from the void lakes into the surrounding spoil material. **The groundwater recovery curves make no distinction between outflows from the void lake into the low-wall backfill material, outflows into an adjacent void or outflows into the regional groundwater system.** As such, a modelled outflow as determined by the model may be associated with the saturation period of the low-wall waste rock until such time as steady state equilibrium is reached. This primarily occurs during the initial recovery period when the spoil material is first becoming saturated.

The interaction between the residual void lake and surrounding regional groundwater (be it net inflow or outflow) considers a range of indicators including:

- Base of Weathering – the threshold between highly weathered material and less permeable hard rock. The base of weathering provides an indication of areas where seepage from a void lake into the surrounding geology might occur if lake levels are forecast to exceed this threshold. Again, such seepage is not immediately representative of a groundwater source into regional groundwater.
- Regional Groundwater Level – when the regional groundwater level exceeds the forecast void lake level then there is a hydraulic gradient into the void and the void is considered to act as a groundwater sink. Alternatively, a void lake level that is forecast to be above the regional groundwater level may result in a hydraulic gradient out of the void into the surrounding geology (a net outflow), but, again, a net outflow is not immediately representative of a groundwater source into regional groundwater.
- Net Zero Flow Level – This level is extracted from the groundwater recovery curves and provides an indication of the direction of water fluxes to the void lake. **As previously stated, outflows resulting from these recovery curves need to be interpreted with care as they may represent movement from one void (a net outflow) to an adjacent void which is a groundwater sink (a net inflow), thus containing void water from both voids (considered as movement within a groundwater sink system), or movement of water into unsaturated low wall spoil material, as opposed to an actual flow into the regional groundwater system.**

A summary of indicator levels for each QNH final void is summarised in **Table 5**.

Table 5 – Base of weathering and regional groundwater levels

Mine SIte	Residual Void	Base of Weathering (mAHD)	Pre- mining Regional Groundwater Level (mAHD)	Net Zero Flow Level (mAHD)
Jax	Jax Main Pit	149.78	140	
	Jax East Pit	146.72	140	
Sonoma	Sonoma Main Pit	153.02	155.67	8.23
	Sonoma East Pit 1	155.80	156.30	Inflows at all levels
	Sonoma East Pit 2	156.92	155.53	Outflows at all levels
Drake	Drake Pit 5	144.39	137.42	Inflows at all levels
	Drake Pit 1	169.07	146.57	Inflows at all levels
	Drake Pit 2	153.4	147.23	100.11
	Drake Pit 2 Expansion	163.99	144.24	Inflows at all levels
	East Pit 1	refer **Section 5.2**.		
	Central 3 (Drake Pit 4 North)	126.96	139.50	Inflows at all levels
	Central 4 (Drake Pit 4 South)	146.72	136.71	Inflows at all levels
	Drake Pit 3Q	161.28	142.55	Inflows at all levels
	Drake Pit 3R	156.72	141.78	83.15

7.3 Rainfall and evaporation data

Engeny (2020) provides detail on the climate data used for the water balance model. Long-term daily rainfall data at the QNH was obtained from the SILO climate database facility hosted by DES. SILO includes both Patched Point Data and Data Drill. The Data Drill utilises grids of data interpolated from point observations by the Bureau of Meteorology to provide climate statistics for a specified location. Patched Point Data is only available at selected rainfall stations and utilises grids of data to 'patch' any data gaps in the climate record at that site. A SILO Patched Point Data climate series was obtained for the nearby Collinsville Post Office (33013) covering the period January 1889 to September 2019. A composite data set was obtained by merging the SILO data with SCM site rainfall to obtain a continuous record from January 1889 to September 2019 (130 years of data).

The largest single day rainfall event measured as 348.7 mm (08/04/1940) and the largest seven day total measured as 454 mm (02/02/1991 – 08/02/1991),

Corrections to the lake evaporation rates were applied in the residual void water balance model to reflect the reduction to the freshwater evaporation rate that occurs for a saline water body. Morton's method for adjusting evaporation rates has been adopted as presented in Hydrological Recipes: Estimation Technique in Australian Hydrology (1996). The method predicts a relatively small evaporation correction for salinity of approximately 1% reduction per 10,000 mg/L total dissolved solids (TDS) for TDS values up to 50,000 mg/L (i.e. 5% reduction for 50,000 mg/L TDS).

7.4 Runoff rates and quality

Engeny (2020) provides detail on the assumed rates and quality of runoff used for the water balance model. Catchment runoff has been simulated using the Australian Water Balance Model (AWBM). The model represents the catchment using three conceptual surface stores to simulate partial areas of runoff. The water balance of each surface store is calculated independently of the others. The model calculates the water balance of each partial area at daily time steps. At each time step, rainfall is added to each of the three surface stores and evapotranspiration is subtracted from each store. If the value of water in the store exceeds the capacity of the store, the excess water becomes runoff. Part of this runoff becomes recharge of the baseflow store if there is a baseflow component to the stream flow. AWBM parameters were adopted from the existing QNH operational water balance model (as for "*Water Management Plan QNH Mines*" (Engeny, 2019)). These parameters are as summarised in **Table 6**.

Table 6 – Adopted AWDM Runoff Parameters

Parameter	Natural	Hardstand & Pits	Rehabilitated Spoil
C1 (mm)	23.0	5.0	10.0
C2 (mm)	125.0	20.0	120.0
C3 (mm)	180.0	40.0	180.0
A1	0.134	0.134	0.134
A2	0.433	0.433	0.433
3	0.433	0.433	0.433
BFI	0.05	0.00	0.35
Kb	0.87	0.60	0.60

For the assessment of final voids, a single indicator parameter is adopted by the water balance modelling to predict dilution and concentration cycles in the void lake. Salinity is the industry standard indicator parameter. Salinity of runoff generated in the water balance is determined based on land use type. Surface water runoff total dissolved solids (TDS) characteristics have previously been calibrated for certain land use types as documented in "*Water Management Plan QNH Mines*" (Engeny, 2019). These runoff TDS characteristics have been adopted for the modelling of the QNH voids and are summarised in **Table 7**.

Table 7 – Adopted runoff quality

Source	Salinity (mg/L)
Pit wall runoff	1300 (1,931 µS/cm EC)
Rehabilitated Spoil runoff	700 (1,040 µS/cm EC)
Natural catchment runoff	700 (1,040 µS/cm EC)
Direct rainfall	5 mg/L, based on latitude and distance from the coast (DNR, 1997)

7.5 Assumed groundwater quality

Monitoring of groundwater quality across a number of monitoring bores at QNH is undertaken on a quarterly basis. For the assessment of final voids, a single indicator parameter is adopted by the water balance modelling to predict dilution and concentration cycles in the void lake. Salinity is the industry standard indicator parameter.

The groundwater quality data has previously been assessed as part of the "*Sonoma Coal Mine Final Void Hydrology Study Main Pit 2015*" (Engeny, 2015) and "*Cows Coal Mine Final Void Hydrology Study Q Pit and B Pit 2017"* (Engeny 2017). Both studies determined a representative groundwater inflow quality of 2,000 µS/cm.

A consistent quality was adopted for the Jax Main Pit and Jax East Pit final voids as described in Engeny (2108), provided as **Appendix A**, and for all other QNH voids as described in Engeny (2020), provided as **Appendix B**.

8 Water Balance Model Results

8.1 Final void lake levels

The final void lake volume and level modelling (including sensitivity analysis) for the Jax Main Pit and Jax East Pit final voids, is described and plotted in detail in Engeny (2108), which has been provided as **Appendix A**. The final void lake volume and level modelling for all other QNH final voids is described and plotted in detail in Engeny (2020), provided as **Appendix B**.

Results have been extracted from the above, and are presented in **Figure 14** - **Figure 26**, with the following key information presented:

- the simulation period:
    - 500 years for Jax Main Pit and Jax East Pit (presented for the first 100 years and the full 500 year simulation separately for both final voids)
    - 200 years for all other QNH final voids
- minimum, median and max levels and volumes are presented for each day of the simulation period for all final voids;
- the observable oscillations are the drying/filling cycles associated with normal seasonal and climactic variations;
- the median has been used to define the equilibrium levels in this assessment;
- the crest/spill level, regional groundwater level and base of weathering assumed in the model is also presented on each figure for each final void:
    - the additional information for Jax Main Pit and Jax East Pit is presented as an un-scaled schematic
    - all other QNH final voids have this information presented as plotted data
- all results reported in this assessment are from modelling of the “base case” which is the catchment extent provided by the LOMP, except for Central 3 (Drake Pit 4 North), where an opportunity to refine the catchment boundary was identified during the modelling (referred to as the mitigated case). For ease of interpretation only the Central Pit 3 (Drake Pit 4 North) mitigated case is included within the body of this assessment; however, Engeny (2020) includes both the base and mitigated cases.

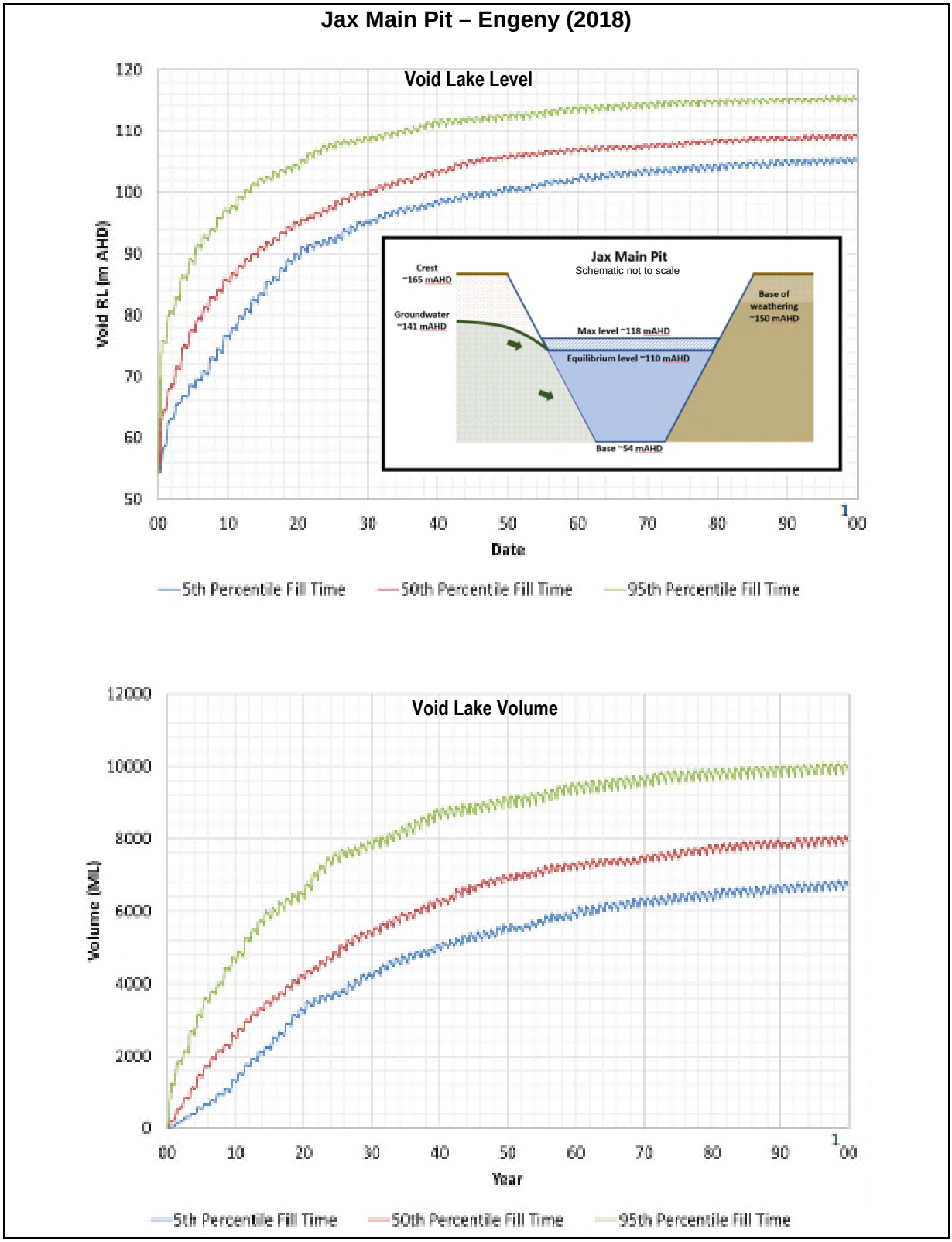


Figure 14 – Jax Main Pit final void water volume and level (base case)

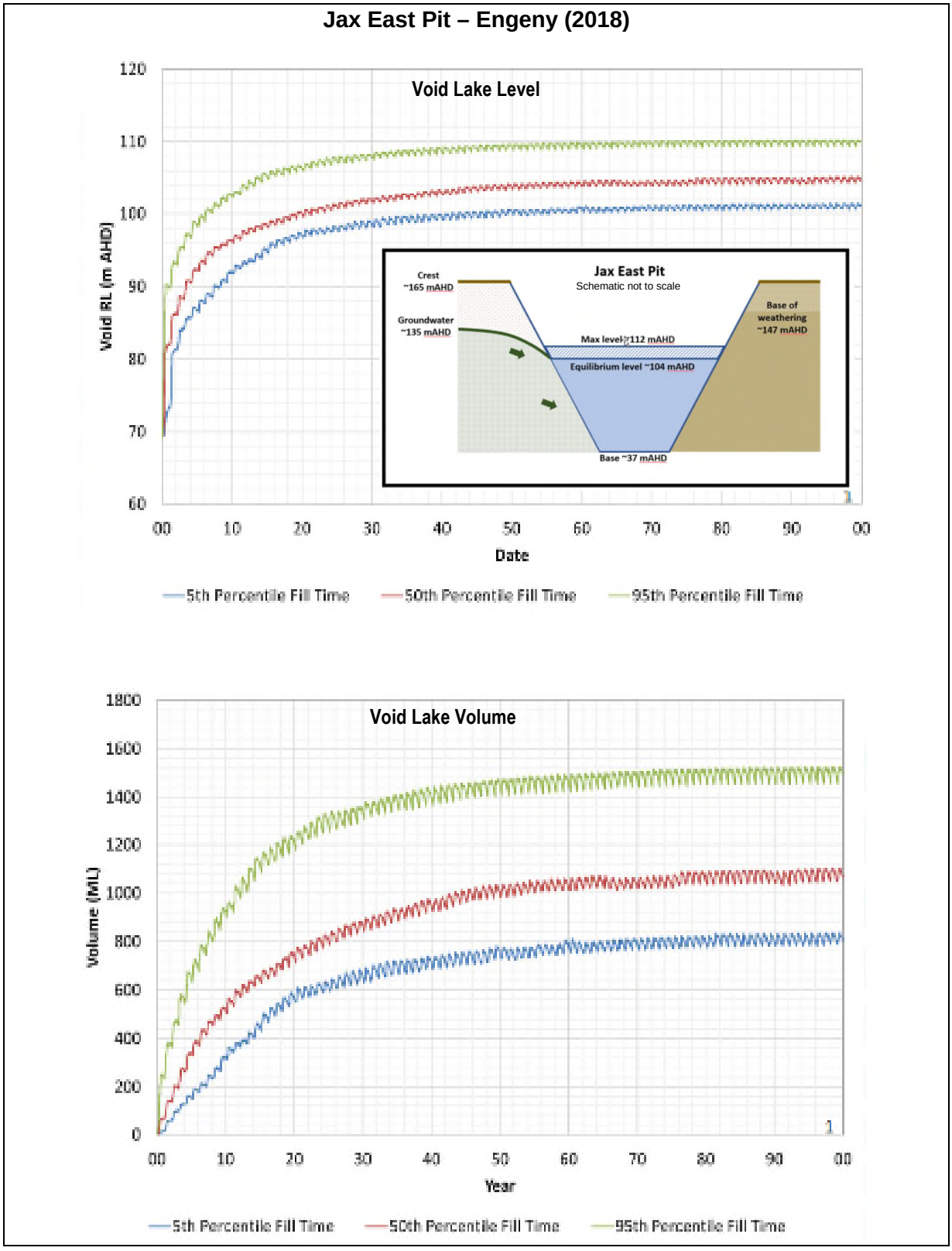


Figure 15 – Jax East Pit final void water volume and level (base case)

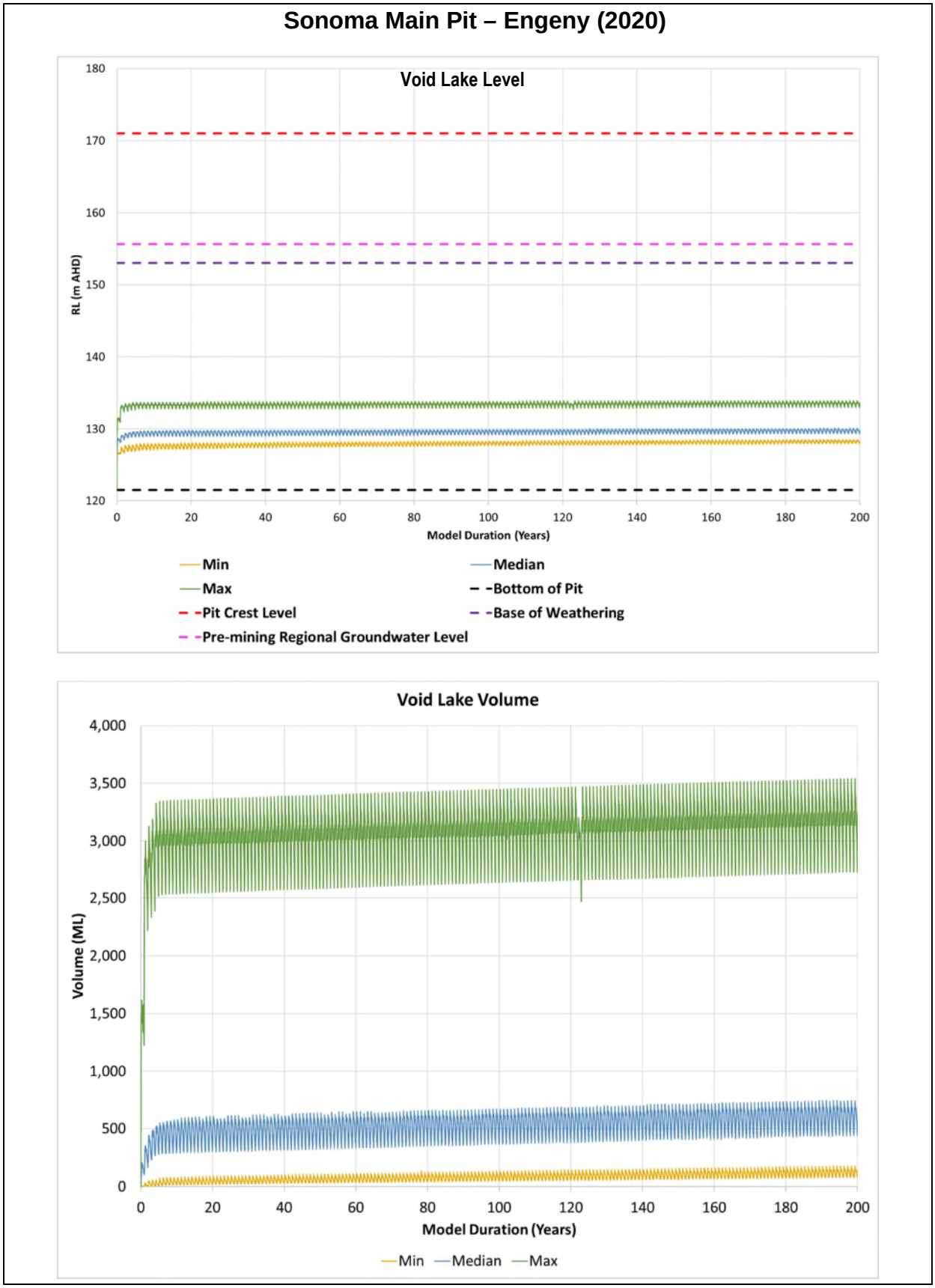


Figure 16 – Sonoma Main Pit final void water volume and level (base case)

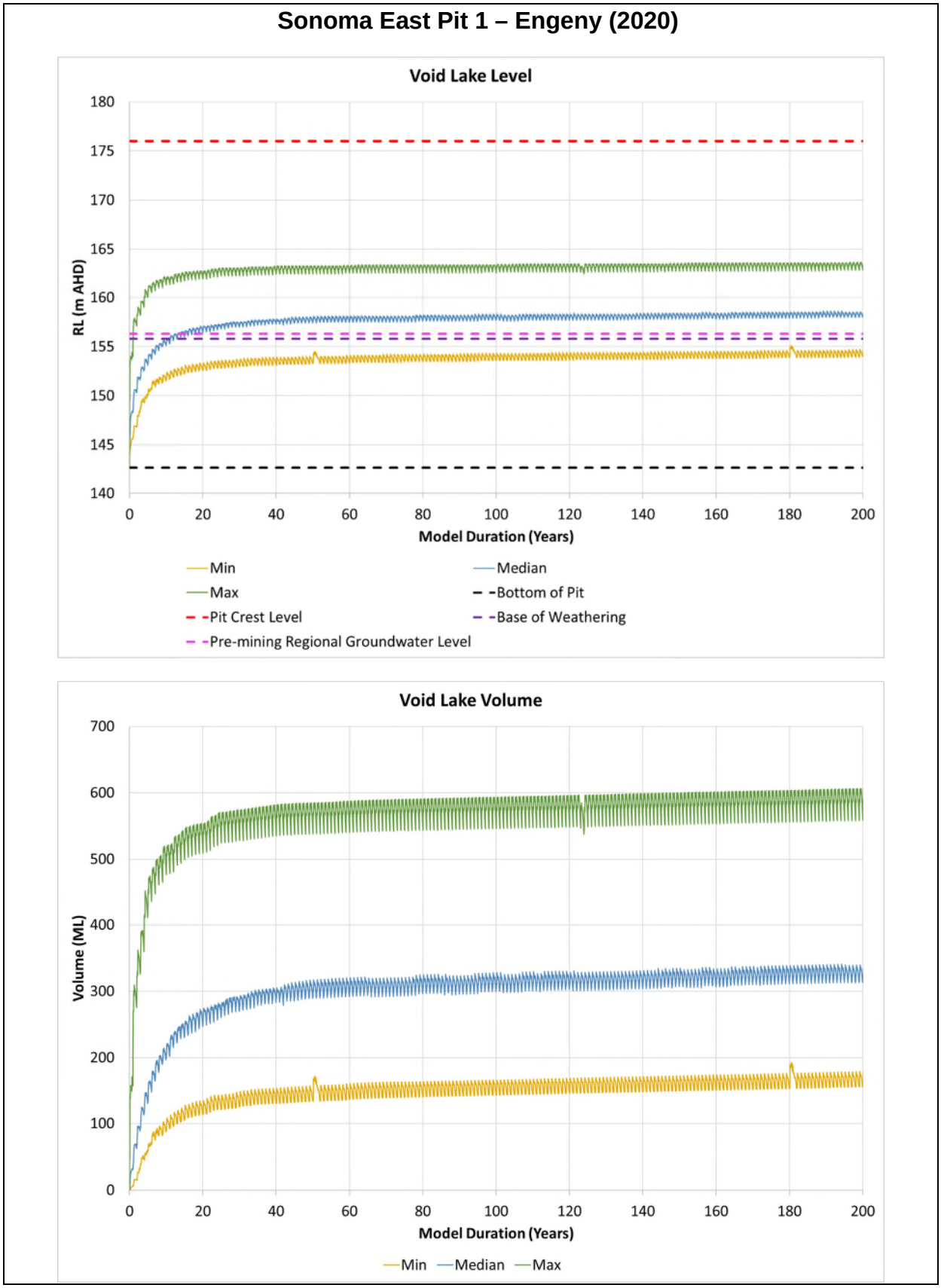


Figure 17 – Sonoma East Pit 1 final void water volume and level (base case)

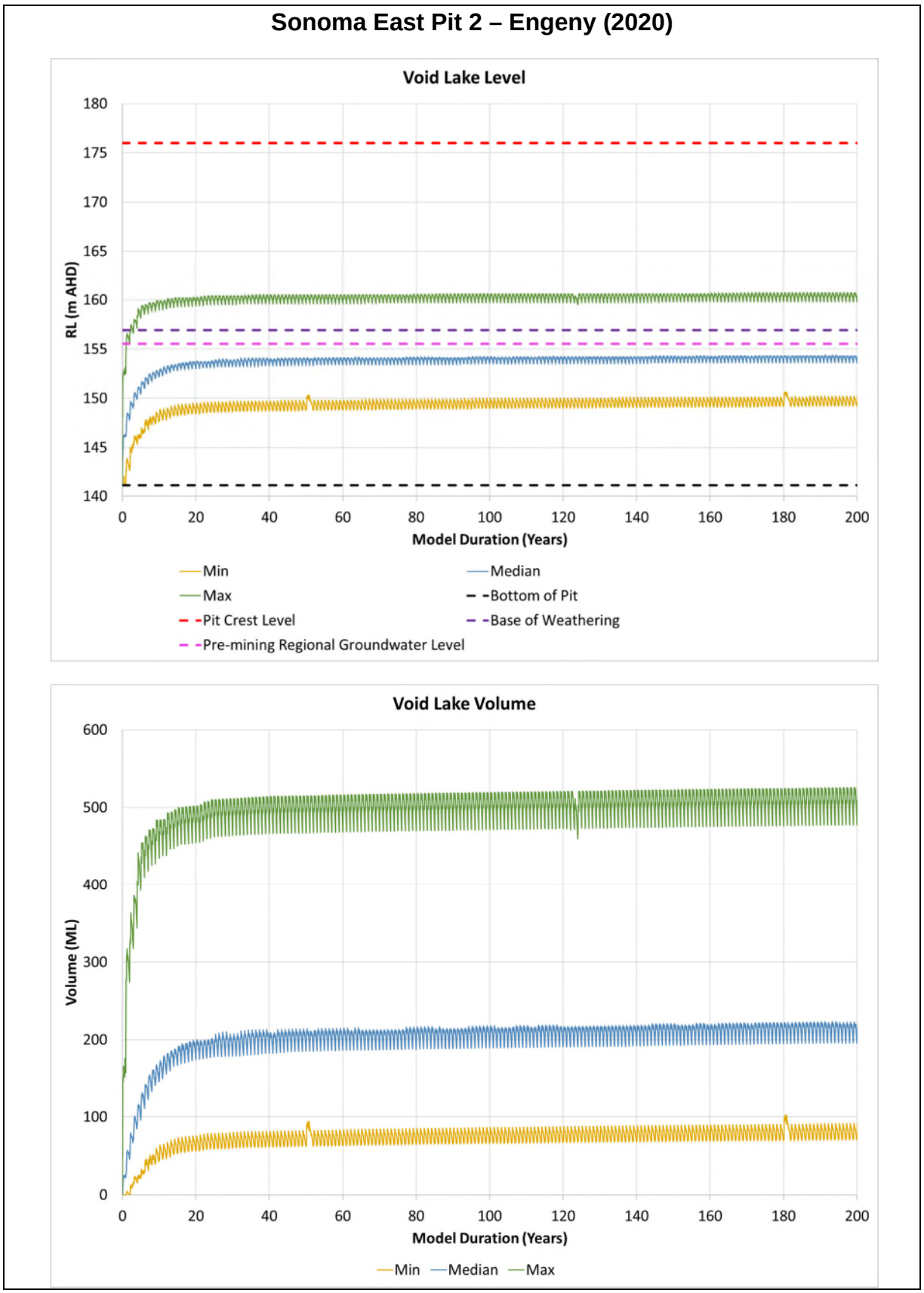


Figure 18 – Sonoma East Pit 2 final void water volume and level (base case)

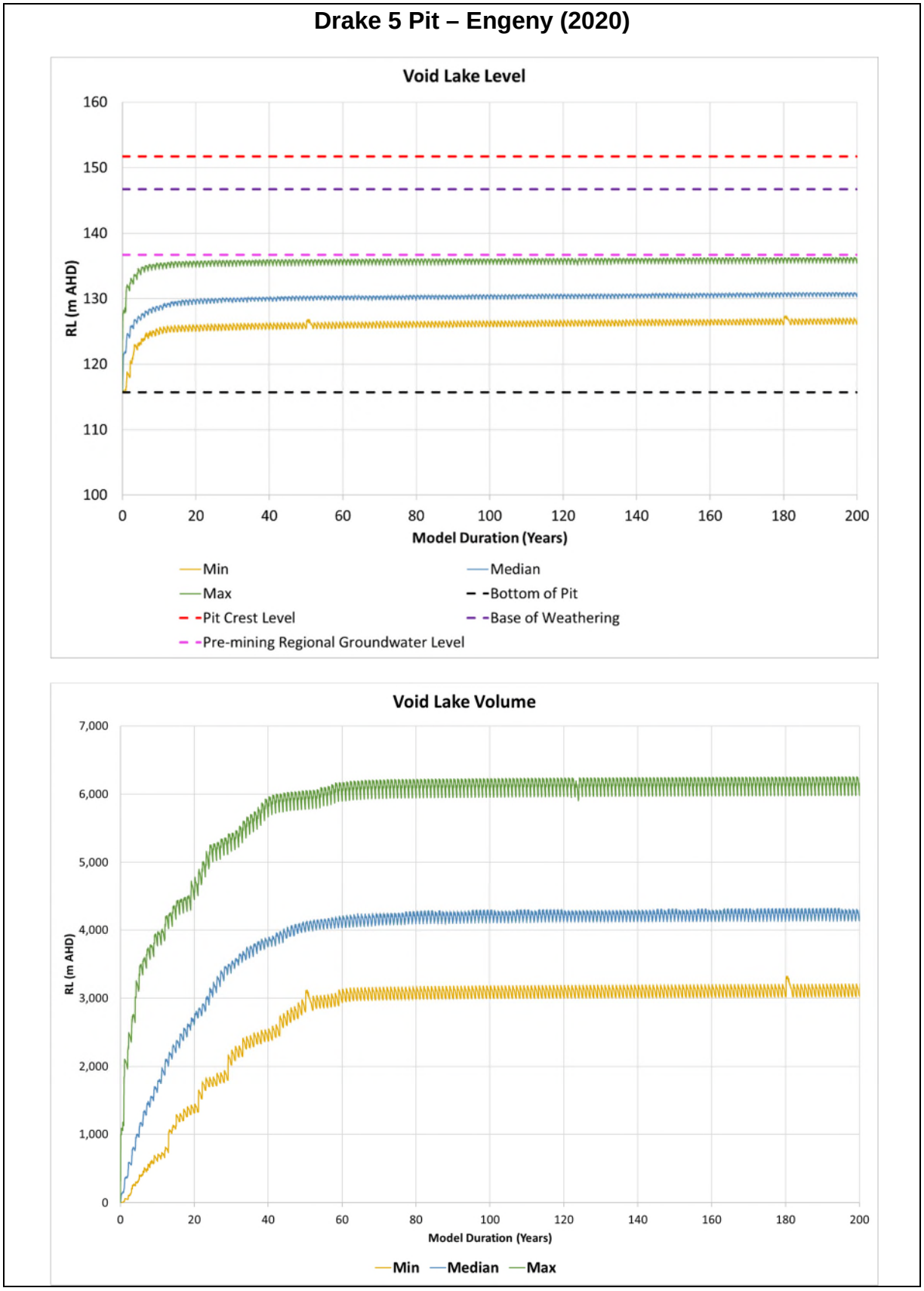


Figure 19 – Drake Pit 5 final void water volume and level (base case)

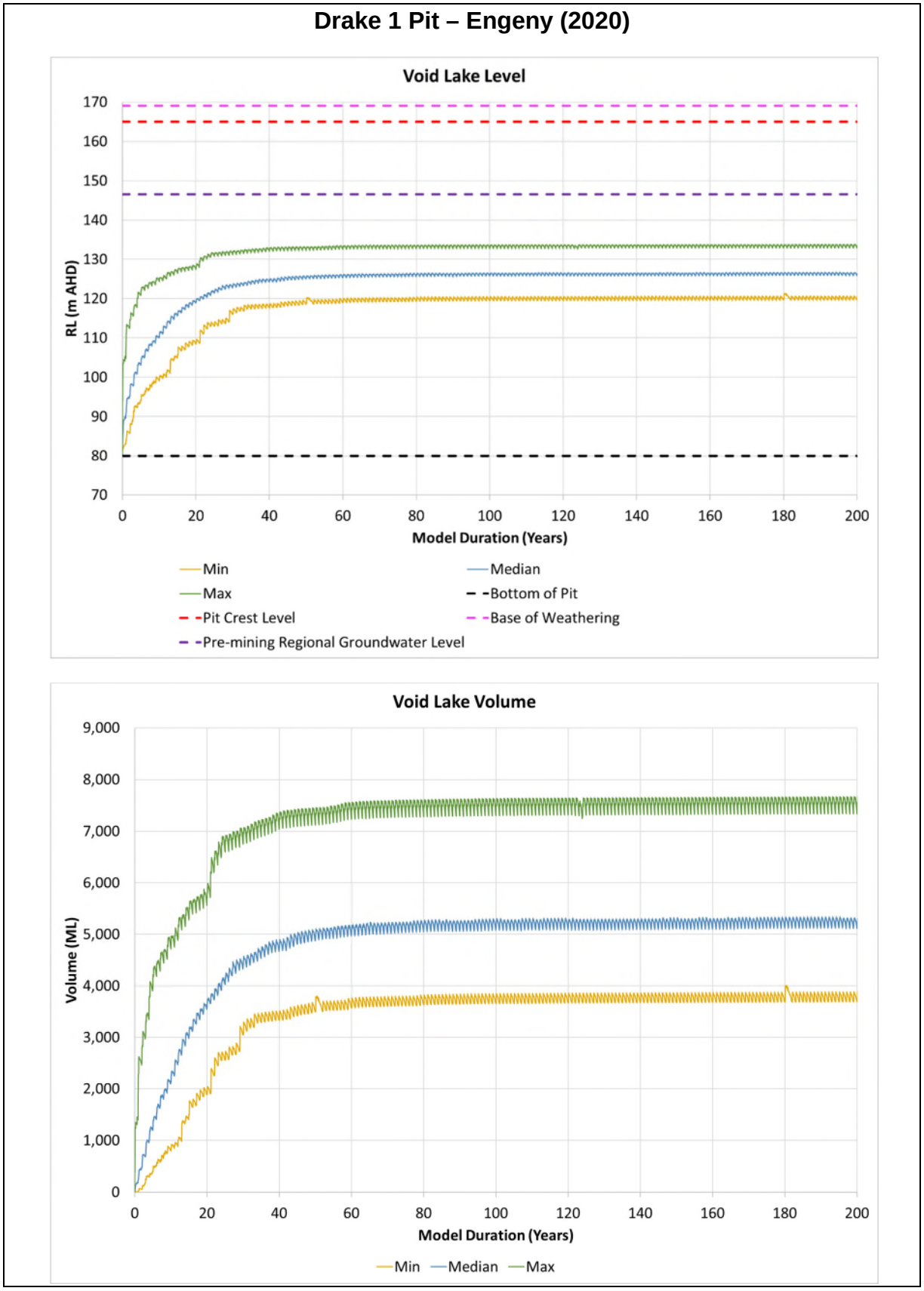


Figure 20 – Drake Pit 1 final void water volume and level (base case)

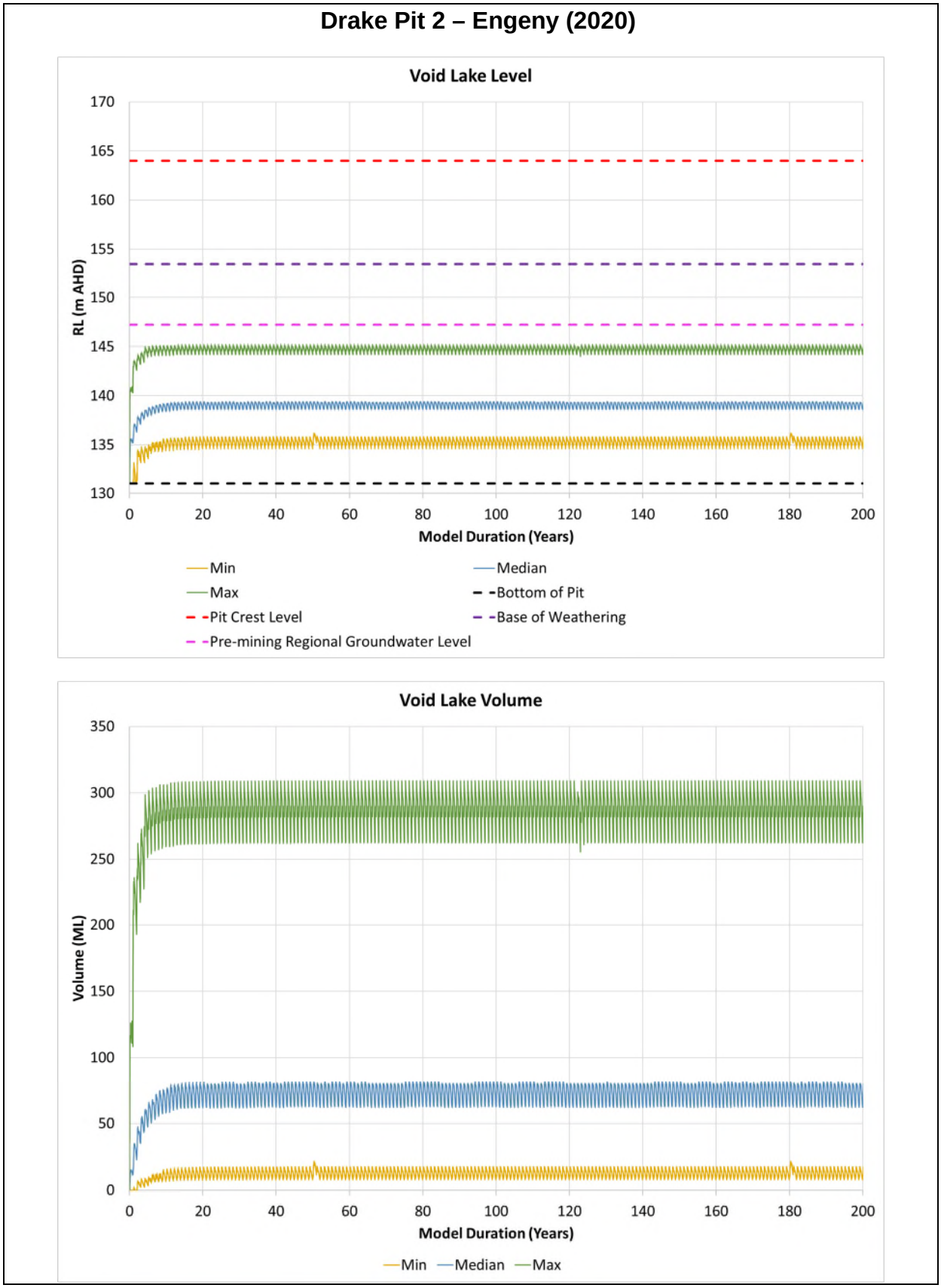
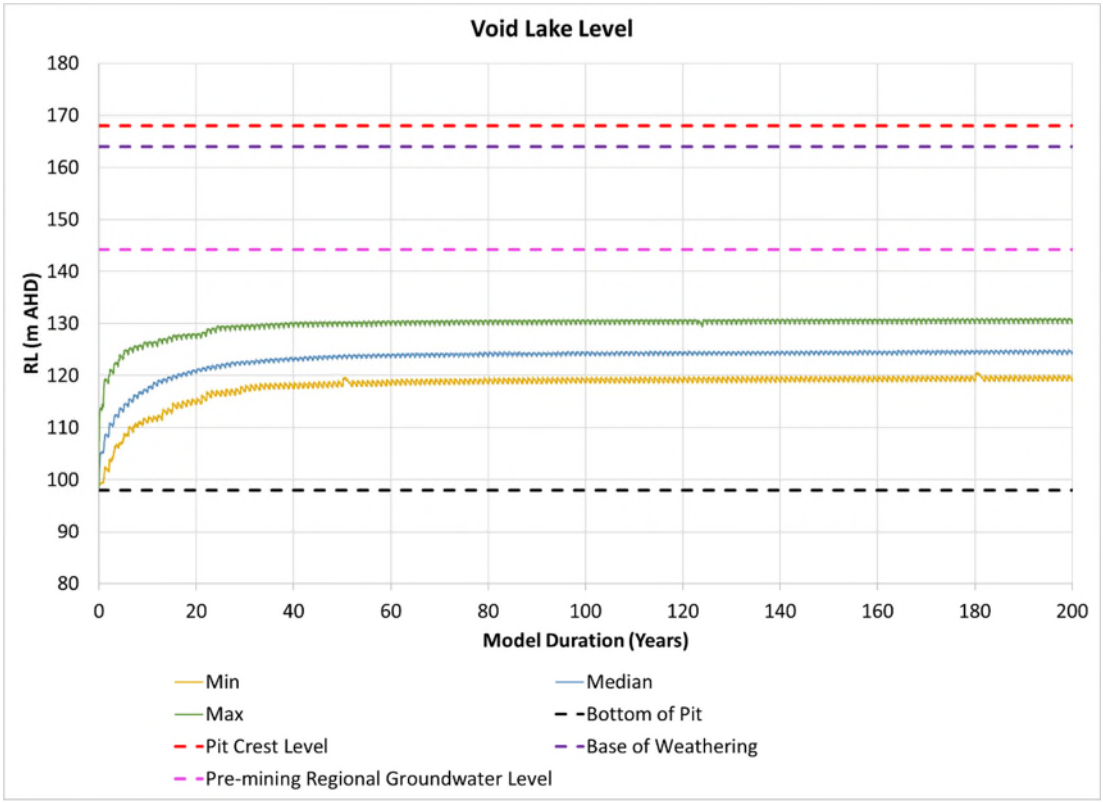


Figure 21 – Drake Pit 2 final void water volume and level (base case)

Drake Pit 2 Expansion – Engeny (2020)



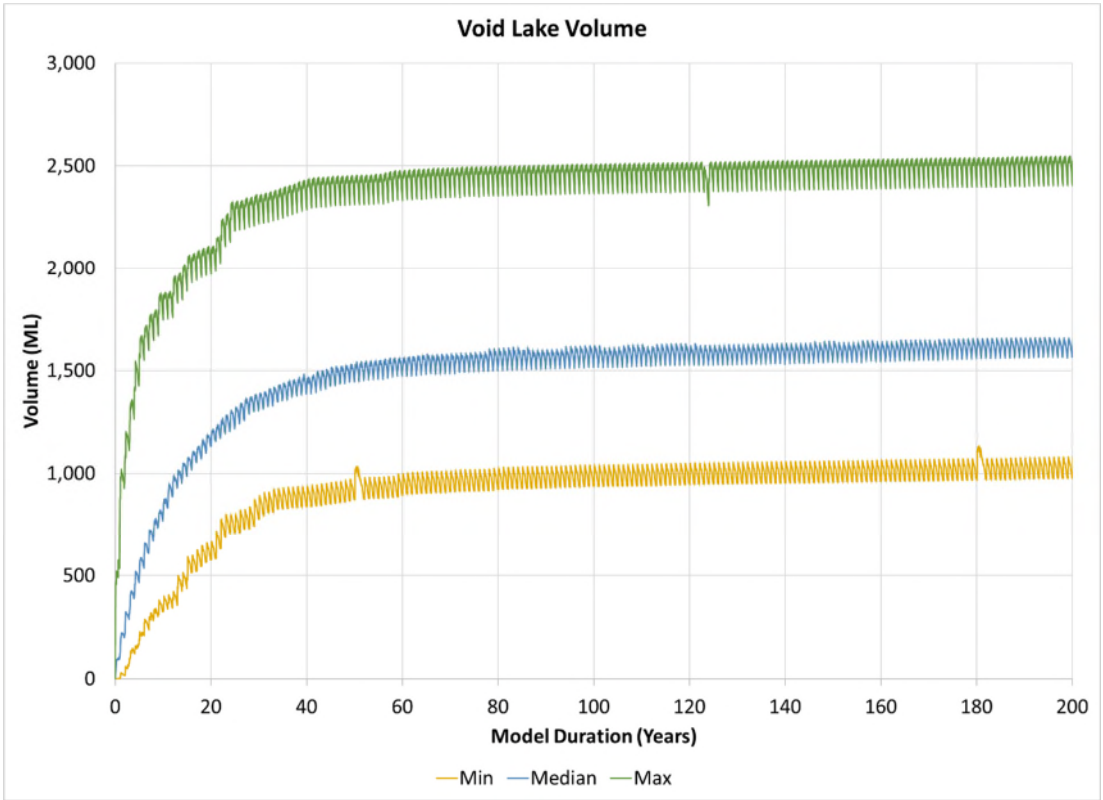
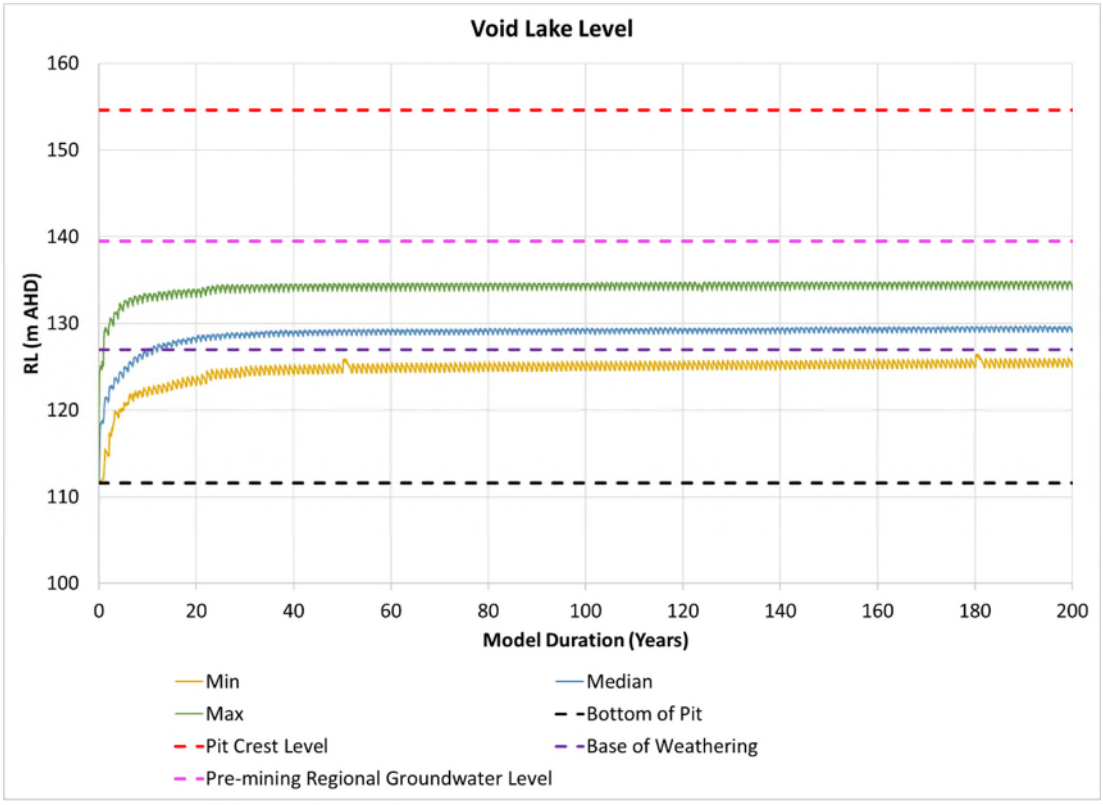


Figure 22 – Drake Pit 2 Expansion final void water volume and level (base case)

Central 3 (Drake Pit 4 North) Mitigated Case – Engeny (2020)



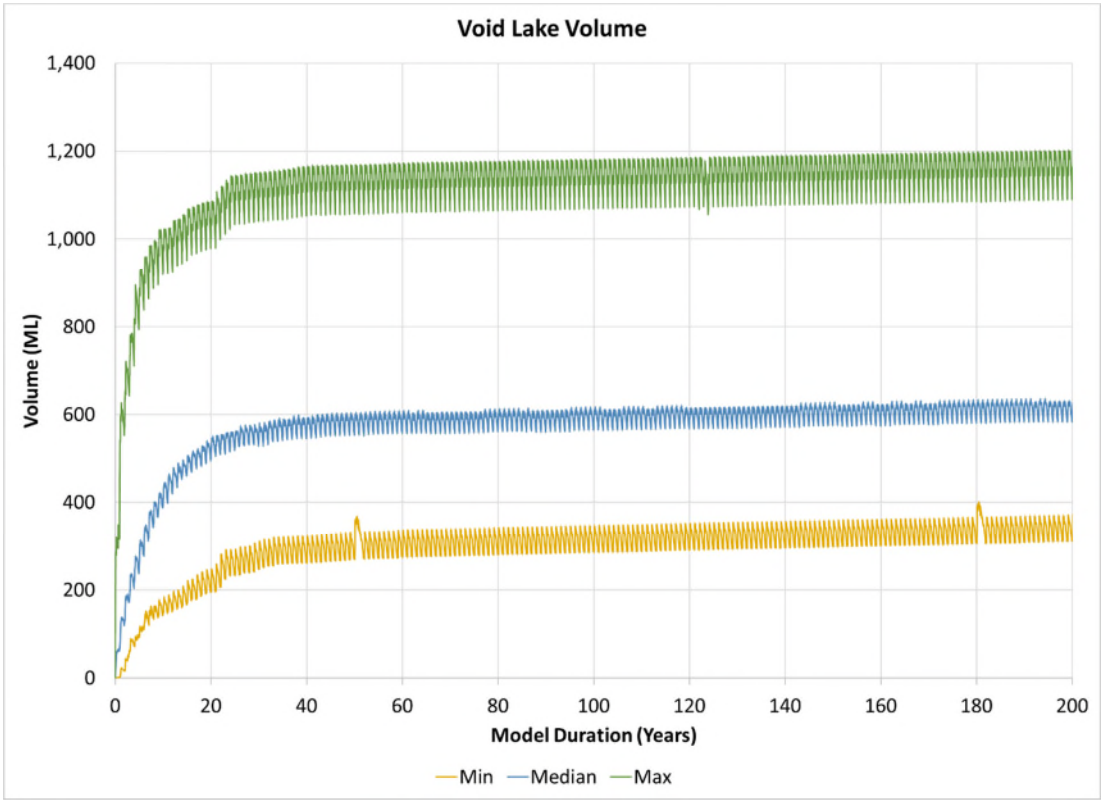
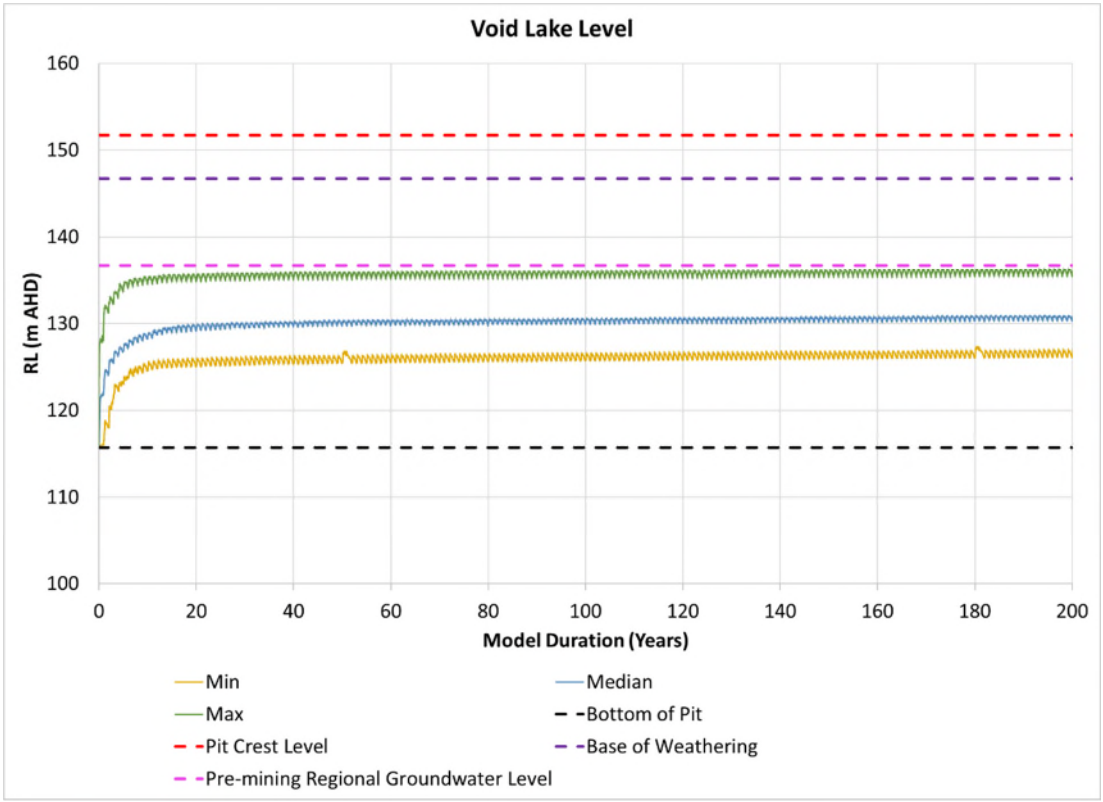


Figure 23 – Central 3 (Drake Pit 4 North) final void water volume and level (mitigated case)

Central 4 (Drake Pit 4 South) – Engeny (2020)



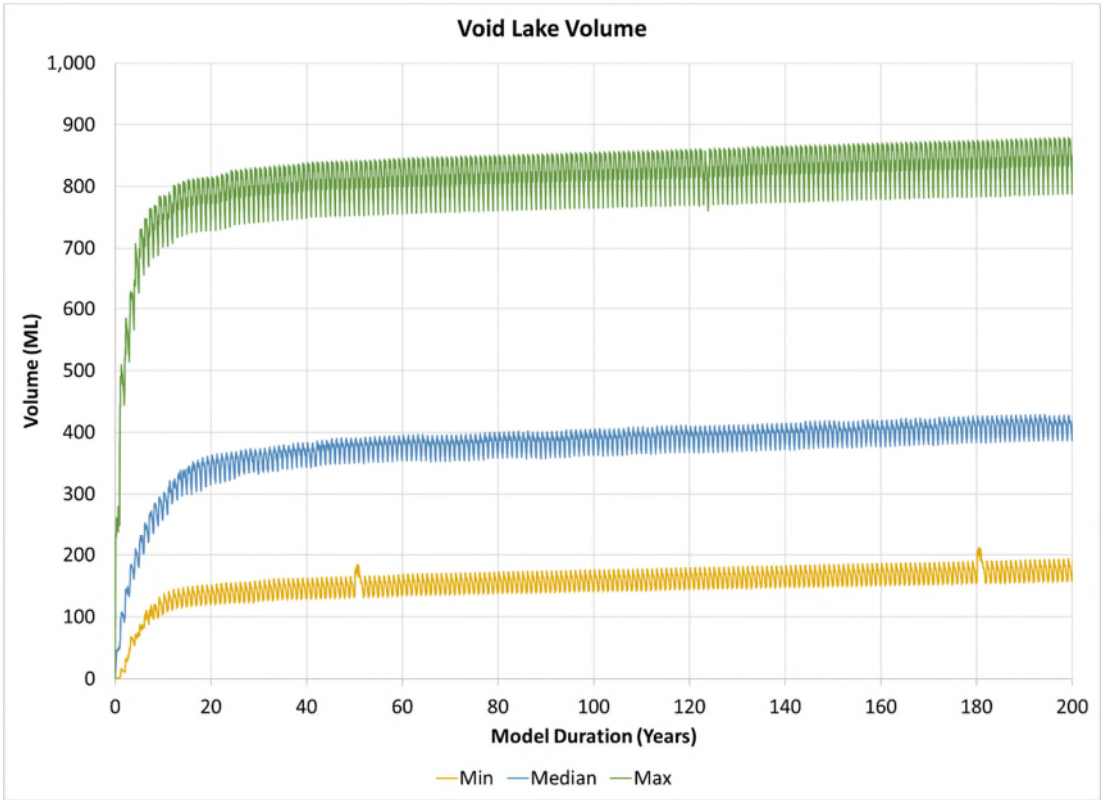
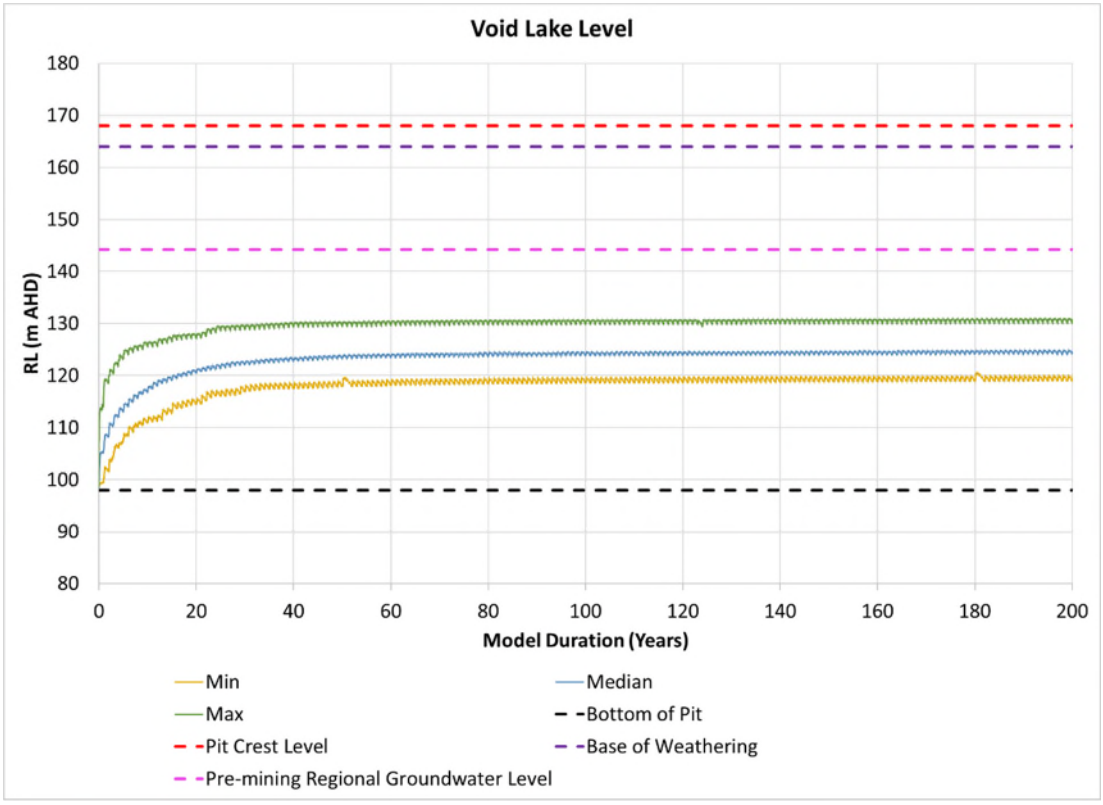


Figure 24 – Central 4 (Drake Pit 4 South) final void water volume and level (base case)

Drake 3Q Pit – Engeny (2020)



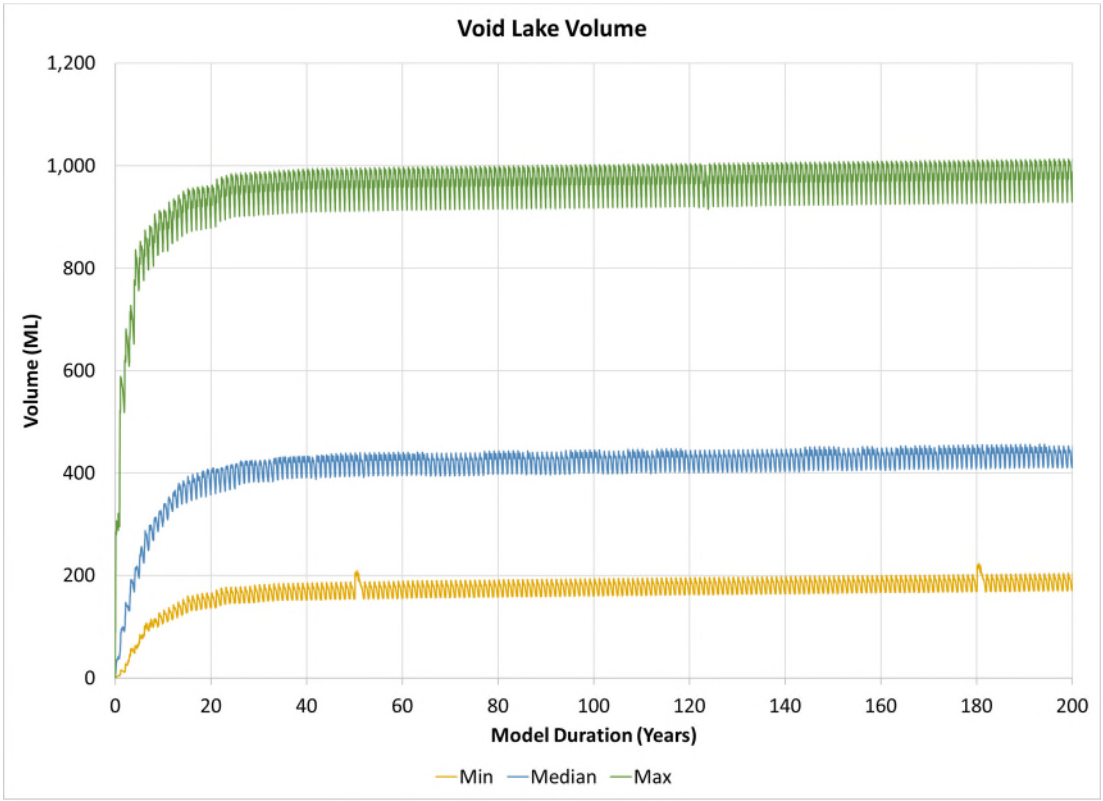
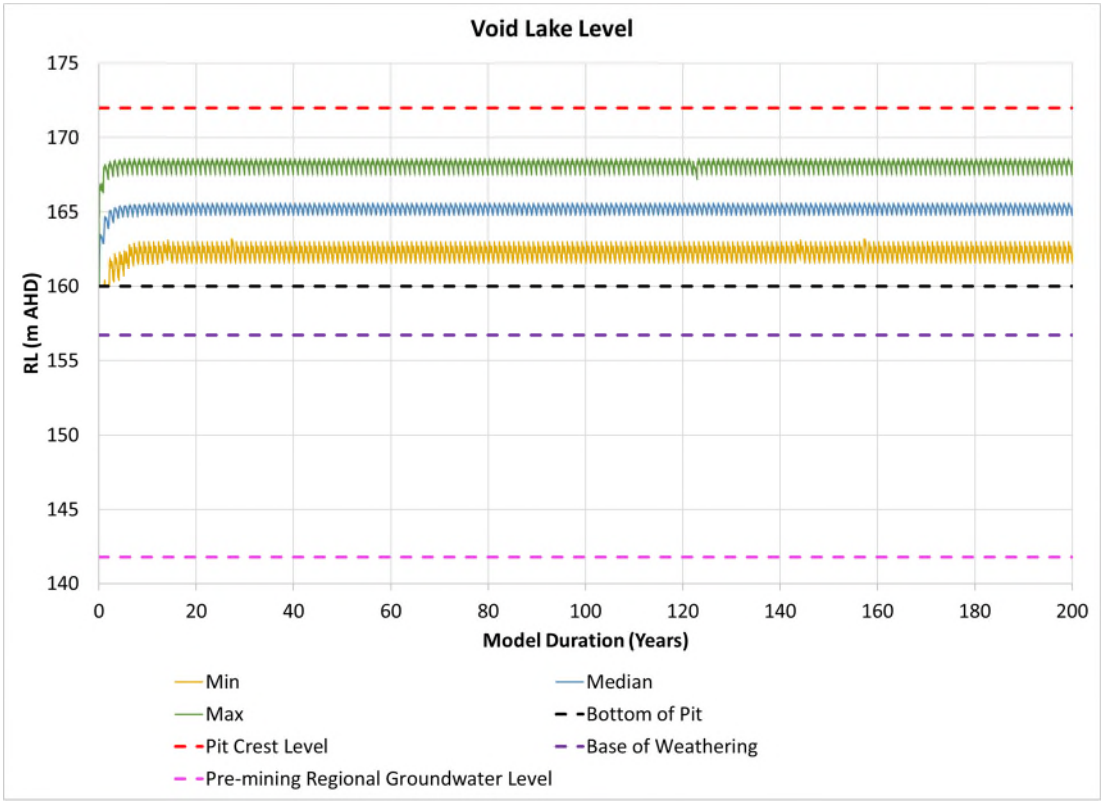


Figure 25 – Drake 3Q Pit final void water volume and level (base case)

Drake 3R Pit – Engeny (2020)



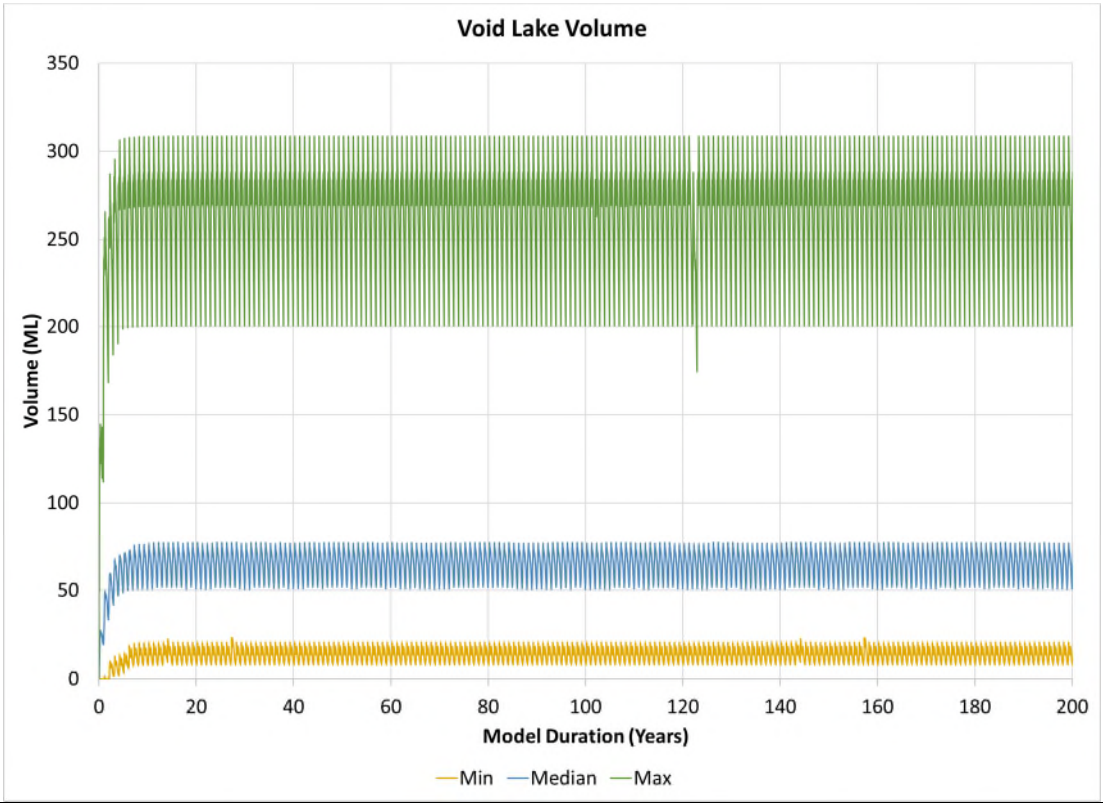


Figure 26 – Drake 3R Pit final void water volume and level (base case)

The time for the void lakes to reach their equilibrium levels varies based on the ratio of catchment area to void volume. The shortest filling time is seen to be Sonoma Main Pit (5 years) while the longest is Jax Main Pit (80 years). A summary of the results for level is provided for each final void (adapted from Engeny (2020)):

- Jax Main Pit – Using the catchment layout for the LOMP (the base case) the void lake equilibrium level (110 m AHD) and maximum void lake level (118 m AHD) are 30.8-30 m and 22.8-22 m below the pre-mining regional groundwater level (140.8-140 m AHD) respectively. Therefore, the residual void is forecast to act as a sink as per Engeny (2018).
    - For comparison, a potential mitigated scenario was also modelled for a reduced catchment. The mitigated void lake equilibrium level (98 m AHD) and maximum void lake level (105 m AHD) are 42.8-42 m below and 35.8-35 m below the pre-mining regional groundwater level (140.8-140 m AHD) respectively.
- Jax East Pit – The void lake equilibrium level (104 m AHD) and maximum void lake level (112 m AHD) are 31.2-23.2 m and 36-28 m below the pre-mining regional groundwater level (135.2-140 m AHD) respectively. Therefore, the residual void is forecast to act as a sink. Therefore, the residual void is forecast to act as a sink as per Engeny (2018).
    - For comparison, a potential mitigated scenario was also modelled for a reduced catchment. The mitigated void lake equilibrium level (103 m AHD) and maximum void lake level (110 m AHD) are 32.2-25.2 m below and 37-30 m below the pre-mining regional groundwater level (135.2-140 m AHD) respectively.
- Sonoma Main Pit - The void lake equilibrium level (130 m AHD) and maximum void lake level (134 m AHD) are 25.7 m and 21.7 m below the pre-mining regional groundwater level (155.67 m AHD) respectively. These outcomes are based on the design landform surface at year 20. It is expected the final co-disposal surface will be as much as 20m higher than this level. The conservative addition of a further 20 vertical metres of rejects material can be expected to result in an equilibrium level of 150 mAHD and a maximum level of 154 mAHD which remain below the regional groundwater level.
    - As such, the Sonoma Main Pit is expected to act as a groundwater sink; however, as it will be subject to in-pit co-disposal of rejects, it will behave differently to the other voids modelled and further consideration is recommended in the detailed mine planning for this void based on the in-pit co-disposal plan.
    - In addition, due the placement of rejects material within the void, the Sonoma Main Pit residual void geometry included a large predominantly flat surface. The void is forecast to behave as an evaporation pan and therefore periodically dries out to very minimal volumes.
- Sonoma East Pit 1 - The void lake equilibrium level (158 m AHD) and maximum void lake level (164 m AHD) are 1.7 m and 7.7 m above the pre-mining regional groundwater level (156.30 m AHD) respectively. The residual void is forecast to have ongoing net outflows to the local geology.
    - The Sonoma East Pit 1 void lake level is forecast to result in a hydraulic gradient out of the void into the surrounding geology (a net outflow). However, as concluded during the numerical groundwater modelling (**Section 6.2**) any outflow from this void will be intercepted by the larger and

deeper voids. In the case of Sonoma Main Pit, Sonoma East Pit 1 and Sonoma East Pit, the numerical groundwater modelling concludes the that groundwater in this complex of pits is fully contained with some amount of inter void movement, predicted to be minor considering the small differential in height of 1.7m.

- Sonoma East Pit 2 - The void lake equilibrium level (154 m AHD) and maximum void lake level (161 m AHD) are 1.5 m below and 5.5 m above the pre-mining regional groundwater level (155.53m AHD) respectively. The residual void is forecast to have ongoing net outflows to the local geology or regional groundwater.
    - The Sonoma East Pit 2 void lake level is forecast to result in a hydraulic gradient out of the void into the surrounding geology (a net outflow). However, as concluded during the numerical groundwater modelling (**Section 6.2**) any outflow from this void will be intercepted by the larger and deeper voids. In the case of Sonoma Main Pit, Sonoma East Pit 1 and Sonoma East Pit, the numerical groundwater modelling concludes the that groundwater in this complex of pits is fully contained with some amount of inter void movement, predicted to be minor considering the small differential in height of 1.5m.
- Drake Pit 5 - The void lake equilibrium level (111 m AHD) and maximum void lake level (119 m AHD) are 26.4 m and 18.4 m below the pre-mining regional groundwater level (137.42 m AHD) respectively. Therefore, the residual void is forecast to act as a sink.
- Drake Pit 1 - The void lake equilibrium level (126 m AHD) and maximum void lake level (134 m AHD) are 20.6 m and 12.6 m below the pre-mining regional groundwater level (146.57 m AHD) respectively. Therefore, the residual void is forecast to act as a sink.
- Drake Pit 2 - The void lake equilibrium level (139 m AHD) and maximum void lake level (145 m AHD) are 8.2 m and 2 m below the pre-mining regional groundwater level (147.23 m AHD) respectively. Therefore, the residual void is forecast to act as a sink.
- Drake Pit 2 Expansion - The void lake equilibrium level (124 m AHD) and maximum void lake level (131 m AHD) are 20.2 m and 13.2 m below the pre-mining regional groundwater level (144.24 m AHD) respectively. Therefore, the residual void is forecast to act as a sink.
- Central 3 (Drake Pit 4 North) – The LOMP is not optimised to consider catchment reduction or completed to a level of detail sufficient to consider specific drainage solutions. As such, a review of catchment reduction options was undertaken which resulted in reduced catchment reporting to the Central 3 (Drake 4 North) final void, which is referred to as the mitigated case and has been assumed as the preferred catchment layout for this void. The mitigated void lake equilibrium level (125 m AHD) and maximum void lake level (130 m AHD) are 14.5 m below and 9.5 m below the pre-mining regional groundwater level (139.50 m AHD) respectively. Therefore, based on the primary indicator of void lake and groundwater interaction, the mitigated residual void is forecast to act as a sink.
- Central 4 (Drake Pit 4 South) - The void lake equilibrium level (131 m AHD) and maximum void lake level (136 m AHD) are 5.7 m and 0.7 m below the pre-mining regional groundwater level (136.71 m AHD) respectively. Therefore, the residual void is forecast to act as a sink.

- Drake Pit 3Q - The void lake equilibrium level (150 m AHD) and maximum void lake level (157 m AHD) are 7.5 m and 14.5 m above the pre-mining regional groundwater level (142.55 m AHD) respectively. Therefore, the residual void is forecast to have ongoing net outflows to the local geology or regional groundwater.
    - The Drake Pit 3Q void lake level is forecast to result in a hydraulic gradient out of the void into the surrounding geology (a net outflow). However, as concluded during the numerical groundwater modelling (**Section 6.2**) any outflow from this void will be intercepted by the larger and deeper voids (in the case of Drake 3Q primarily to Jax Main Pit which is a groundwater sink) and will not migrate away from the site.
- Drake Pit 3R - The void lake equilibrium level (165 m AHD) and maximum void lake level (169 m AHD) are 23.2 m and 27.2 m above the pre-mining regional groundwater level (141.78 m AHD) respectively. Therefore, the residual void is forecast to have ongoing net outflows to the local geology or regional groundwater
    - The Drake Pit 3R void lake level is forecast to result in a hydraulic gradient out of the void into the surrounding geology (a net outflow). However, as concluded during the numerical groundwater modelling (**Section 6.2**) any outflow from this void will be intercepted by the larger and deeper voids (in the case of Drake 3R primarily to Jax Main Pit which is a groundwater sink) and will not migrate away from the site.

8.2 Final void lake quality

The final void lake water quality modelling (including sensitivity analysis) for the Jax Main Pit and Jax East Pit final voids, is described and plotted in detail in Engeny (2108) and the Engeny (2018) Supplementary Memo, provided as **Appendix A**.

The final void lake water quality modelling for all other QNH final voids is described and plotted in detail in Engeny (2020), provided as **Appendix B**.

Results extracted from the above are presented in **Figure 28**-

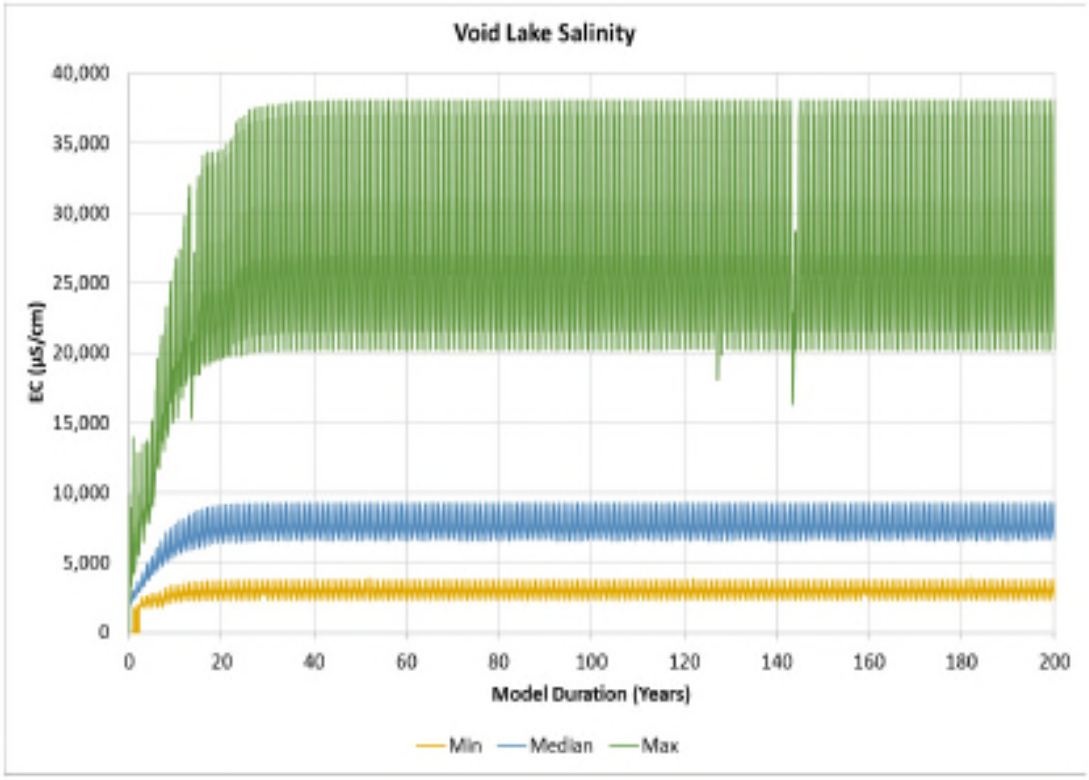


Figure 42, with the following key information presented:

- the simulation period:
    - 500 years for Jax Main Pit and Jax East Pit (presented for the first 100 years and the full 500 year simulation separately for both final voids)
    - 200 years for all other QNH final voids
- minimum, median and max levels and volumes are presented for each day of the simulation period for all final voids;
- the observable oscillations are the normal concentration and dilution cycles associated with normal seasonal and climactic variations;
- the median has been used to define the equilibrium levels in this assessment;
- all results reported in this assessment are from modelling of the “base case” which is the catchment extent provided by the LOMP, except for Central 3 (Drake Pit 4 North), where an opportunity to refine the catchment boundary was identified during the modelling (referred to as the mitigated case). For ease of interpretation only the Central Pit 3 (Drake Pit 4 North) mitigated case is included within the body of this assessment; however Engeny (2020) includes both the base and mitigated cases.

Enegeny (2020) concludes that the salinity of all residual voids modelled as part of this assessment is forecast to continue to increase over time due to the ongoing concentration resulting from evaporation with no significant outflow of salts from either net outflow, seepage or overflow. **It should be noted that pits with net outflow (Section 8.1) were still shown to accumulate salts throughout the model duration**. The reason for this occurrence is that predicted net outflow rates into the surrounding geology at all levels of

rating curves for all pits (**Section 7.2**) were significantly smaller in magnitude that flows associated with rainfall, runoff, and evaporation.

The results indicate significant variation in the EC of the voids as a result of differing pit storage curves and catchment sizes. However, all void lakes are forecast to exceed 10,000 µS/cm after 200 years (with the exception of Jax Main Pit which is closer to 220 years), with some pits reaching 10,000 µS/cm after 40 years. The overall water quality outcome is consistent for all void lakes (i.e. high levels of salinity that continue to increase over time). Ultimately, salts will continue to concentrate with the maximum concentration only limited by the solubility of the constituent salts within the lake. This is conceptually the case for any comparable water body receiving inflow, which experiences evaporation as either the only outflow, or at a rate exceeding all other outflows. As such, the water quality in all QNH voids is predicted to ultimately be unsuitable for any use.

As a comparison, typical guidelines for livestock water quality are presented in **Figure 27**, (note the values are in mg/L for TDS).

Livestock	Total dissolved solids (mg/L)		
	No adverse effects on animals expected	Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production	Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually
Beef cattle	0–4000	4000–5000	5000–10 000
Dairy cattle	0–2500	2500–4000	4000–7000
Sheep	0–5000	5000–10 000	10 000–13 000[b]
Horses	0–4000	4000–6000	6000–7000
Pigs	0–4000	4000–6000	6000–8000
Poultry	0–2000	2000–3000	3000–4000

a From ANZECC (1992), adapted to incorporate more recent information
b Sheep on lush green feed may tolerate up to 13 000 mg/L TDS without loss of condition or production

Figure 27 – Livestock water quality guidelines

Additionally, "*Draft Environmental Values and Water Quality Guidelines for Burdekin Basin and fresh estuarine waters* " (Department of Science, Information Technology and Innovation March 2017) identified a guideline EC for aquatic ecosystems in the Pelican Creek sub-catchment of 1,800 µs/cm.

The water quality forecast for the Sonoma Main Pit residual void exhibits characteristics not evident in other residual voids modelled at QNH in that modelled salinity at 200 years is an order of magnitude higher than any other modelled void. The proposed residual void for Sonoma Main Pit has a large, relatively flat surface produced by the co-disposal of tailings and rejects within the pit. Therefore, any ponding within Sonoma Main Pit is subject to very large evaporation surface areas. The modelled void behaviour is conceptually similar to an evaporation pan, or, as is naturally present in the QNH areas, an ephemeral creek with senescing pools that dry out in the dry season. In those situations, the void lake volume decreases during drying periods, and the remaining water becomes highly saline as the void does not have any mechanisms (net outflow to groundwater or spills) for salt mass reduction.

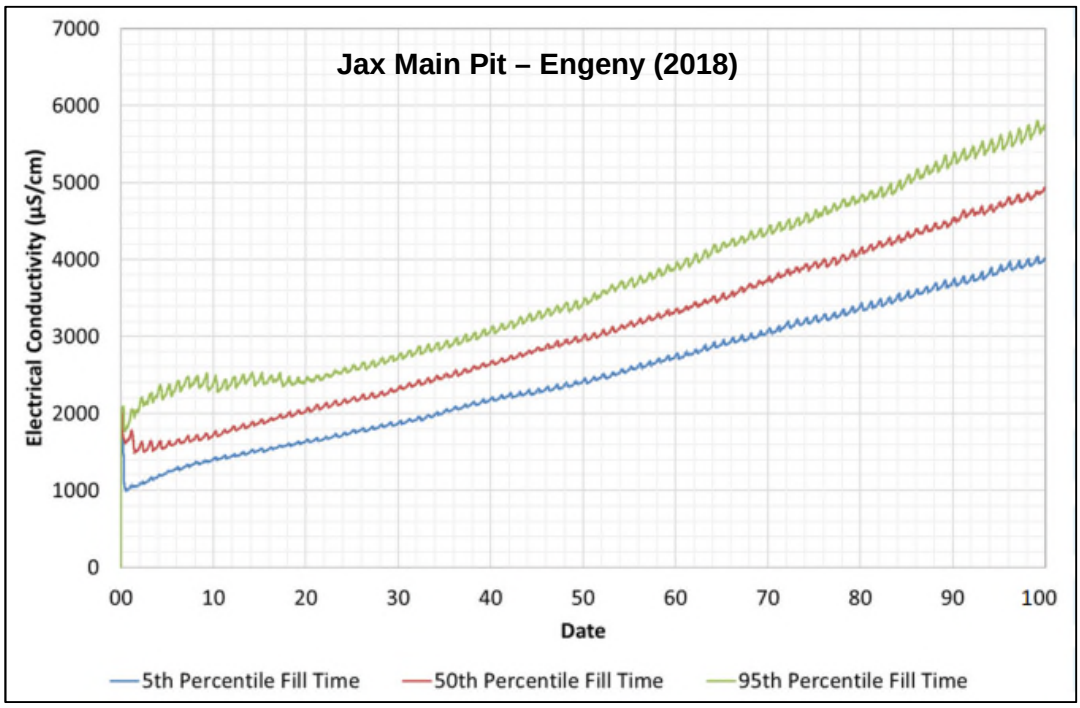


Figure 28 – Jax Main Pit final void lake EC modelling (base case)- 100 years

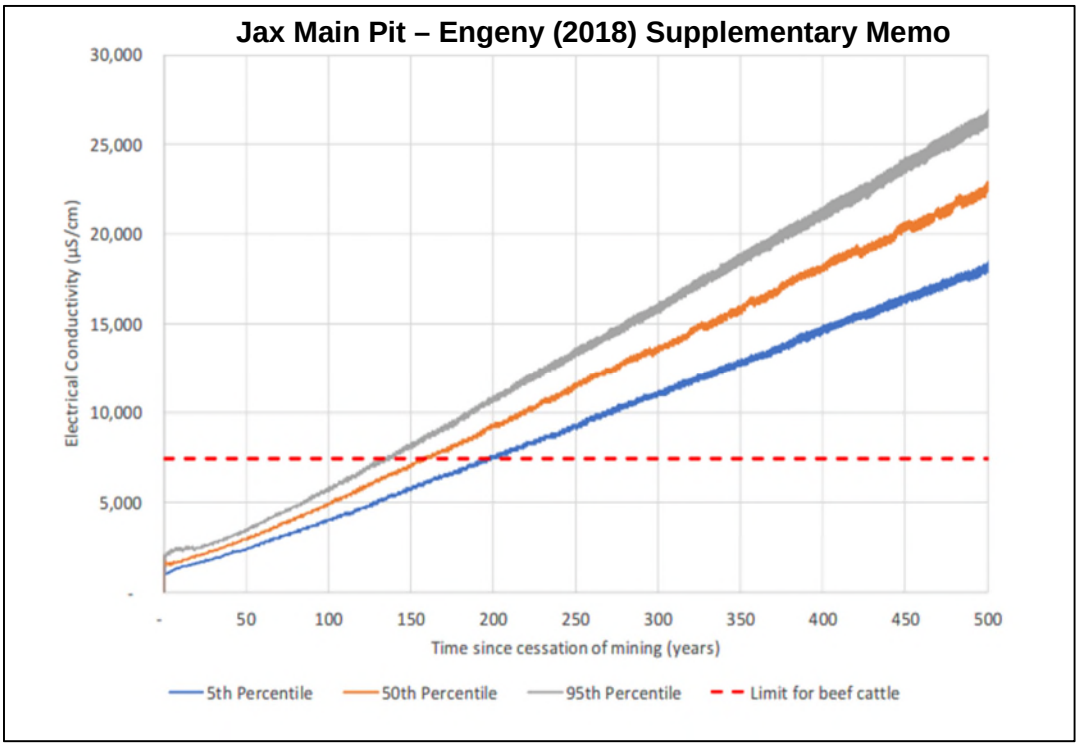


Figure 29 – Jax Main Pit final void lake EC modelling (base case) -500 years

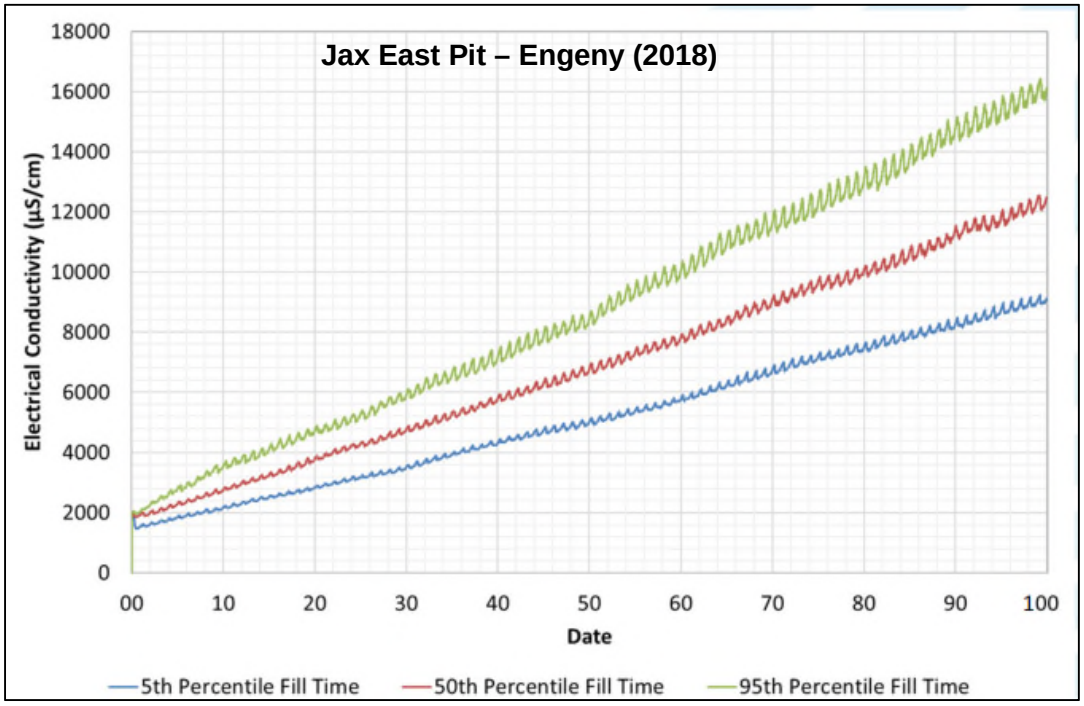


Figure 30 – Jax East Pit final void lake EC modelling (base case) – 100 years

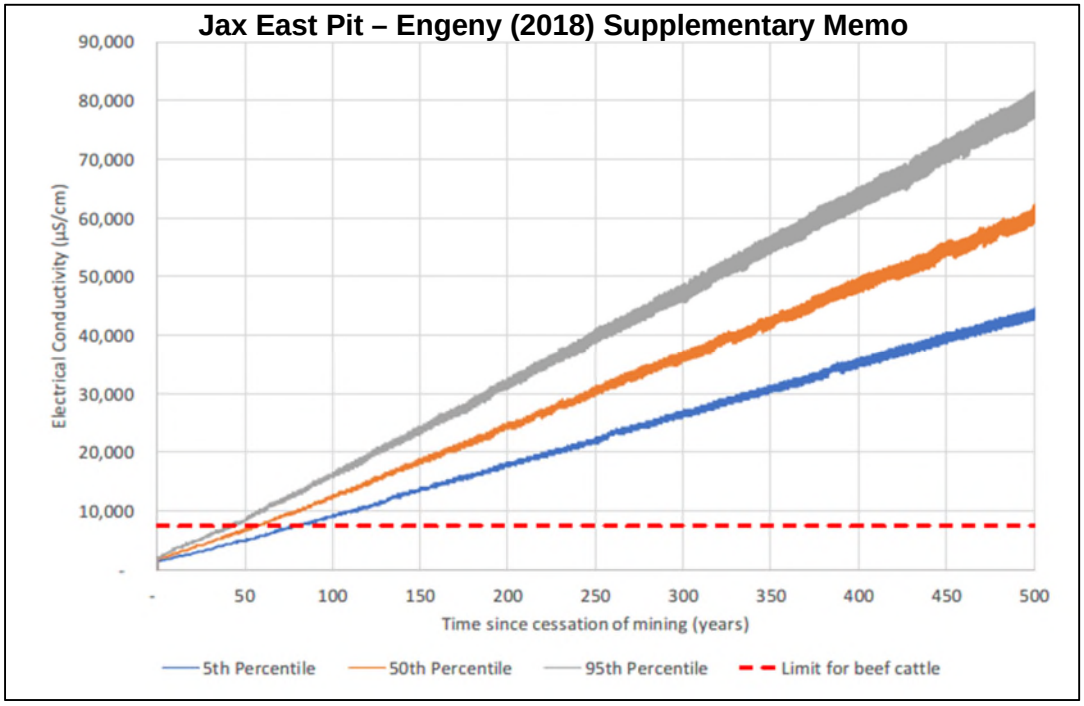


Figure 31 – Jax East Pit final void lake EC modelling (base case) – 500 years

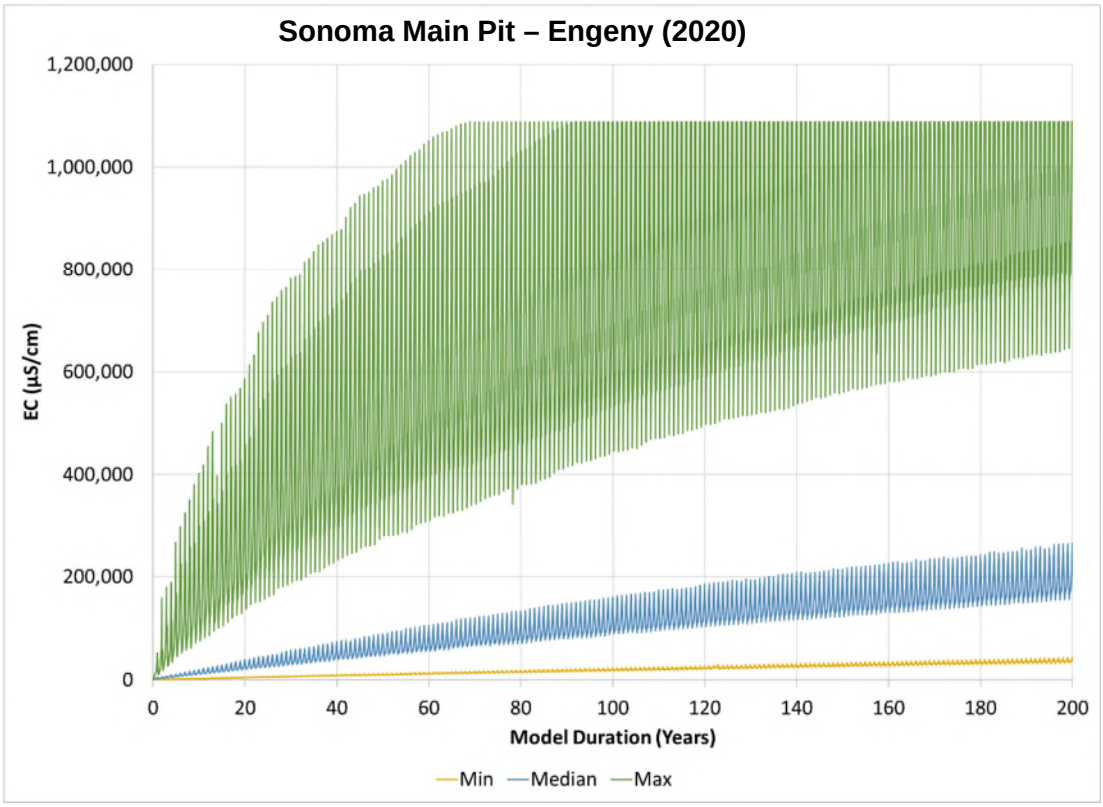


Figure 32 – Sonoma Main Pit final void lake EC modelling (base case)

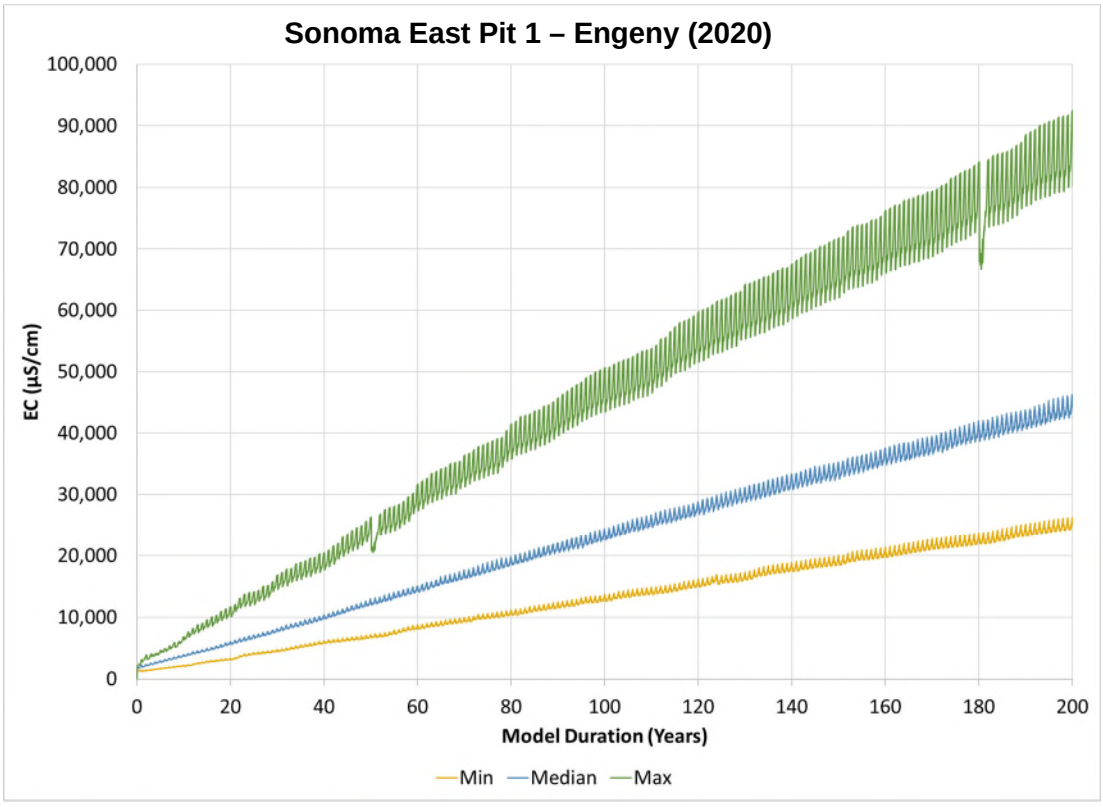


Figure 33 – Sonoma East Pit 1 Pit final void lake EC modelling (base case)

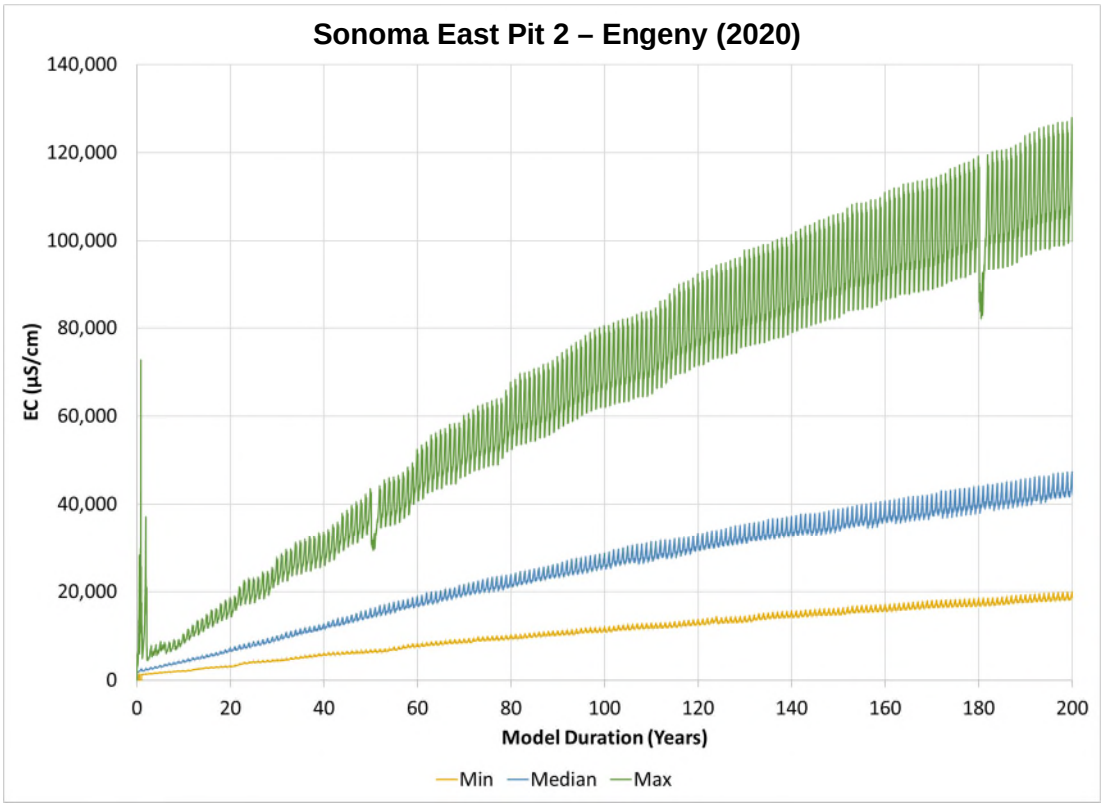


Figure 34 – Sonoma East Pit 2 final void lake EC modelling (base case)

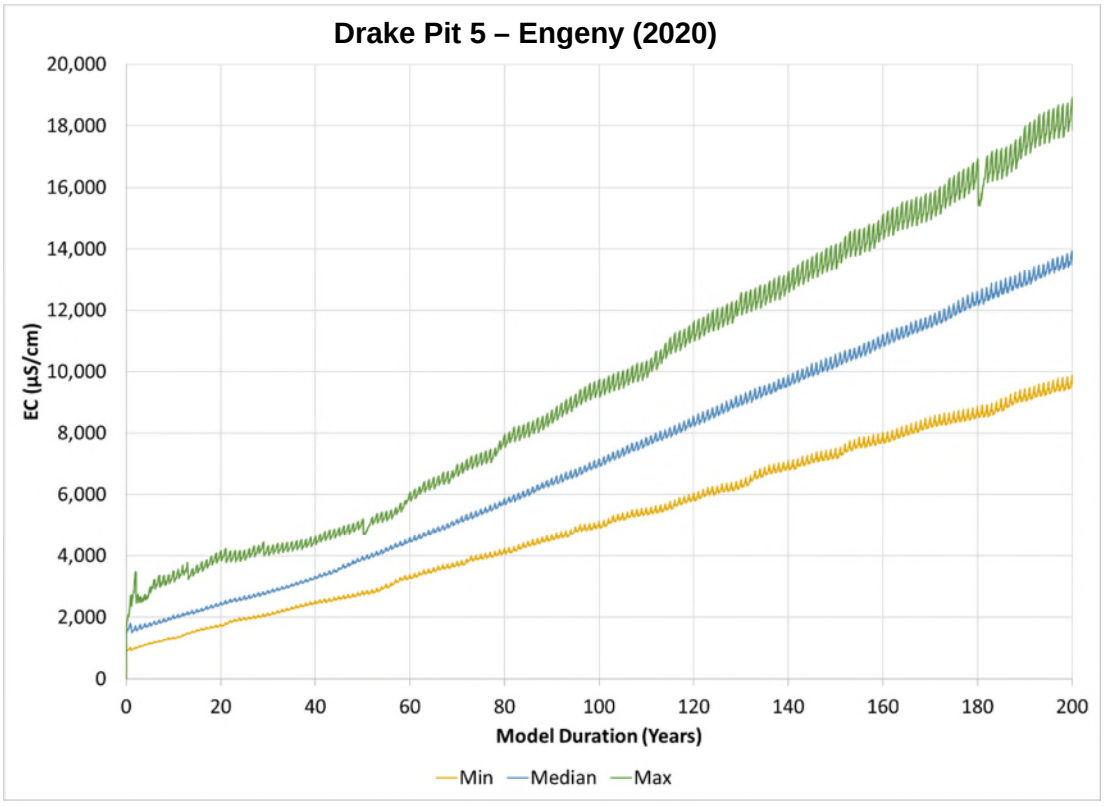


Figure 35 – Drake Pit 5 Pit final void lake EC modelling (base case)

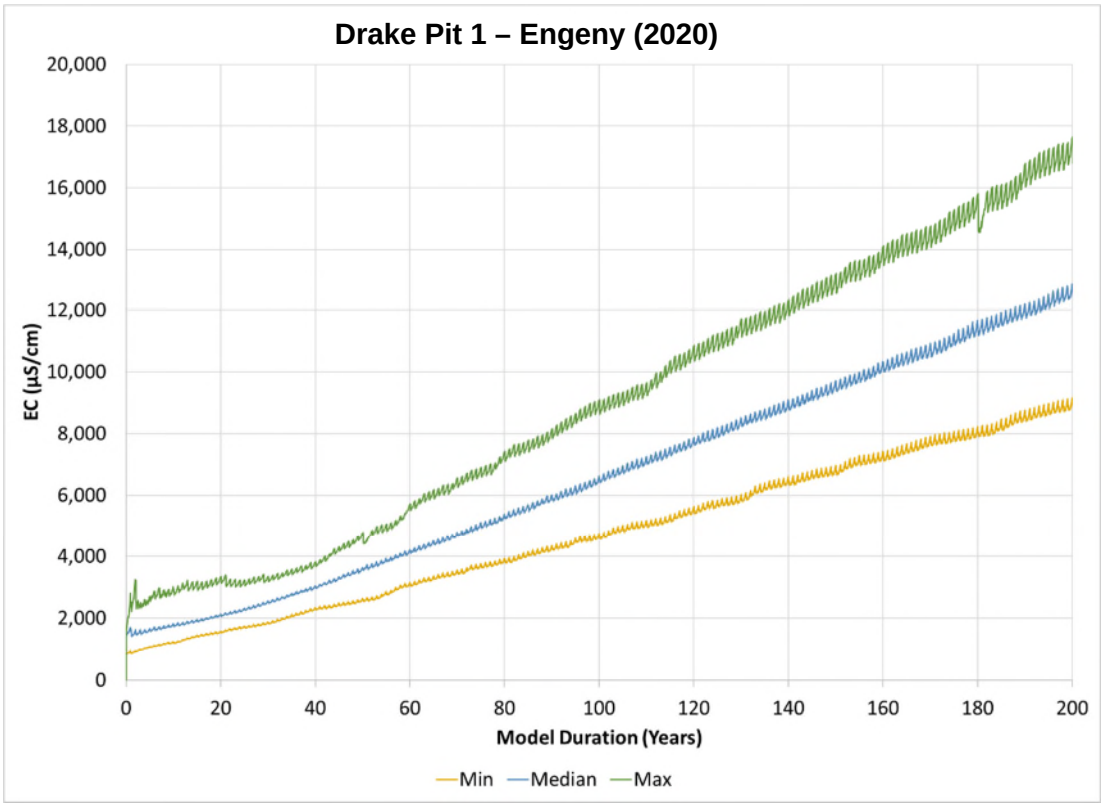


Figure 36 – Drake Pit 1 final void lake EC modelling (base case)

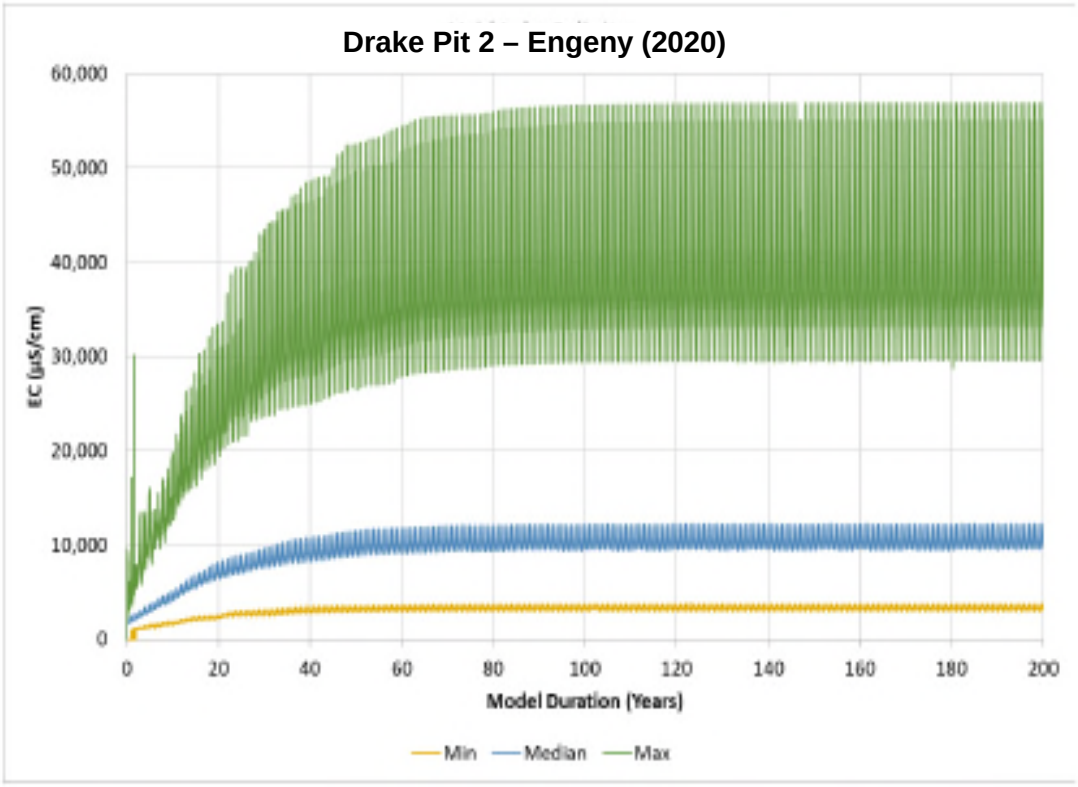


Figure 37 – Drake Pit 2 final void lake EC modelling (base case)

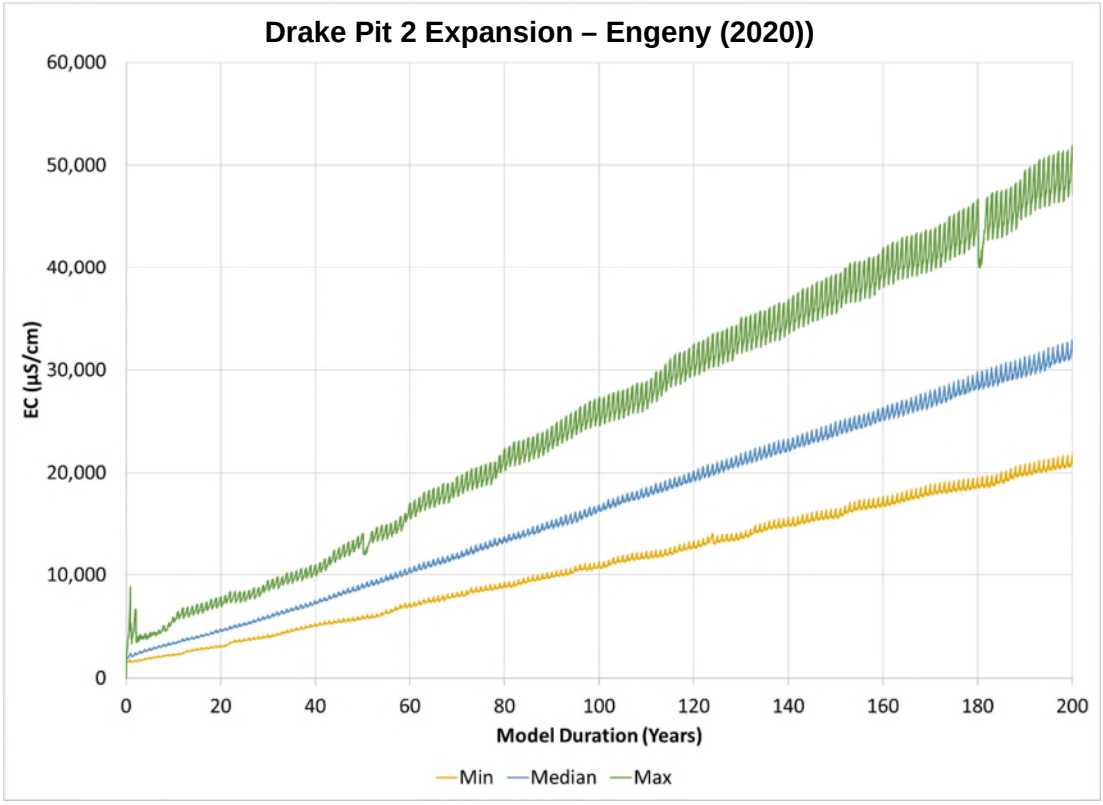


Figure 38 – Drake Pit 2 Expansion final void lake EC modelling (base case)

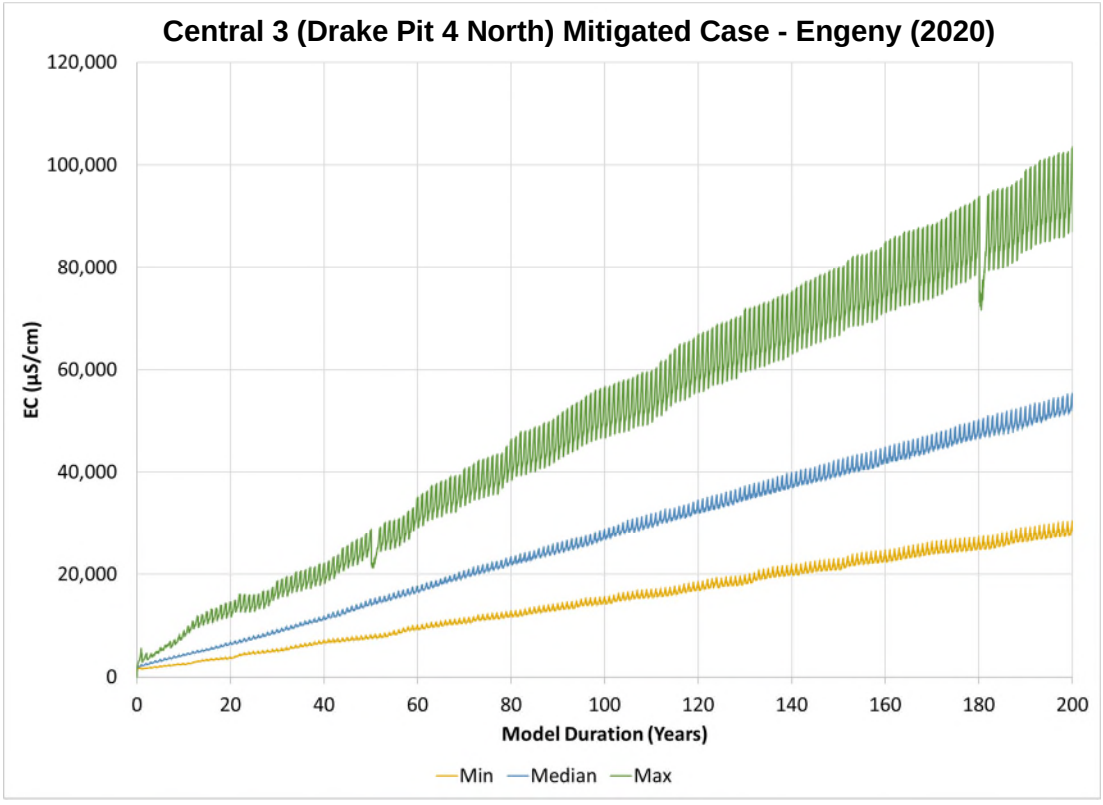


Figure 39 – Central 3 (Drake Pit 4 North) final void lake EC modelling (mitigated case)

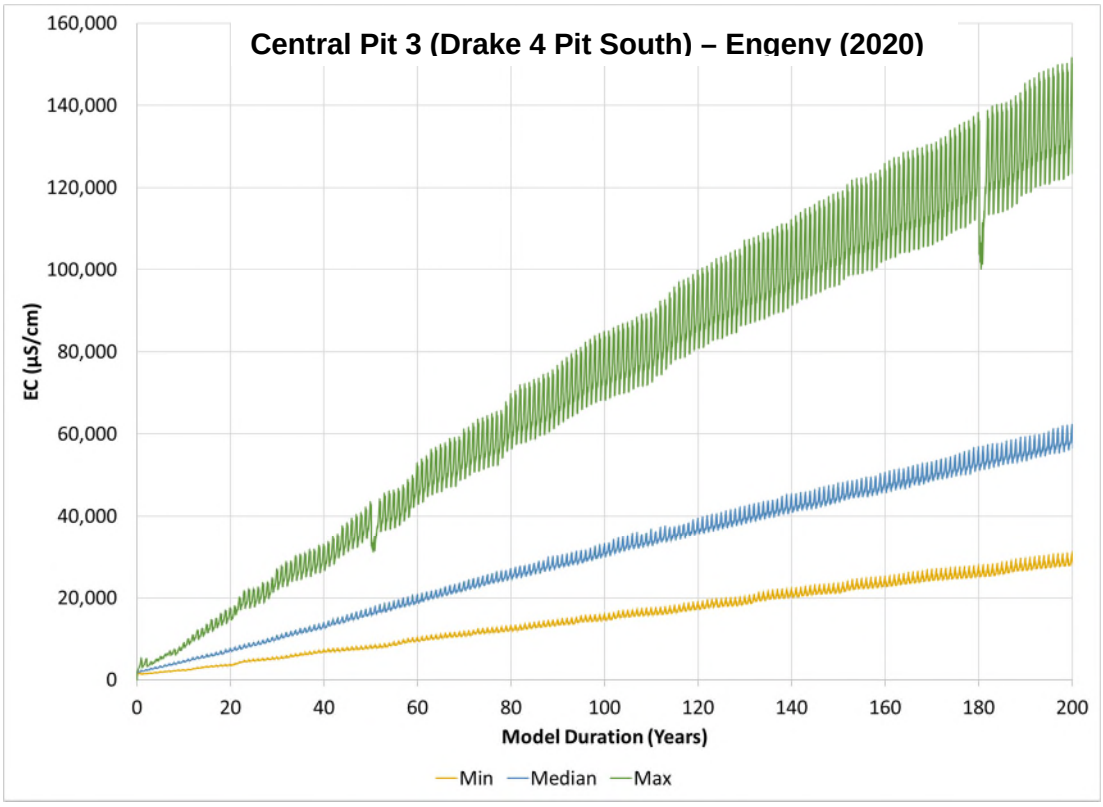


Figure 40 – Central 3 (Drake 4 Pit South) final void lake EC modelling (base case)

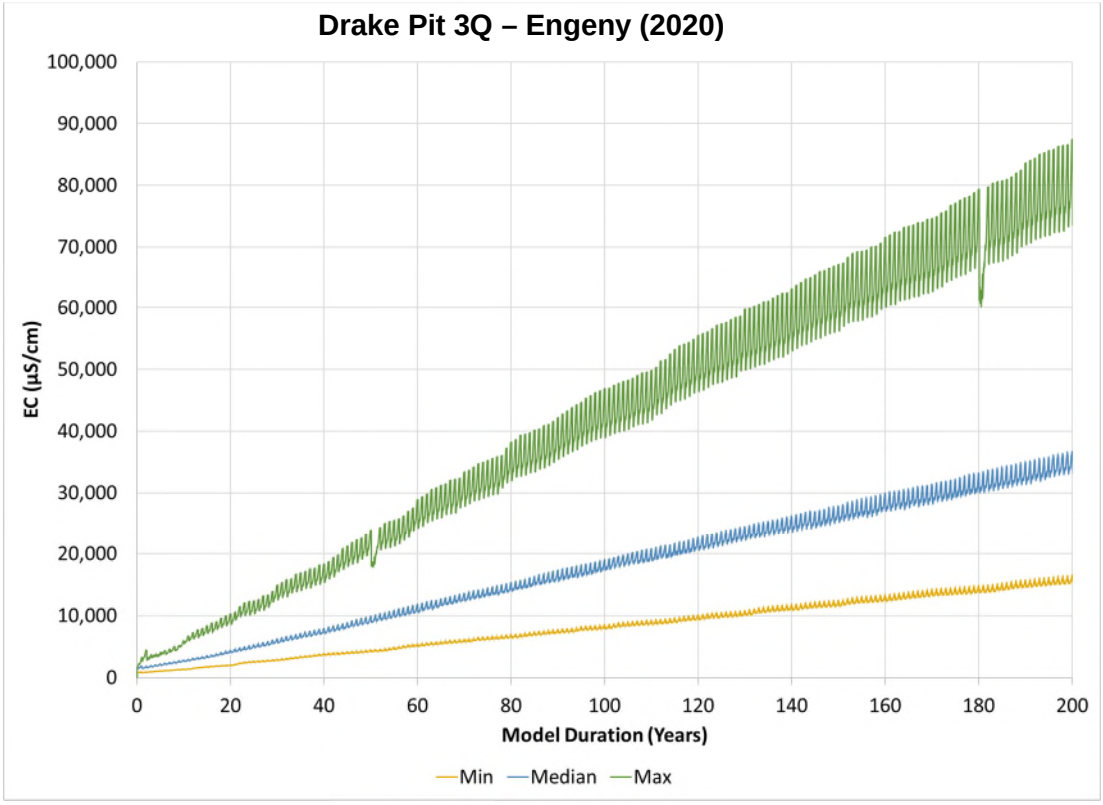


Figure 41 – Drake Pit 3Q final void lake EC modelling (base case)

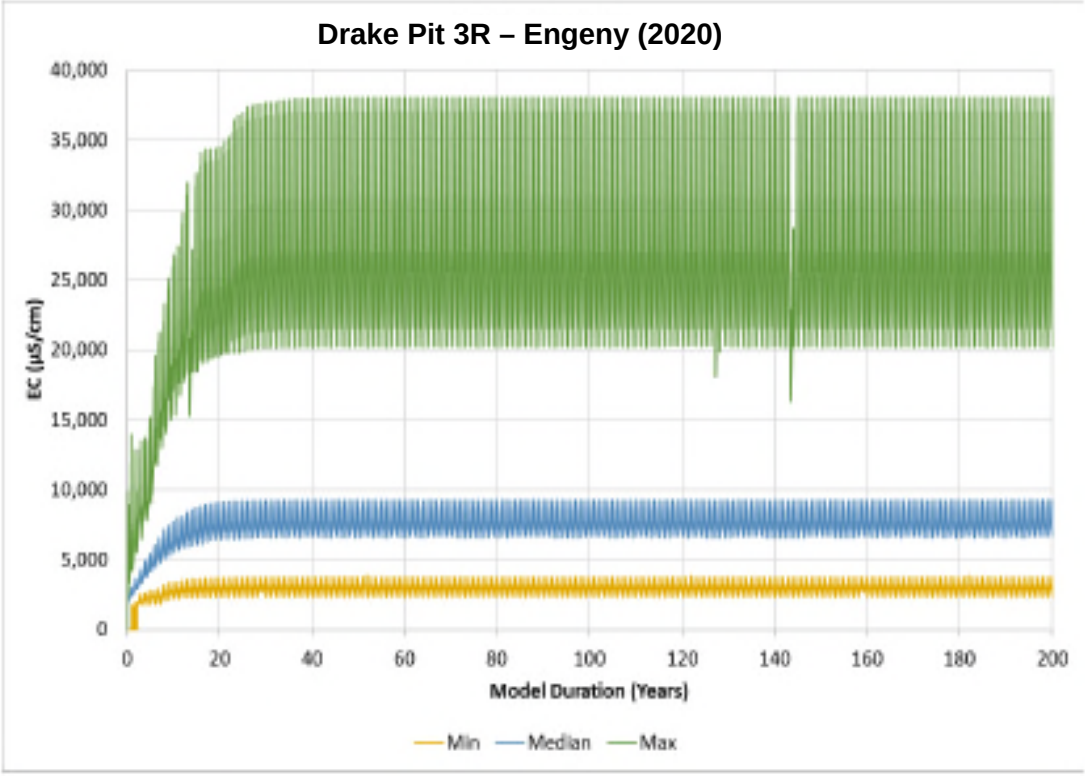


Figure 42 – Drake Pit 3R final void lake EC modelling (base case)

9 Rehabilitation

Since the commencement of operations in the QNH several rehabilitation plans have been implemented and subsequently superseded as the QNH has expanded and rehabilitation conditions within the various QNH EAs have been amended. This section should be read in conjunction with the QNH RMP. Land disturbed by mining and ancillary activities on the QNH is grouped into rehabilitation domains based on areas which require similar rehabilitation requirements and/or levels of environmental risks. Residual voids are referred to as Domain 1 in the QNH RMP. This investigation only considers the rehabilitation of final voids and therefore does not address any other rehabilitation domain.

9.1 Rehabilitation goals

Broad rehabilitation goals for the QNH are defined in **Condition H1** of the QNH EAs., which generally align with the rehabilitation goals summarised in the *Rehabilitation Requirements for Mining Projects* (EHP, 2014). The **Condition H1** rehabilitation goals in all QNH EAs are:

- Safe to humans and wildlife;
- Stable (referring specifically and only to geotechnical stability);
- Non-polluting; and
- Self-sustaining for the post-mining land use of grazing pasture, with the exception of residual voids.

This definition of “stable” for rehabilitated landforms is distinct from the from the definition of “stable condition” in the Environmental Protection Act 1994 (EP Act) Section 111A (applicable to mines under EAs). Section 111A of the EP Act defines a final landform as being in “stable condition” only if it meets all the following conditions:

- safe and structurally stable (i.e. geotechnical wall stability); and
- there is no environmental harm being caused by anything on or in the land; and
- the land can sustain a post-mining land use (i.e. self-sustain a specified use for the landform after rehabilitation).

As such, where a landform does not meet all three of the requirements under Section 111A of the EP Act, it is not considered to be in “stable condition” as per the EP Act definition.

Rehabilitation of final landforms, including voids on the QNH, is therefore undertaken to achieve one of two scenarios:

- rehabilitated to a “stable condition” as per Section 111A of EP Act; or
- rehabilitated to a condition which does not satisfy all the requirements to be considered in “stable condition” as per Section 111A of the EP Act (i.e. the final landform is unable to meet all of the criteria to be considered in “stable condition”):
    - Section 112 of the EP Act defines such landforms as “non-use management areas” (NUMAs) – specifically defining a NUMA as an area of land the subject of a Progressive Rehabilitation and Closure plan (PRC Plan) that cannot be rehabilitated to a “stable condition” after all relevant activities for the PRCP carried out on the land have ended.
    - until such time as the SCM, DCM and JCM transition into the PRC Plan framework, any final landforms which are determined not to be in “stable

condition" under Section 111A will be managed as NUMAs whilst not definitionally be referred to as NUMAs – once transitioned into the PRC Plan framework any such landforms will then also be definitionally referred to as NUMAs.

- **it is noted that as per Condition H1 of the QNH EAs, all rehabilitated landforms (including those managed as NUMAs) must be safe, structurally stable and not cause any environmental harm – otherwise it is a non-compliance with the EA.** As such, where a final landform (including a void) is not considered to be in "stable condition" and is therefore managed as a NUMA, it is due only to the inability of the landform to sustain a post-mining land-use.

9.2 Void outcomes

As stated in **Section 8.2**, the water quality modelling results for final void lake water in all QNH final voids modelled as part of this assessment indicated that the water quality will continue to degrade over time, with solubility being the untlimate limiting factor. The reason for the degradation, as detailed in **Section 8.2**, is that:

- for the voids determined to be groundwater sinks in **Section 8.1**, (namely Jax Main Pit, Jax East Pit, Sonoma Main Pit, Drake Pit 5, Drake Pit 1, Drake Pit 2, Drake Pit 2 Expansion, Central Pit 3 (Drake Pit 4 North), Central Pit 4 (Drake Pit 4 South)), evaporation is the only water loss, and, as such, evaporative concentration of salts from the various inflows occurs over time; and
- for the voids determined to have a mathematical net outflow (**Section 8.1)** into an adjacent final void (**Section 6.2**) in (namely Sonoma East Pit 1, Sonoma East Pit 2, Drake Pit 3-Q and Drake Pit 3-R), the rate of net outflow into the QNH cone of depression was notably less than the evaporation rate and as such evaporative concentration of salts from the various inflows occurs over time.

As further stated in **Section 8.2**, due the degradation of quality over time, resulting from the net evaporative climate of the region, the water quality in all QNH voids will become unsuitable for any human use, agricultural or livestock use, as drinking water or designated habitat for native fauna. The time it takes for quality to reach the levels where it is unsuitable (which differ depending on the acceptable limits for each use) varies between pits; however, in all pits the quality is modelled to continue to degrade beyond acceptable limits for all potential uses identified.

In consideration of those results, it is concluded that none of the QNH final voids can self-sustain a designated post-mining land use, as all potential uses are contingent on having an acceptable level of quality for that use, none of which can be met over time.

As discussed in **Section 9.1**, where a final void is demonstrably unable to sustain a post-mining land use, it does not satisfy the requirement to be considered in "stable condition" under the definition of Section 111A of the EP Act. Accordingly, the QNH final voids modelled in this assessment are recommended to have a void outcome of "residual void unable to sustain a post mining land use".

The Jax Main Pit and Jax East Pit voids already have this void outcome conditioned in the JCM EA, which is consistent with the findings of this assessment and the findings of *"Investigation into Residual Void Jax Coal Mine – QCoal October 2018"* (submitted to DES 12 October 2018), which included the technical study "*Jax Coal Mine Final Void Hydrology Study Main Pit – Engeny Water Management 2018*" (Engeny 2018).

It is also noted that these findings are consistent with the void outcomes previously identified for Sonoma Main Pit in *"Investigation into Residual Void Sonoma Coal Mine – QCoal January 2016"* (submitted to DES 29 January 2016), which included the technical study "*Sonoma Coal Mine Final Void Hydrology Study Main Pit – Engeny Water Management 2015*" (Engeny 2015a).

As also stated in **Section 8.1**, final voids with an outcome of "unable to self-sustain a post mining land use", are required to be rehabilitated to be safe and geotechnically stable condition, and to not cause environmental harm as per conditions of the QNH EAs.

9.3 Safe and structurally stable

9.3.1 Slope designs

As stated in **Section 3**, the QNH comprises a consistent contiguous geology, soils profile and hydrogeology across the four mines. Geotechnical understanding of the QNH pit high-walls and low-walls is based on geotechnical studies undertaken for the SCM (being the first of the QNH mines). The SCM slope designs were derived from the geotechnical study "*QCoal Sonoma Project Initial Geotechnical Assessment*" undertaken by Sherwood Geotechnical and Research Services (Simmons 2006). Simmons (2006) provided the following summary (detailed therein) for the slope design:

- Alluvium: 37° overall
- Weathered coal measures rock: 45° overall
- Fresh coal measures rock: 70° overall separated by benches to suit drilling and high wall ramp/road requirements
- Benching: a minimum 10m bench at the base of alluvium or weathered coal measures (i.e. top of "hard" digging)
- Excavated faces in-pit spoil: 37° overall, 45° to max height of 15m above floor
- Dumped spoil (alluvium and coal measures): rill angle 37°, max. height of rill slope 30m normally, separated by benches to suit operational requirements
- Ex-pit dump toe setback to pit crest: not less than 20m under any conditions until in-pit spoil dump has been developed.

The above slope design targets were further investigated by consultant GHD in "*Sonoma Mine Management Residual Void Outcome of Sonoma Mine July 2010"* (GHD 2010), which provided acceptance criteria for slope rehabilitation to meet the recommended design.

The slope requirements for final voids are conditioned in the QNH EAs, as discussed in **Section 5.2**, and are presented again in **Table 8**.

The QNH EAs conditions for slopes on the low and high-walls in voids are informed by the aforementioned geotechnical assessments.

Table 8 – QNH EA void slope criteria

Site	QNH Operational Complex	Void Name	Approved High Wall Slope	Approved Low Wall Slope
Jax	Jax	Jax Main Pit	High wall – 60°	Low wall – 32°
		Jax East Pit		
Sonoma	Sonoma	Sonoma Main Pit	High wall – Maximum slope of 70° with the top 10m having a maximum of 45° including a 1m bund	Low wall – 17°-37°
		Sonoma East Pit 1		
		Sonoma East Pit 2		
Drake	Drake 5	Drake Pit 5	High wall – 65°	Low wall – 45°
	Drake 1-2	Drake Pit 1		
		Drake Pit 2		
		Drake Pit 2 Expansion		
		East Pit 1		
	Drake 3-4	Central Pit 3 (Drake Pit 4 North)		
		Central Pit 4 (Drake Pit 4 South)		
		Drake Pit 3-Q		
		Drake Pit 3-R		

Further to the above, quarterly geotechnical inspections across the QNH operational pits have been undertaken by GeoTek Solutions (GeoTek) under the supervision of an RPEQ, with reports submitted after each inspection. The objective of those inspections and reports is to monitor, assess and provide ongoing operational recommendations on the geotechnical stability of the major landforms across the QNH, including slopes, drainage, loose materials etc. Inspections provide actual geotechnical observations of active pits in the same material which will comprise final void walls and which are therefore directly applicable to likely final void conditions. A list of the RPEQ geotechnical quarterly inspection reports for the last five years are listed as follows:

- Geotechnical Inspection of QCNH, 21-22 Apr 2015 (GeoTek Solutions 26/4/15);
- Geotechnical Inspection of QCNH, 23-24 Aug 2015 (GeoTek Solutions 29/4/15);
- Geotechnical Inspection of QCNH, 10-13 Nov 2015 (GeoTek Solutions 21/11/15);
- Geotechnical Inspection of QCNH, 15-17 Feb 2016 (GeoTek Solutions 28/2/16);
- Geotechnical Inspection of QCNH, 8-10 Nov 2016 (GeoTek Solutions 3/12/16);
- Geotechnical Inspection of QCNH, 13-15 Feb 2017 (GeoTek Solutions 16/2/17);
- Geotechnical Inspection of QCNH, 22-24 May 2017 (GeoTek Solutions 26/6/17);
- Geotechnical Inspection of QCNH, 14-16 Aug 2017 (GeoTek Solutions 20/8/17);
- Geotechnical Inspection of QCNH, 13-14 Nov 2017 (GeoTek Solutions 4/12/17);
- Geotechnical Inspection of QCNH, 2-3 Mar 2018 (GeoTek Solutions 9/3/18); and
- Geotechnical Inspection of QCNH, 8-9 Aug 2018 (GeoTek Solutions 27/8/18).
- Geotechnical Inspection of QCNH, 30 Nov-1 Dec 2018 (GeoTek Solutions 22/12/18);
- Geotechnical Inspection of QCNH, 5-6 Apr 2019 (GeoTek Solutions 11/6/19);
- Geotechnical Inspection of QCNH, 3-4 Oct 2019 (GeoTek Solutions 28/11/19); and
- Geotechnical Inspection of QCNH, 10-11 Jan 2020 (GeoTek Solutions 23/3/2020).

These inspections directly inform the geotechnical condition of walls in all pits, refer to original design slopes recommended in Simmons (2006), and inform ongoing and regular assessment of the suitability of final void approved design slopes.

As such, and in addition to regular geotechnical inspections, GeoTek Solutions has periodically undertaken assessment of, and made specific recommendations relating to, the wall design slopes across the QNH. These periodic assessments are undertaken as pits develop and walls become exposed and available for actual geotechnical observation. For example, the report "Compilation of Current Pit Slope Design Recommendations Ver 5 30/08/16" (GeoTeck Solutions 30/8/16). was undertaken on pit slope designs for all QNH pits and determined that no notable changes were required to the existing approved design slopes.

Subsequent and future inspections may make recommendations based on updated and new observations. If such recommendations make suggestions that a revision to the approved EA final void design slopes for a specific EA is required (i.e. the maximum slope is recommended to be reduced), then EA amendments would be made accordingly.

QNH final void detailed designs will be subject to RPEQ review.

9.3.2 Erosion and weathering

This section addresses the potential erosion and weathering of the void walls. Specific geochemical studies completed for the SCM are directly applicable to the broader QNH (as per **Section 3**), and it is noted that the JCM ML was approved by the Queensland Government, relying on SCM waste rock investigations being directly applicable to the JCM. Key geochemical studies are listed below:

- *"Sonoma Coal Project – Overburden assessment report May 2006"*, (Parsons Brinckerhoff 2006).
- "*Geochemical Assessment of Mining Waste and Coal Reject Materials Sonoma Coal Mine – Dec 2012*" (Terrenus 2012)
- "*Mining waste and coal reject management plan Ver 1: Jan 2013*" (Terrenus 2013)

Parsons Brinkerhoff (2006) described the tertiary/quaternary material in the SCM and CCM areas, making a determination that the materials were consistent from the SCM into the CCM, indicating continuity of the soils and geology from north to south (as per **Section 3**). Parsons Brinkerhoff (2006) made the following comments on tertiary/quarternary material:

- slightly alkaline (pH 7.8 – 8.6);
- low to moderate salinity/EC (EC 200 – 700 ms/cm);
- ESP <15% (<5% is non-dispersive);
- Emerson class results of 4-6 (5-6 is considered non-dispersive);
- dispersivity index 2-6% (<30% is non-dispersive); and
- suitable for capping.

Terrenus (2012) and (2013) provide geochemical comment for the SCM factoring in operational pit data and pit wall observations. Of note are the findings relating to dispersion of the wall material (reported as overburden and interburden). Soil dispersion is the loss of cohesion and the breaking down of soil structures into soil particles, making spoils susceptible to erosion or loss of geotechnical competence.

The following relevant conclusions have been extracted from Terrenus (2012) and (2013) regarding the potential for erosion of the overburden and interburden of the SCM as applicable to the QNH:

- Terrenus (2013) stated that Permian spoil is generally moderately sodic, however it is not expected to be significantly dispersive or prone to significant soil erosion. Alluvial spoil was noted as generally having lower sodicity.
- Terrenus (2012) stated that weathered and un-weathered Permian over burden and interburden is expected to be moderately sodic, but is not expected to be dispersive or prone to significant soil erosion, based on:
  - in-pit and drill core spoil samples of weathered and unweathered Permian overburden and interburden;
  - exchangeable sodium percentage (ESP) tests which are an indirect measure of the potential for dispersion - ESP results indicated moderate sodicity with no notable difference between weathered and unweathered overburden; and
  - Emerson Class tests which area a direct measure of soil dispersion - Emerson Class results (class No. 8 on a scale of 1-8 for all samples tested) indicated that the overburden and interburden soils are non-slaking, non-swelling and non-dispersive.

Therefore, pit walls on the QNH, which comprise an upper layer of surficial tertiary/quaternary material underlain by weathered and unweathered Permian material, are considered to be potentially sodic but unlikely to be dispersive. The risk of erosion on the QNH final void walls is considered to be more likely associated with normal weathering of material, or hydraulic or gully erosion, which requires mitigation in drainage designs.

9.3.3 Significant hydrological events

As detailed in **Section 7.3**, the water balance model used climate data from 1889 to September 2019 (a 130 year period) measured in the QNH area (Collinsville). The largest single day rainfall event measured as 348.7 mm (08/04/1940) and the largest seven day total measured as 454 mm (02/02/1991 – 08/02/1991), as such the adoption of this climate data factors in actual measured significant hydrological events. Specific consideration of these events as they relate to geotechnical stability of the JCM and SCM final voids was considered in the previous void assessment and modelling reports:

- *"Investigation into Residual Void Jax Coal Mine – QCoal October 2018"* (submitted to DES 12 October 2018), which included the technical study "*Jax Coal Mine Final Void Hydrology Study Main Pit – Engeny Water Management 2018*" (Engeny 2018); and
- *"Investigation into Residual Void Sonoma Coal Mine – QCoal January 2016"* (submitted to DES 29 January 2016), which included the technical study "*Sonoma Coal Mine Final Void Hydrology Study Main Pit – Engeny Water Management 2015*" (Engeny 2015a).

The other aspect of significant rainfall events potentially affecting pit wall stability is associated with infiltration of rain water into the walls from the surface down, saturating the material behind the wall surface, reducing the geotechnical competency of the wall material. The geotechnical inspections listed in **Section 9.3.1**, include assessment of drainage and saturation of wall materials. As such the final detailed landform designs associated with the QNH final void closures (which will include drainage requirements above the highwall to prevent pooling and saturation) will be well informed by geotechnical highwall observations made on the QNH operational pits.

9.3.4 Revegetation

Revegetation considerations for the QNH final voids are only applicable to the sections of the low-walls between the void lake level and the upper sections of the low-wall where the rehabilitation domain transitions from final void to waste rock dump. This is because there is no practical revegetation activities which could be undertaken on the high-wall or the void lake itself (as it is a water body).

As stated in **Section 9.2**, the recommended void outcome for all QNH final voids is "Residual void unable to sustain a post-mining-land-use", with the Jax Main Pit and Jax East Pit voids already having that outcome as a rehabilitation condition in Table H1 of the JCM EA. Revegetation of the applicable sections of the low walls on the QNH final voids is not intended to be utilised habitat or grazing, but is for the purpose of slope stabilisation and erosion protection. As such, a primary metric of successful rehabilitation will be the capability of the void to support establishment, survival and propagation of suitable vegetation species to stabilise slopes and reduce erosion.

QCoal (2018) provides guidance on establishing vegetation in rehabilitated areas, including a list of preferred native and pasture species for revegetation, and should be referred to accordingly. Additional detailed information is provided in the QNH RMP

Indirect/incidental establishment of grasses is anticipated to occur on the final void low-walls based on observed and monitored progressive rehabilitation of areas of rehabilitated waste rock dump on the QNH mines

It is important to note that grass and shrub cover has been well established on rehabilitated areas of the QNH for several years, which is a clear demonstration of the suitability of the QNH waste rock and re-spread topsoil to support vegetation. In addition, it is noted that this revegetated area was not actively seeded as part of rehabilitation works, but was revegetated by seedbank within the material and the indirect/incidental processes described above.

9.4 Potential for environmental harm

This section considers the potential for the final voids on the QNH to directly or indirectly cause environmental harm once they have been rehabilitated to achieve the approved final landform design criteria (**Section 9.5**) and void outcomes (**Section 9.2**).

The potential for environmental harm to occur exists where there is an environmental or human value which could experience long-term negative impact beyond the normal range of natural variations.

9.4.1 Groundwater levels

As presented in **Section 4.2**, the following are not considered values of groundwater in the QNH:

- inter-aquifer connectivity;
- springs wetlands of GDEs;
- stygofauna; or
- human groundwater use.

In specific consideration of potential impacts to surface water baseflow, conceptually for there to be any impact to baseflow associated with a QNH final void, two conditions would need to be satisfied simultaneously:

- a surface water body needs to have demonstrated baseflow which is (at least partly) fed by a hydraulic connection to the underlying groundwater; and
- the extent of a cone of depression would need to intercept that same underlying groundwater causing a reduction in level.

As stated in **Section 4.2**, Pelican Creek, Coral Creek, Two Mile Creek and Twelve Mile Creek are ephemeral, and are considered to be losing-disconnected systems with no notable hydraulic connection to groundwater. As such, despite the prediction of a cone-of-depression in the vicinity of Coral Creek, Two Mile Creek and Twelve Mile Creek, no potential impact is considered likely.

As also stated in in **Section 4.2**, the Bowen River does experience a baseflow; however, previous studies have determined that no hydraulic connection exists with the underlying groundwater. The modelling results from groundwater modelling presented in **Section 6.2** (and previously in AGE (2015)), indicate that cones-of-depression do not extend to the Bowen River. As such, the Bowen River is not expected to experience any impact to baseflow as a result of the QNH final voids.

9.4.2 Non-polluting

The mechanisms by which pollution (that is the release of a contaminant to the environment **outside of the natural range of concentrations**) could occur as the result of the presence of the QNH voids, are:

- void lake water of a degraded quality (as discussed in **Section 8.2**) migrating into the **regional** groundwater system; or
- void lake water of a degraded quality (as discussed in **Section 8.2**) spilling over the pit crest and into surrounding drainage channels flowing into the Bowen River.

The potential for void lake water to migrate to the regional groundwater is addressed in **Section 6.2 and Section 8.1**, which collectively describe that:

- Modelling predictions indicate that all final voids on the QNH are predicted to be groundwater sinks with a net inflow, except for Drake Pit 3Q, Drake Pit 3R, Sonoma East 2 and Sonoma East 1 (in the water balance model), where the modelling returned a mathematical net outflow;
- **Section 6.2** determines that in all such cases any such net outflow is intercepted by an adjacent groundwater sink final void on the QNH, that QNH voids when assessed as complexes are all groundwater sinks and that QNH when assessed cumulatively is a groundwater sink with no migration away from the QNH
- As such, the modelling results indicate that no water from the QNH final void lakes is predicted to migrate outside of the cumulative cone of depression, with nine of the 14 final voids predicted to not experience any outflow at all. The mechanisms by which pollution of the regional groundwater might occur are not predicted by the modelling.

The potential for void lake water to spill over void crests is addressed for every QNH final void in **Section 8.1**, where water balance modelling results indicated that no QNH final void maximum water level height was above the final landform crest elevation. This modelling was in consideration of all possible inflows including natural catchment and disturbed catchment runoff, direct rainfall and pit inflows (no flood ingress was identified as potentially occurring on any QNH final void as a result of location and landform design)

9.5 Rehabilitation completion criteria

The void outcome for all QNH voids has been recommended as “residual void unable to sustain a post-mining-land use” (with the Jax Main Pit and Jax East Pit voids already having this outcome as a condition in the JCM EA). As such, rehabilitation of the QNH final voids is required to achieve the following goals:

- Safe to humans and wildlife;
- Structurally and geotechnically stable; and
- Non-polluting with no environmental harm being caused by anything on or in the land.

In order to demonstrate that a rehabilitated final void has achieved the rehabilitation goals, objectives for each goal have been identified along with competition criteria to be applied to each objective. Completion criteria are the specific quantifiable metrics by which the status, progress and ultimately completion of a rehabilitation objective can be demonstrated. The completion criteria comprise an indicator and a target value for the indicator. Once the rehabilitation criteria are achieved, the final void can said to have been rehabilitated to the required condition.

Table 9 provides a summary of the rehabilitation goals, objectives and completion criteria recommended for the QNH final voids.

Table 9 – QNH voids rehabilitation goals, indicators and completion criteria

Goal	Rehabilitation objective	Completion Criteria	
		Indicator	**Target to be achieved**
Safe to humans and wildlife	Safety risk to people, fauna and livestock is managed	- Access to high walls minimised	Bunds present, stable and self-sustaining. Fencing around high walls present.
Structurally and geotechnically stable	Void walls are geotechnically stable	- Slope of high wall and low wall; - No evidence of cracking/collapse; - No evidence of significant erosion	- high wall slope: ≤ 173% (60°) - low wall slope: ≤ 86% (32°) - RPEQ monitoring of void walls - Drainage design and completion to prevent scouring or gully erosion - RPEQ sign-off of drainage design - RPEQ inspection of completed slopes
Non-polluting with no environmental harm being caused by anything on or in the land.	Void water does not present a risk of impacting on the surface water environmental values (overtopping)	Results from water balance model determining overtopping risk.	Model results predict low risk of overtopping including consideration of significant hydrological events.
	Void water does not present a risk of impacting on the groundwater environmental values of the local aquifer/s (seepage into groundwater)	Results from water balance model and numerical groundwater model	Model results predict a low risk of void lake water migrating into the regional groundwater system Specific model findings may be that voids are individually groundwater sinks or (if there is a mathematical outflow) are located within a cone of depression associated with an adjacent pit such that there is a net groundwater inflow into the QNH.
	Void drawdown does not present a risk of impacting on the groundwater values of the local aquifer/s	Surrounding groundwater level	Model results provide a maximum drawdown extent inside of which there are either no groundwater values which can be impacted, or if groundwater values are identified the drawdown extent, the risk of impact is determined to be low.

10 Conclusions

There are 14 approved QNH final voids, three on the SCM, two on the JCM and nine on the DCM. At cessation of active operation, dewatering will cease and the natural hydrological/hydrogeological process will commence the formation of void lakes.

The groundwater in the QNH area has no notable value as baseflow in surrounding surface water features, as stygofauna habitat, or as source water for springs, wetlands or GDEs. In addition, there is limited human use of groundwater in the vicinity of the QNH.

A numerical hydrogeological model and a numerical water balance model were developed for the QNH final voids to predict an equilibrium state after completion of rehabilitation. The results indicated an equilibrated state where:

- Groundwater drawdown cones-of-depression will occur surrounding the void complexes, as expected, with the extent of drawdown not shown to intercept the Bowen River or any surrounding potential supply bores.
- Void water is fully contained within the QNH final void complexes:
    - void water from Drake 3Q Pit and Drake 3R flows into the Jax Main Pit.
    - void water in the Sonoma Main Pit, Sonoma East Pit 1 and Sonoma East Pit 2 voids may experience localised flow between voids dependent on the final level of in-pit rejects disposal within Sonoma Main Pit.
    - all other individual QNH final voids are groundwater sinks predicted not to experience any net outflow.
    - the QNH voids when assessed as complexes are all groundwater sinks, and the QNH when assessed cumulatively is a groundwater sink. As such, there is no scenario which results in migration of QNH void water out of the cumulative cones of depression.
- No scenario was predicted where any void lake water level will reach spill/crest elevation.

The salinity of all residual voids modelled is forecast to continue to increase over time due to the ongoing concentration resulting from evaporation in conjunction with no significant outflow of salts from either net outflows seepage or overflows. **It should be noted that pits with net outflow were still shown to accumulate salts throughout the model duration**. The reason for this occurrence is that predicted net outflow rates into the surrounding geology, at all levels of rating curves, for all pits, were significantly smaller in magnitude than flows associated with rainfall, runoff, and evaporation. The results indicate significant variation in the EC of the different voids; however, all void lakes are forecast to exceed 10,000 µS/cm after 200 years (with the exception of Jax Main Pit which is closer to 220 years), with some pits reaching 10,000 µS/cm after 40 years. Ultimately, salts will continue to concentrate with the maximum concentration only limited by solubility of the constituent salts within the lake. This is conceptually the case for any comparable water body receiving inflow, which experiences evaporation as either the only outflow, or at a rate exceeding all other outflows. As such, the water in the QNH voids is predicted to be unsuitable for any use and be contained within the QNH voids for all modelled scenarios. In consideration of those results, it is concluded that none of the QNH final voids can self-sustain a designated post-mining land use, as all potential uses are contingent on having an acceptable level of quality for that use, none of which can be met over time.

The specific slope design criteria for the QNH final void walls is conditioned in the respective EAs. The origin of those slopes was the initial geotechnical assessment for the SCM followed by specific subsequent geotechnical studies which informed the slopes designs adopted in the EAs. Since commencement of operation, QNH pit walls have been subject to RPEQ geotechnical inspections, including specific reviews of the design slopes for pit walls. None of the findings in the RPEQ geotechnical assessments indicate that the final void slopes proposed in the QH EAs are unsuitable, provided contributing factors are addressed (such as drainage), and a final RPEQ design of final voids is undertaken to consider the specific materials exposed in the final high walls. As such, provided an RPEQ final design is undertaken which includes full drainage design, there is no impediment to achieving a geotechnically stable final landform.

There have been several studies previously completed into the geochemistry of the QNH including which included comment on sodicity and dispersion. The materials comprising QNH final void walls are not considered especially dispersive, and, as such, erosion and weathering risk is considered more likely to be associated with hydraulic erosion (gully, erosion, tunnel erosion and scouring), which is to be addressed in drainage designs. In additional saturation of walls (leading to a risk of failure) is also to be addressed in final drainage designs.

Revegetation of the applicable sections of the low walls on the QNH final voids is not intended to be utilised for habitat or grazing but is for the purpose of slope stabilisation and erosion protection. QCoal (2018) provides guidance on establishing vegetation in rehabilitated areas, including a list of preferred native and pasture species for revegetation, and should be referred to accordingly. Additional detailed information is provided in the QNH RMP. Indirect/incidental establishment of grasses is anticipated to occur on the final void low-walls based on observed and monitored progressive rehabilitation of areas of waste rock dump on the QNH mines. It is important to note that grass and shrub cover has been well established on rehabilitated areas of the QNH for several years, which is a clear demonstration of the suitability of the QNH waste rock and re-spread topsoil to support vegetation.

Accordingly, all QNH final voids modelled in this assessment are determined not to be in “stable condition” as defined in Section 111A of the EP Act, and are recommended to have a void outcome of “residual void unable to sustain a post mining land use”. Until such time as the SCM, DCM and JCM transition into the PRC Plan framework, any final landforms which are determined not to be in “stable condition” under Section 111A will be managed as NUMAs whilst not definitionally be referred to as NUMAs. Once transitioned into the PRC Plan framework any such landforms will then also be definitionally referred to as NUMAs.

The Jax Main Pit and Jax East Pit voids already have this void outcome conditioned in the JCM EA, which is consistent with the findings of this assessment and *“Investigation into Residual Void Jax Coal Mine – QCoal October 2018”* (submitted to DES 12 October 2018).

These findings are also consistent with the void outcomes previously identified for Sonoma Main Pit in *“Investigation into Residual Void Sonoma Coal Mine – QCoal January 2016”* (submitted to DES 29 January 2016).

Final voids with an outcome of “unable to self-sustain a post mining land use”, are required to be rehabilitated to be safe and geotechnically stable condition, and to not cause environmental harm as per conditions of the QNH EAs.

10.1Recommendations

The following recommendations are made based on this investigation:

1) The goals for all QNH residual voids are that they should be safe, geotechnically stable and not cause any environmental harm or carry any additional level of risk, beyond what is inherent to the existence of the void itself. The nominated completion criteria reflect this objective.
2) All QNH residual voids have been found to be unable to sustain a PMLU as a result of degrading water quality. This is reflected in the JCM EA for the JCM voids. The SCM and DCM EAs should be amended to also reflect this finding.
3) From the cessation of pit dewatering until the completion of rehabilitation activities:
    a) undertake a monthly survey or measurement of water level in the main pit final voids;
    b) undertake quarterly water quality monitoring of final void water;
    c) undertake a monthly inspection of the pit walls by a geotechnical engineer/mining engineer/pit geologist for any visual signs of weakening, slipping, failure or gully/tunnel erosion
        - if required, the inspection may make recommendations for remedial actions
        - if required, the inspection may make recommendations for further pit wall stability studies.
4) Prior to final rehabilitation, engage a third party RPEQ engineer to undertake a final assessment and design of the high wall and low wall, in consideration of the completion criteria in the EA. Such a design should be informed by the prior quarterly RPEQ operational inspections and data.
    a) Any recommendations made by the RPEQ should be factored into rehabilitation works.

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QCoal Northern Hub Water Management Plan – Engeny Water Management 2016 (Engeny 2016))

QCoal Northern Hub Water Management Plan – Engeny Water Management 2017 (Engeny 2017))

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APPENDIX A

Jax Coal Mine Final Void Hydrology Study Main Pit – Engeny Water Management 2018 (Engeny 2018)

and

Long Term Water Quality of Jax Coal Mine Residual Voids - 2 April 2019 (Engeny (2018) Supplementary Memo)

QCOAL GROUP

ENGENY
WATER MANAGEMENT

JAX COAL PTY LTD

JCM Final Void Hydrology Study

Jax Main Pit and Jax East Pit






November 2018

M4100_031

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Rev 0	Client Issue	Amir Joorabchi	Sean Frazer	Sean Frazer	30 November 2018
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1. INTRODUCTION

The Jax Coal Mine (JCM) is located approximately 8 km south of Collinsville within the Bowen Basin. Sonoma Coal Mine (SCM), Drake Coal Mine (DCM) and Cow Coal Mine (CCM) are located to the north and west of JCM. These four mines are owned and operated by subsidiaries of QCoal Pty Ltd (QCoal) and are collectively referred to as the QCoal Northern Hub (QNH).

There is currently one open cut mining pit within the JCM mining lease (ML10346), JCM Main Pit. JCM East Pit is a planned open cut mining pit, which has not yet commenced. The site layout is illustrated in Figure 1.1.

The JCM is authorised to operate under Environmental Authority (EA) EPML00337613 dated 5th September 2017. The EA specifies the following requirements for final voids:

- ***Condition F9 Residual Void Outcome***
  Residual voids must comply with the following outcomes:
  a) Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority.
  b) residual voids must comply with Table F1: Residual void design.
  c) with the exception of the residual void (Jax Pit 1) referred to in Table F1, all voids must be backfilled.

- ***Condition F10***
  Complete an investigation into residual voids and submit a report to the administering authority for review and approval. The report must propose acceptance criteria to meet the landform design criteria stipulated in the Rehabilitation Management Plan and Table F1: Residual void design by 31 July 2018.

QCoal has commissioned Engeny Water Management (Engeny) to undertake a void hydrology study of the proposed JCM voids, to inform the assessment report required under **Condition F10**. This void hydrology study has been prepared under the direct supervision of Sean Frazer (RPEQ No. 21211).

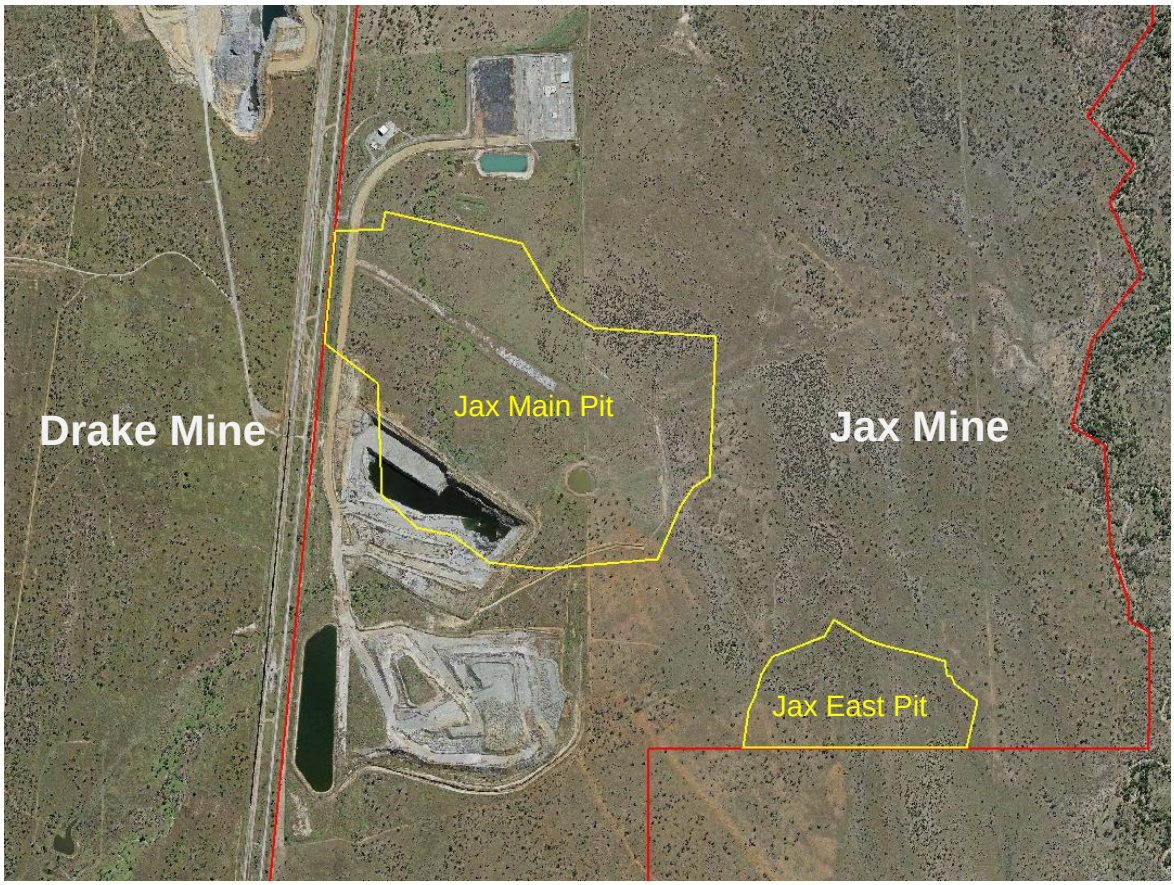


Figure 1.1 JCM Site Layout

2. DATA REVIEW

2.1 Previous Studies

A number of previous studies have been referred to for this assessment including:

- *Water Management Plan 2017 QCNH Mines* (Engeny, December 2017).
- *SCM Final Void Hydrology Study Main Pit* (Engeny, November 2015).
- *CCM Final Void Hydrology Study Q Pit and B Pit* (Engeny, April 2017).
- *Drake Coal Project Groundwater Model* (AGE, January 2015).

2.1.1 Water Balance Model

Engeny has previously developed a water balance model of the QNH mines (including JCM) in the GoldSim software. The development of the model, input parameters and calibration are detailed in *Water Management Plan Northern Hub Mines* (Engeny, Dec 2017). The existing model has been adopted as a basis for this final void hydrology study.

2.2 Final Void Landform

The purpose of this study is to conservatively inform the overall report required as per Condition F10; therefore, a final void scenario has been assumed which has both Jax pits retained as final voids. As such the final landforms for the JCM voids (including storage curves) have been determined based upon the latest mine planning designs supplied by QCoal. Catchment areas for the base case have been estimated from the mine plans and existing survey while a sensitivity analysis has been undertaken with potential catchment variations. The actual final landforms on the JCM are not considered likely to differ from the final landforms modelled in this report to a degree which would negate the findings of this study.

2.2.1 Storage Curve

The assumed final landform storage curves are presented in Figure 2.1 and Figure 2.2. The Jax Main Pit and Jax East Pit voids are estimated to have a storage capacity of 32 GL and 11 GL respectively. The storage curves have been adopted as a reasonable estimate of the final pit void storage characteristics.

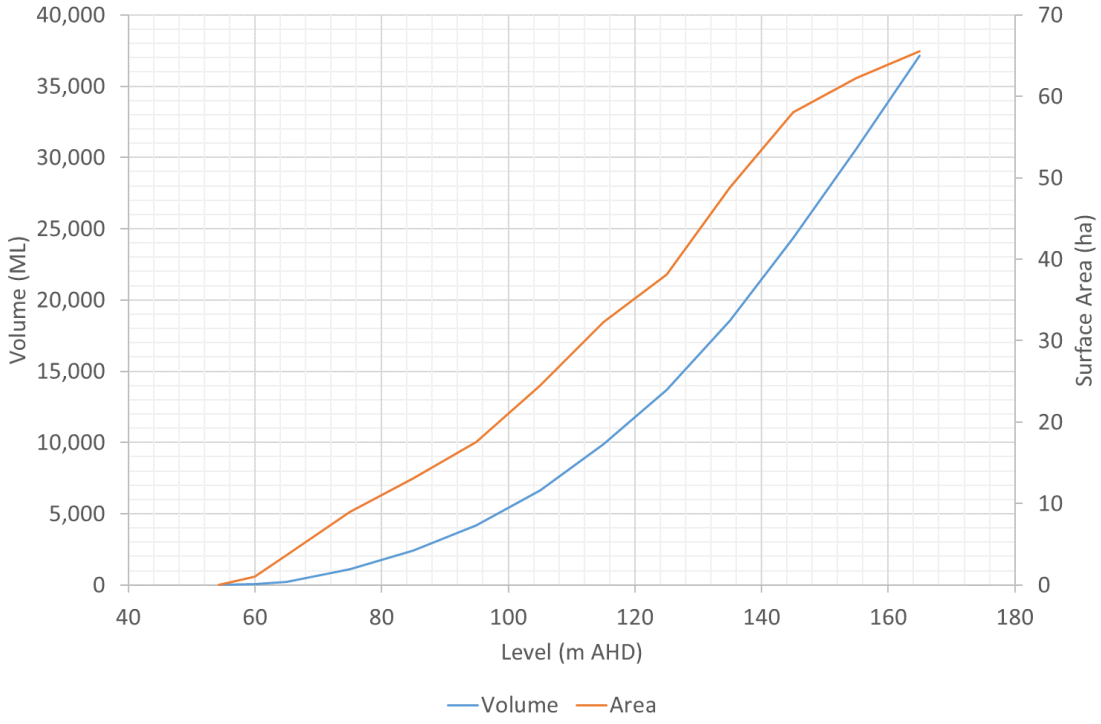


Figure 2.1 Jax Main Pit Storage Curve

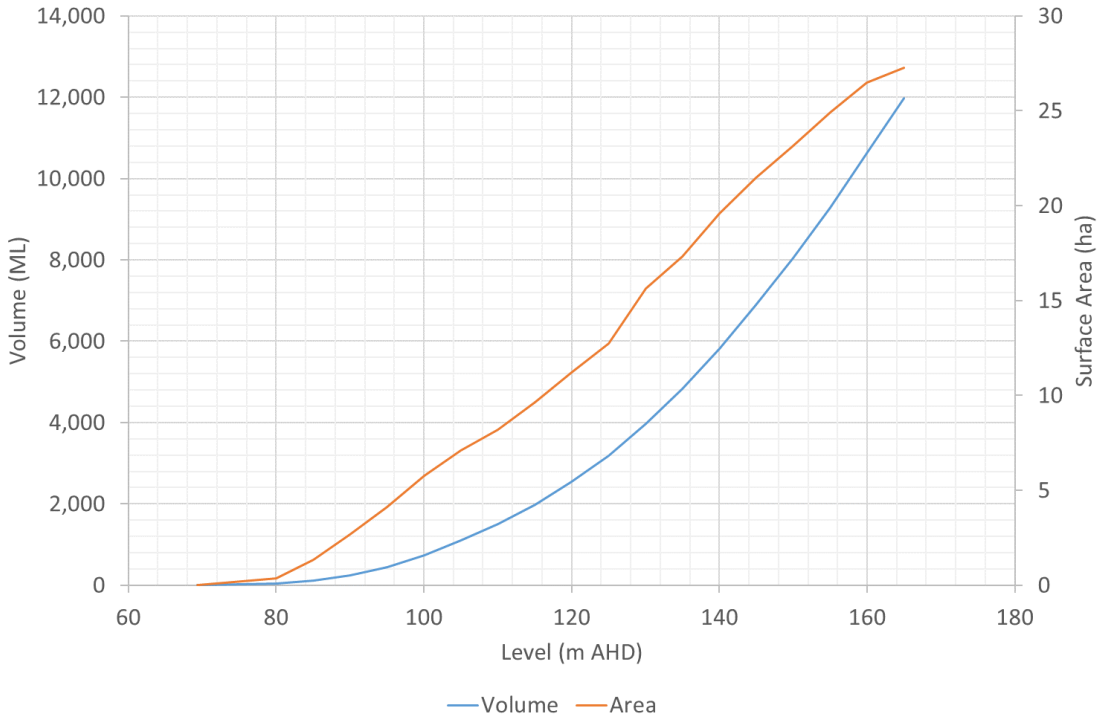


Figure 2.2 Jax East Pit Storage Curve

2.2.2 Contributing Catchment

In addition to the LiDAR data, aerial photography from July 2018 and mine plans have been used to model the final landform catchments. It has been assumed that all out-of-pit spoil areas will be rehabilitated following the cessation of mining.

The adopted final void catchments for JCM pits are presented in Figure 2.3 and Figure 2.4 for the Base Case Scenario. These catchments have been determined from current topography and final void designs. Review of the topography indicates that the natural catchment to the east of Jax Main Pit can be readily diverted away from the void and it was therefore considered reasonable to exclude this area from the Base Case catchment (refer to pink shaded region in Figure 2.3).

Both final voids have additional upslope natural catchments that would require more substantial drainage infrastructure to divert. The impact of diverting this additional catchment has been assessed by undertaking a sensitivity assessment presented in the Reduced Catchment Scenario. The contributing catchments for this scenario are presented in Figure 2.5 and Figure 2.6 and represent the minimum contributing catchment, which will minimise the void lake level.

A summary of the contributing catchment areas for the two scenarios is provided in Table 2.1.

Table 2.1 Contributing Catchment and Landuse

Pit	Scenario	Area (ha)			
		Pit	Rehab	Natural	Total
Jax Main Pit	Base case	69.4	59.8	134.3	263.5
Jax Main Pit	Reduced catchment	69.4	59.8	14.1	143.3
Jax East Pit	Base case	28.3	-	20.3	48.6
Jax East Pit	Reduced catchment	28.3	-	12.9	41.2

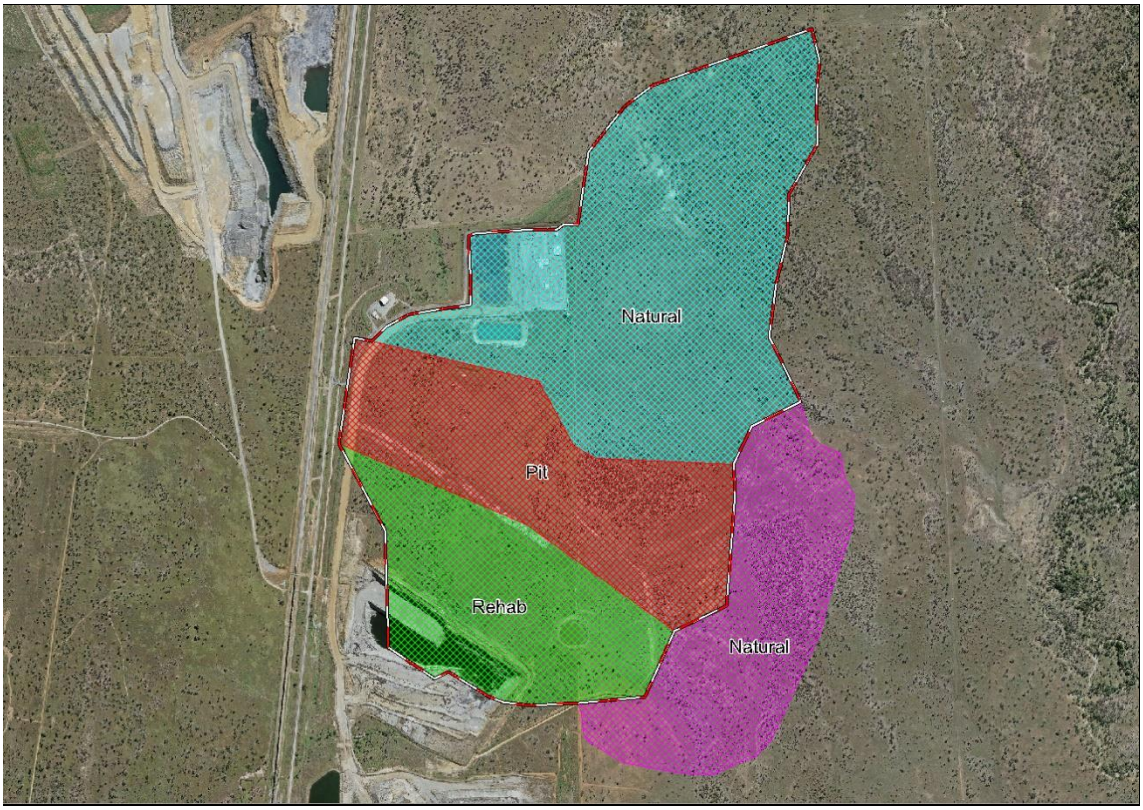


Figure 2.3 Jax Main Pit Catchment (Base Case)

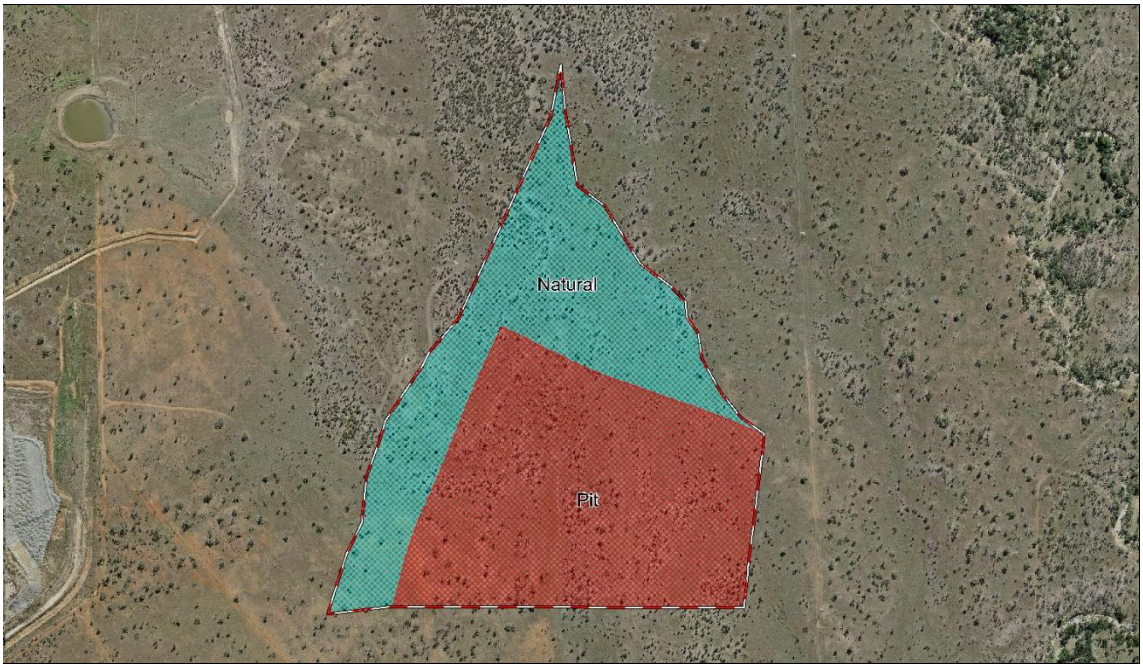


Figure 2.4 Jax East Pit Catchment (Base Case)

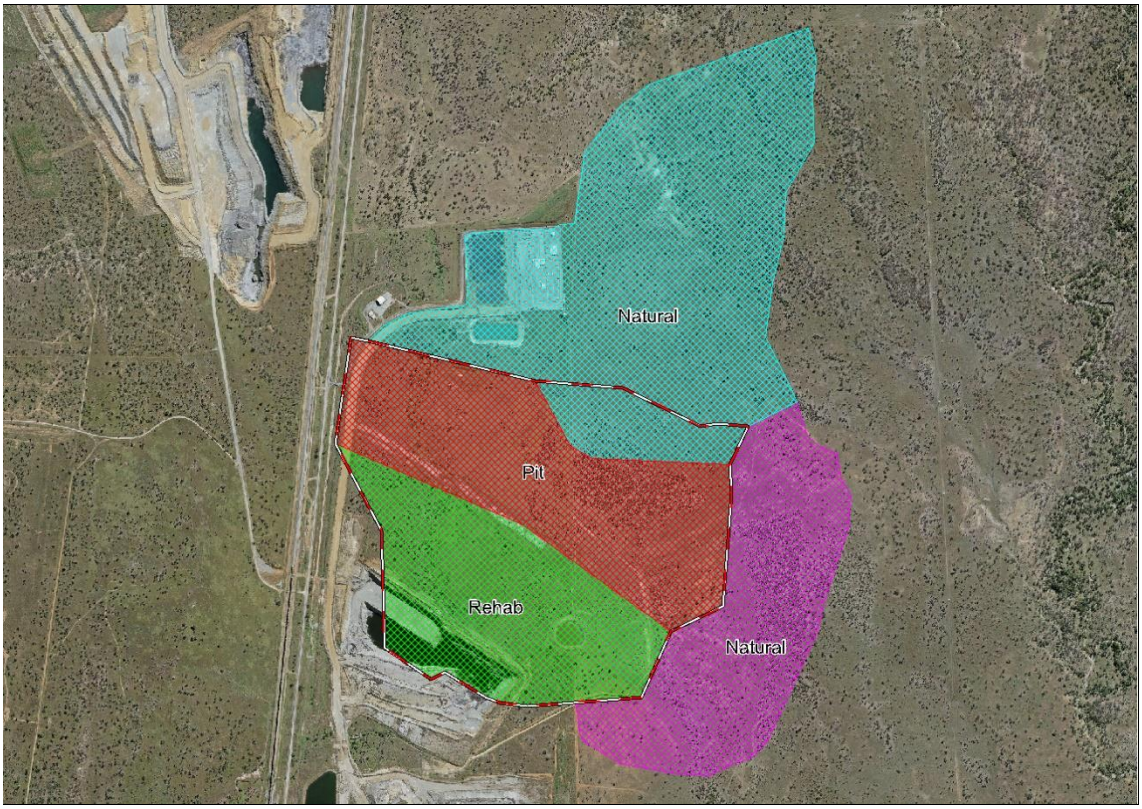


Figure 2.5 Jax Main Pit Catchment (Reduced Catchment Scenario)

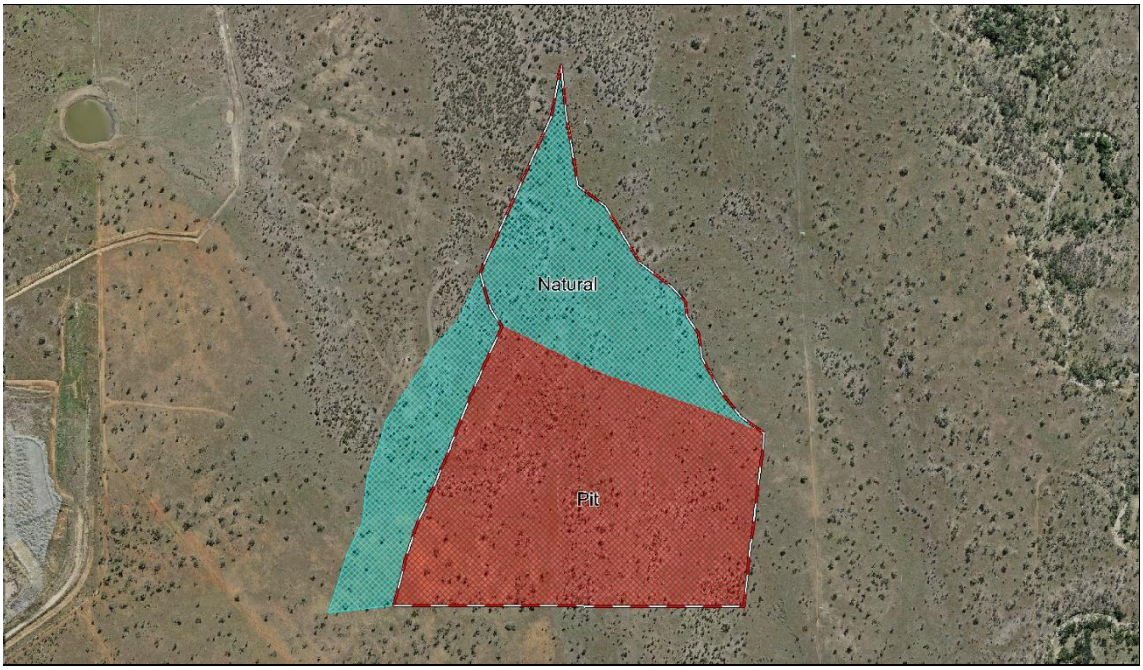


Figure 2.6 Jax East Pit Catchment (Reduced Catchment Scenario)

2.3 Connections to Groundwater

The regional groundwater system in the vicinity of the JCM has been described in a number of previous studies, the most recent of which is the Drake Coal Project Groundwater Model (AGE, 2015) which informed a broader groundwater assessment inclusive of the JCM, in the Drake Coal Mine Groundwater Monitoring and Management Plan (QCoal, 2014).

Numerical groundwater modelling of the design final voids was undertaken by AGE in September 2018 to predict groundwater inflow in the Jax Pit voids. From the model, a rating curve of groundwater inflow vs pit water level for the two Jax Voids was developed. The modelling included both a combined assessment (assuming the water level in each void is the same) as well as Jax Main Pit and East Pit in isolation. The groundwater inflow relationship for the base case scenario is based on the combined pits model. A sensitivity analysis was undertaken using the rating curves derived for each pit in isolation.

The AGE assessment (Sep 2018) identified the following key findings:

- The pre-mining regional groundwater levels in the vicinity of Jax Pits is approximately 140 m AHD. As shown in Figure 2.7, the zero flow level (i.e. the level at which there is no net inflow or outflow from the pit lake to groundwater) is 143 m AHD for Main Pit and 131 m AHD for East Pit.

- The base of weathering around Jax Main Pit varies from approximately 140 m AHD in the south west of the pit to around 160 m AHD in the north east of the pit.

- The base of weathering at Jax East Pit ranges from 143 m AHD to 154 m AHD across the pit footprint.

- The numerical model indicate that the pre-mining regional water table is coincident with the base of weathering.

The base case relationship between water level and groundwater inflows for both Jax Main Pit and Jax East Pit are presented in Figure 2.7. Negative flows shown in the figure indicate a net outflow from the pit into the surrounding groundwater system. In theory, this would occur in the situation where the water level in the pit is higher than the groundwater level surrounding the pit. It is noted that these hypothetical net outflow rates are likely to be artificially high due to the application of an “infinite sink” as a boundary condition on the groundwater model.

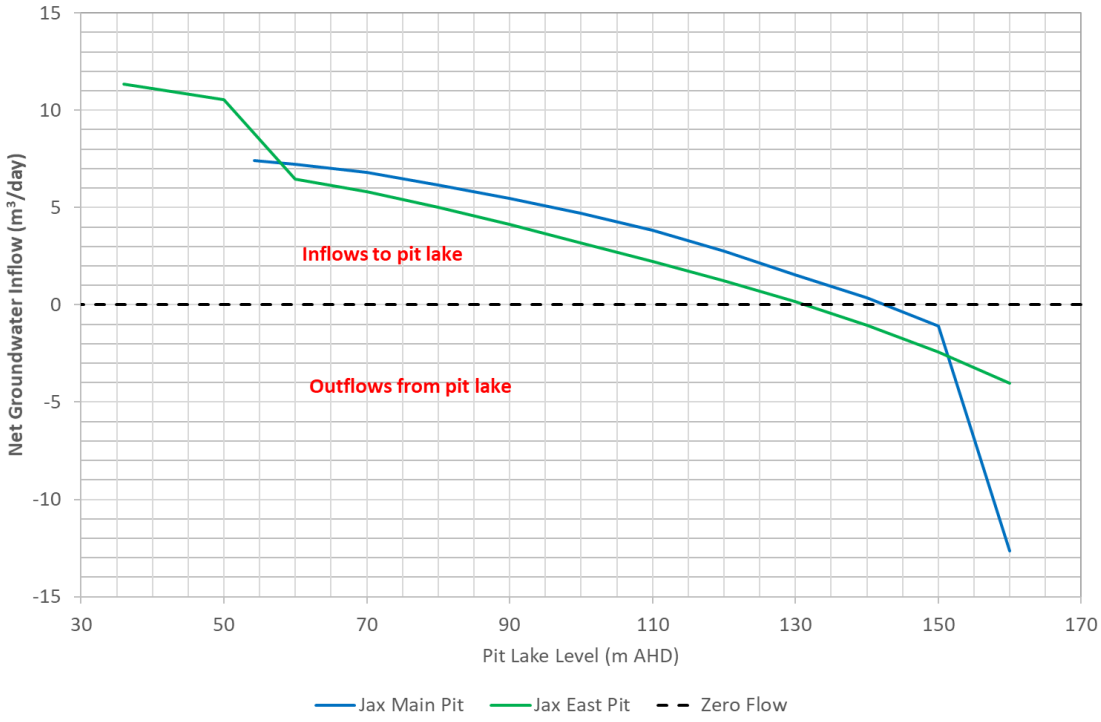


Figure 2.7 Pit Lake Level vs Groundwater Inflow Relationship for JCM Pits

2.4 Water Quality

Electrical conductivity (EC) and Total Dissolved Solids (TDS) are key indicators of water quality and can be simulated within the existing water balance model. The model directly simulates TDS using a salt mass balance and converts to EC via a constant conversion factor (1 mg/L TDS = 1.49 µS/cm EC). Water quality inputs to the water balance model have been reviewed and are summarised in the following sections.

2.4.1 Groundwater

Monitoring of groundwater quality across a number of monitoring bores at QNH is undertaken on a quarterly basis. The groundwater quality data has previously been assessed as part of the *SCM Final Void Hydrology Study Main Pit* (Engeny, 2015) and *CCM Final Void Hydrology Study Q Pit and B Pit* (Engeny 2017). Both studies determined a representative groundwater inflow quality of 2,000 µS/cm. A consistent quality has been adopted for the JCM Void Assessment, which is considered suitable to model the rate of change resulting from hydroligcal processes within the pit voids. The impact of a higher groundwater inflow EC has been assessed via a sensitivity analysis (as presented in Section 3.4).

2.4.2 Surface Water

Surface water runoff TDS characteristics have previously been calibrated for a number of land use types as documented in *Water Management Plan Northern Hub Mines* (Engeny, Dec 2017). These runoff TDS characteristics have been adopted for the modelling of both JCM voids in this void hydrology study and are summarised in Table 2.2.

Table 2.2 Runoff TDS

Landuse Type	TDS (mg/L)
Pit	1,300
Rehabilitated Spoil	Varies with runoff depth: $547 \times (\text{Rainfall Excess})^{-0.19}$ max 700 mg/L

2.4.3 Potential for Stratification

Due to the depths of the final void lakes and the likely thermal gradients, the lakes are considered to have a potential for stratification. This is likely to occur on a seasonal cycle with stratification in the warmer summer months followed by mixing in the cooler winter months or under climatic conditions that would promote the turnover of the void lake stratification (e.g. strong winds).

3. WATER BALANCE MODEL ASSESSMENT

3.1 Final Void Inflows and Outflows

The water balance of the final void will be governed by the following water inflows and outflows:

- Inflows:
  - Surface runoff inflows from rehabilitated spoil areas that drain to the void.
  - Surface runoff inflows from the walls and ramps of the void.
  - Inflows from incident rainfall on the void lake.
  - Groundwater inflows to the void (if the void lake level is lower than the regional groundwater level).
- Continuous Outflows:
  - Outflows due to evaporation losses from the surface area of the void lake.
- Potential Outflows (conditional on void lake level):
  - Seepage outflows from the void lake to groundwater (if the void lake level is higher than the regional groundwater level).
  - Discharges to surface water (only if the void fills to its' spill level).

3.2 Modelled Scenarios

A number of scenarios have been simulated using the water balance model in order to assess the hydrological behaviour of the final voids. The scenarios assessed are presented in Table 3.1. Scenario 1 (i.e. the Base Case) has adopted the best available estimates of model inputs, while Scenarios 2 to 8 provide a sensitivity analysis of uncertainties in key adopted input parameters.

The model has been simulated for a period of 100 years. The historical climate record (as detailed in the Water Management Plan (Engeny, 2017) has been utilised to assess 124 potential realisations of the void behaviour under different climate sequences.

Table 3.1 Water Balance Model Scenarios

ID	Scenario	Description
1	Base	Jax Main Pit: Pit shell = 69.4 ha; Rehab spoil = 59.8 ha, Natural = 134.3 ha Jax East Pit: Pit shell = 28.3 ha; Natural = 20.3 ha

ID	Scenario	Description
2	Reduced catchment sensitivity	Jax Main Pit: Pit shell = 69.4 ha; Rehab spoil = 59.8 ha, Natural = 14.1 ha Jax East Pit: Pit shell = 28.3 ha; Natural = 12.9 ha
3	Groundwater inflow sensitivity	Base with 50% increase in groundwater rates (both inflow and outflows)
4	Regional groundwater level sensitivity	Groundwater inflow relationship shifted up by 5m (i.e. higher inflows at the same void lake level)
5	Groundwater TDS sensitivity	Base with EC of groundwater inflows increased to 15,000 µS/cm
6	Reduced evaporation sensitivity	Base with 30% reduced lake evaporation due to reduced wind, increased shading and increased salinity
7	Isolated Groundwater Inflow	Base model with groundwater rates associated with each pit in isolation
8[1]	Increased catchment sensitivity	Base with natural catchment at the east of Jax Main Pit Jax Main Pit: Pit shell = 69.4 ha; Rehab spoil = 59.8 ha, Natural = 194.6 ha

Note 1: Assessed increased catchment sensitivity for Jax Main Pit only

3.3 Base Case Results

3.3.1 Void Lake Volume

The predicted future void lake volume over time in Jax Main Pit and Jax East Pit are presented in Figure 3.1 and Figure 3.2 respectively. The range of forecast void lake behaviour is illustrated, including:

- A high void lake level (95th Percentile).
- A median void lake level (50th Percentile).
- A low void lake level (5th Percentile).

The results indicate that the void lake levels will rise steadily over the first decades following the cessation of mining. Although the void lake levels are forecast to fluctuate over time as a result of the prevailing climate conditions, an equilibrium volume of approximately 8 GL and 1 GL is forecast for Jax Main Pit and East Pit respectively.

The time required for the void lakes to reach their equilibrium volume is presented in Table 3.2 and ranges from approximately 70 to 90 years for Jax Main Pit to 40 to 50 years for Jax East Pit.

The equilibrium volumes correspond to void lake levels of approximately 110 m AHD (Jax Main Pit) and 104 m AHD (Jax East Pit). These levels are 47 m to 58 m below the level at which the void lakes would spill to the receiving waterways. No overtopping of the void lakes to the receiving environment is forecast to occur.

The modelled Jax Main Pit equilibrium level (110 m AHD) is 30 m below the pre-mining regional groundwater level (140 m AHD) and 33 m below the zero flow level (143 m AHD). The Jax Main Pit final void is therefore forecast to operate as a sink, with a groundwater inflow of 3.9 m^3/day (i.e. 1.4 ML/year) and no flow from the void to groundwater expected to occur.

The modelled Jax East Pit equilibrium level (104 m AHD) is 36 m below the pre-mining regional groundwater level (140 m AHD) and 27 m below the zero flow level (131 m AHD). The Jax East Pit final void is therefore forecast to operate as a sink, with a groundwater inflow of 2.7 m^3/day (i.e. 1.0 ML/year) and no flow from the void to groundwater expected to occur.

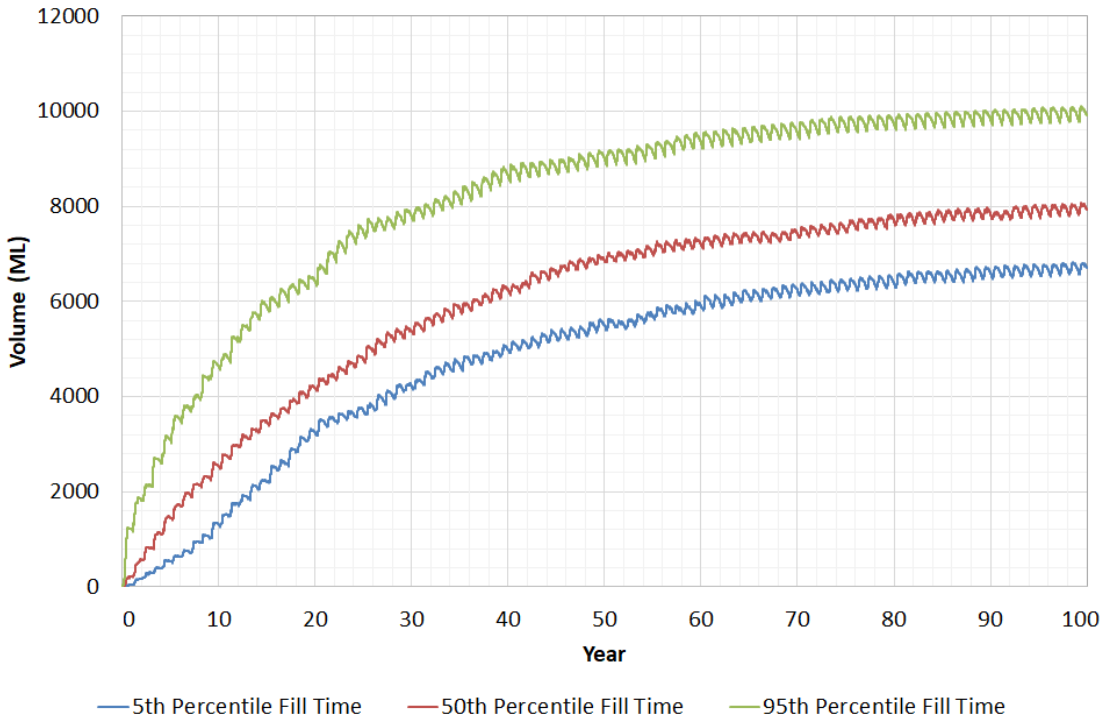


Figure 3.1 Forecast Jax Main Pit Void Lake Volume (Base Case)

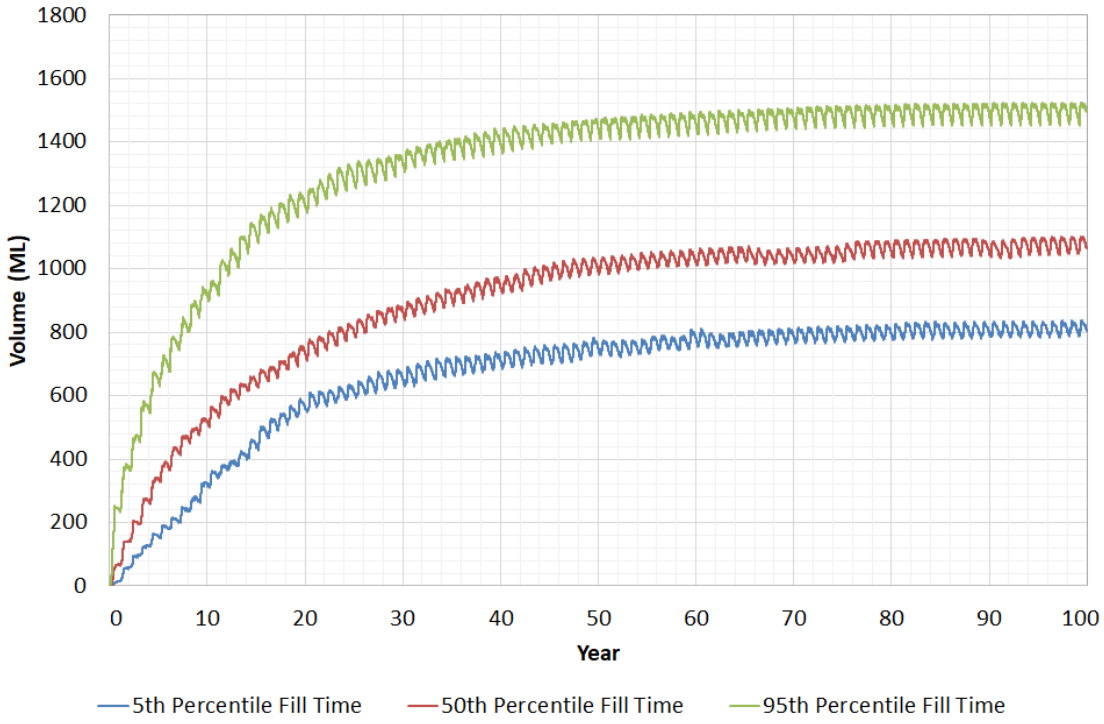


Figure 3.2 Forecast Jax East Pit Void Lake Volume (Base Case)

Table 3.2 Forecast Time for Void Lake to Fill to Equilibrium Level

Percentile	Filling Time (Years)	
	Jax Main Pit	Jax East Pit
95	90	50
50	80	45
5	70	40

The average annual inflows and outflows to the final voids following the initial filling to the equilibrium void level are presented in Table 3.3. The results indicate that:

- Groundwater inflows are a negligible component of the void lake water balance.
- Direct rainfall on the lake surface is approximately 35% smaller than the catchment runoff.
- Evaporation is the only significant water loss from the lake.

Table 3.3 Average Void Water Balance at Equilibrium

Inflow / Outflow		Average Annual Volume (ML/yr)	
		Jax Main Pit	Jax East Pit
Inflow	Rainfall on Void Lake	209	52
	Surface Runoff	328	79
	Groundwater Inflow	1.4	1.0
Outflow	Evaporation	522	131
	Groundwater Outflow	0	0

3.3.2 Water Quality

The void lake EC for the base case scenario was modelled and is presented in Figure 3.3 (Jax Main Pit) and Figure 3.4 (Jax East Pit).

The salinity of the final void lakes is predicted to increase over time. This is a result of evaporation being the only significant outflow from the lakes, which results in an ongoing concentration of salts. Modelling indicates that salts will continue to concentrate with a generally linear trend at an average rate of approximately 30 – 100 µS/cm per year. Ultimately the maximum EC will be limited by solubility, which will vary with temperature both seasonally and with depth throughout the void lake water column.

It is noted that the invert levels of drainage paths in the vicinity of Jax Final Voids are significantly higher than equilibrium lake levels. Consequently, surface water quality in the drainage paths is not expected to be impacted by the void lakes.

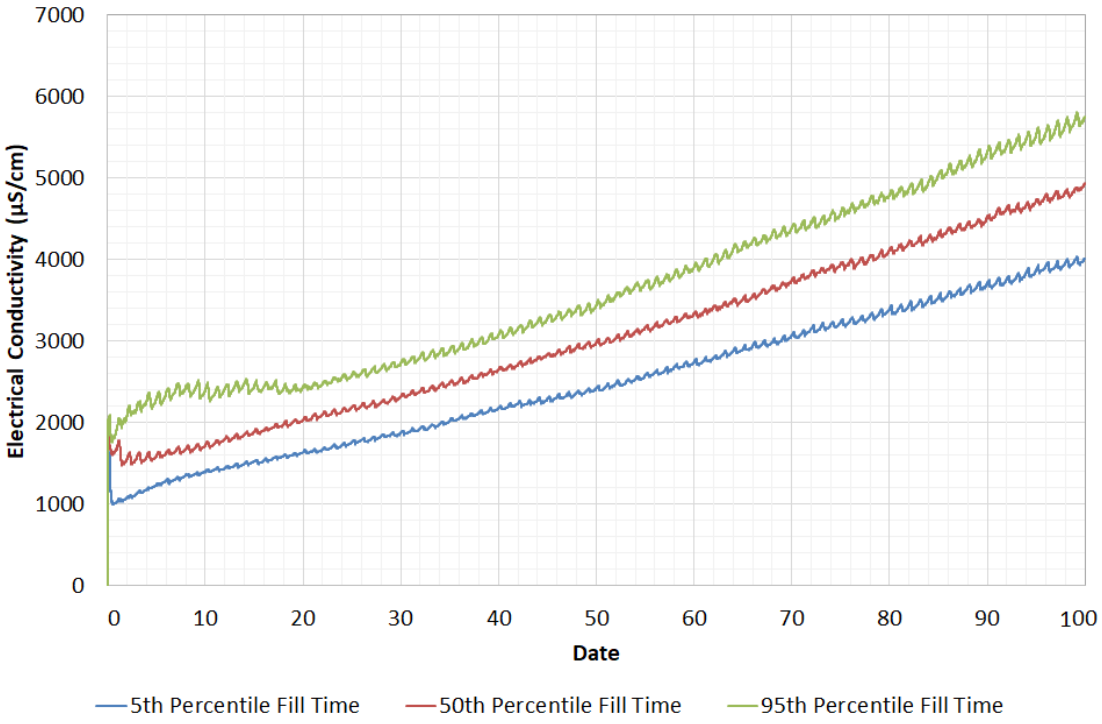


Figure 3.3 Forecast Jax Main Pit Void Lake EC (Base Case)

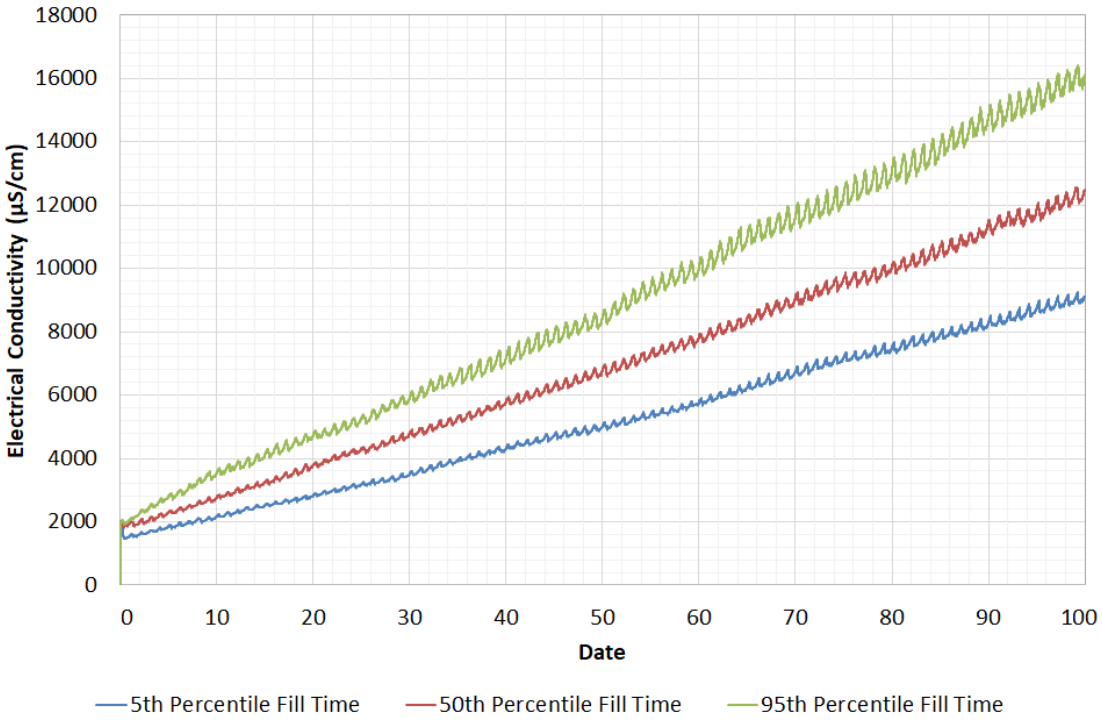


Figure 3.4 Forecast Jax East Pit Void Lake EC (Base Case)

3.4 Sensitivity Results

3.4.1 Void Lake Volume

The median forecast void lake volumes for the range of sensitivity analysis scenarios summarised in Table 3.1 are presented in Figure 3.5 and Figure 3.6 for Jax Main Pit and Jax East Pit respectively. Results indicate:

- Changes to the groundwater inflow rates and regional groundwater level (Scenario 3 and 4) are seen to have minimal impact on the void filling times and equilibrium void lake volumes.
- Scenario 7 uses the alternative groundwater inflow vs pit water level curve developed by AGE for the case of either Jax Main Pit or Jax East Pit in isolation (i.e. a one final void scenario). This scenario indicates that the void lake behaviour does not change significantly based on the there being only one final void instead of two.
- Reducing the out-of-pit catchment (Scenario 2) results in lower equilibrium volumes due to the smaller catchment.
- The greatest variation is a result of reduced evaporation (Scenario 6), which results in increased filling rates and higher equilibrium levels.
    - The equilibrium level in Jax Main Pit of 133 m AHD (17 GL) is 7 m lower than to the pre-mining regional water table (140 m AHD) and 10 m lower than the zero flow level (143 m AHD). The void is forecast to remain a minor groundwater sink of 1.4 m^3/day (i.e. 0.5 ML/yr).
    - The equilibrium level in Jax East Pit of 121 m AHD (17 GL) is 29 m lower than to the pre-mining regional water table (140 m AHD) and 10 m lower than the zero flow level (131 m AHD). The void is forecast to remain a minor groundwater sink of 1.2 m^3/day (i.e. 0.4 ML/yr).
- Inclusion of the natural catchment in the east of Jax Main Pit (Scenario 8) results in a slightly higher equilibrium volume due to the increased catchment. This impact is less than the Scenario 6 sensitivity.

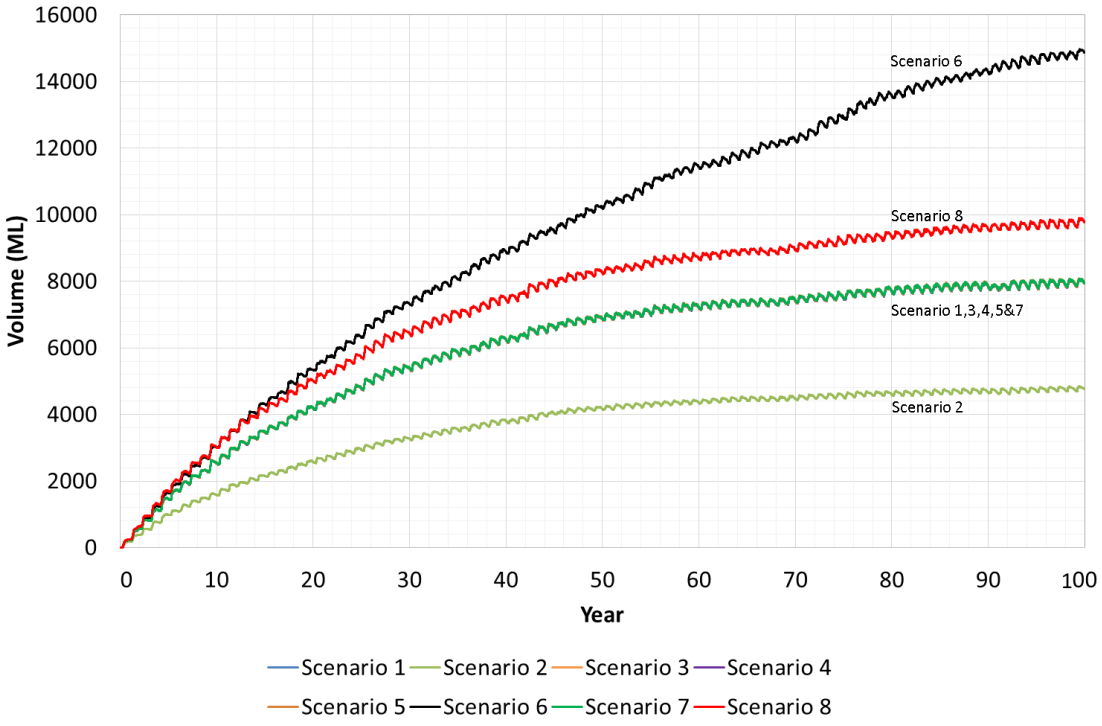


Figure 3.5 Forecast Jax Main Pit Void Lake Median Volume (Sensitivity)

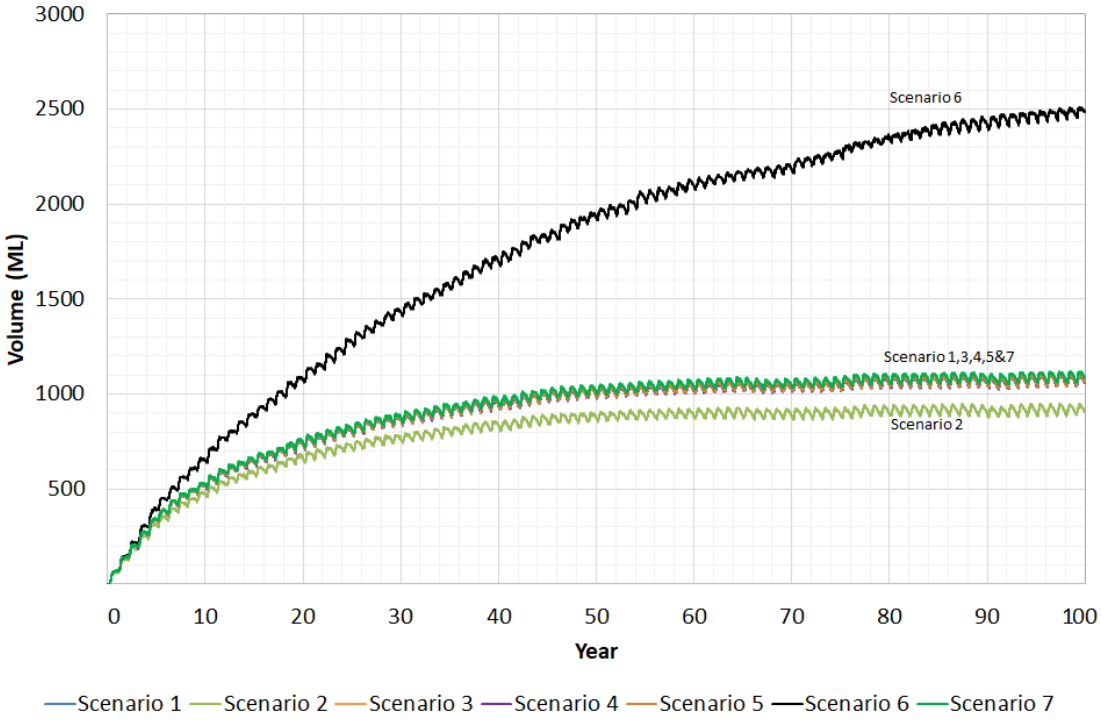


Figure 3.6 Forecast Jax East Pit Void Lake Median Volume (Sensitivity)

3.4.2 Water Quality

The median forecast void lake EC for the range of scenarios summarised in Table 3.1 are presented in Figure 3.7 and Figure 3.8 for Jax Main Pit and Jax East Pit respectively, for the period up to volumetric equilibrium for each void. Results indicate:

- Changes to the groundwater inflow rates, regional groundwater level and isolated pit groundwater inflow rate (Scenario 3, 4 and 7) are seen to have minimal impact on the long-term void lake salinity.
- Reducing the out-of-pit catchment (Scenario 2) results in the salinity of the void lakes increasing more quickly, although this difference in quality is minor. This is a result of the comparative reduction in rehabilitated catchment area, which produces 'clean' runoff to dilute void lake EC.
- By contrast, increasing the natural catchment to the east of Jax Main Pit (Scenario 8) is forecast to result in a slower increase in the concentration of salts in the void lake.
- Increasing the groundwater EC is found to result in a very minor increase in the rate of increase of overall void lake EC (Scenario 5). This is due to groundwater being a negligible component of the void lake water balance.
- Reducing evaporation (Scenario 6) is forecast to result in a slower increase in the concentration of salts in the void lake. However, as for the Base Case, maximum EC will be governed by the salt solubility limit rather than the evaporation rate.

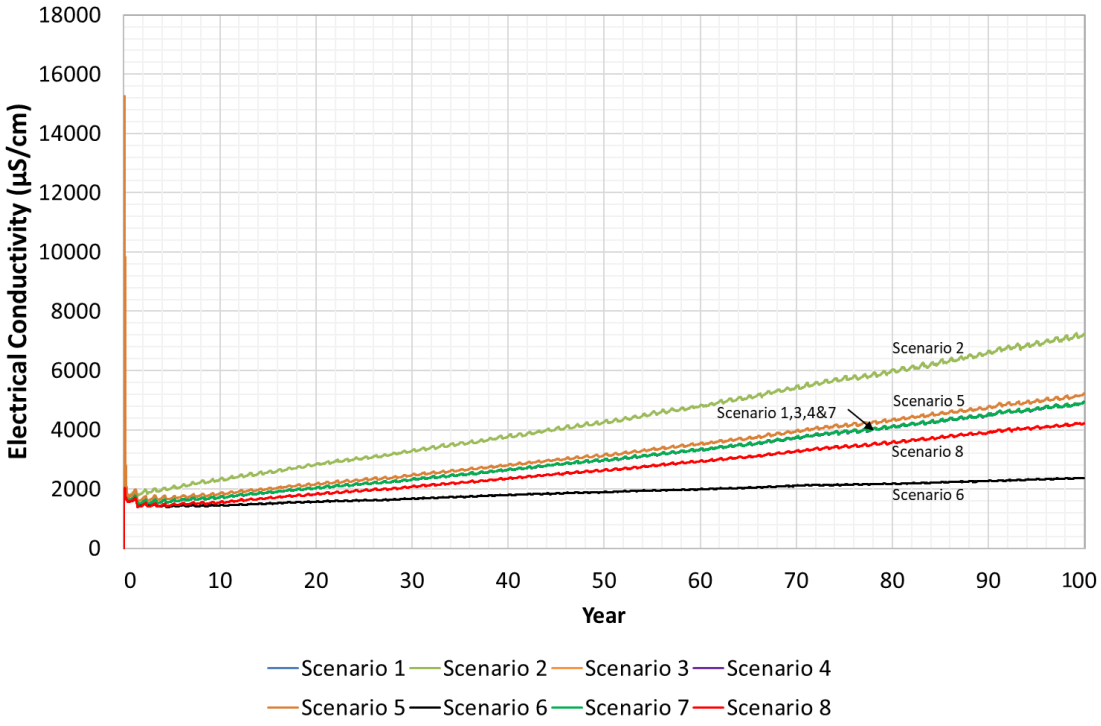


Figure 3.7 Forecast Jax Main Pit Void Lake Median EC (Sensitivity)

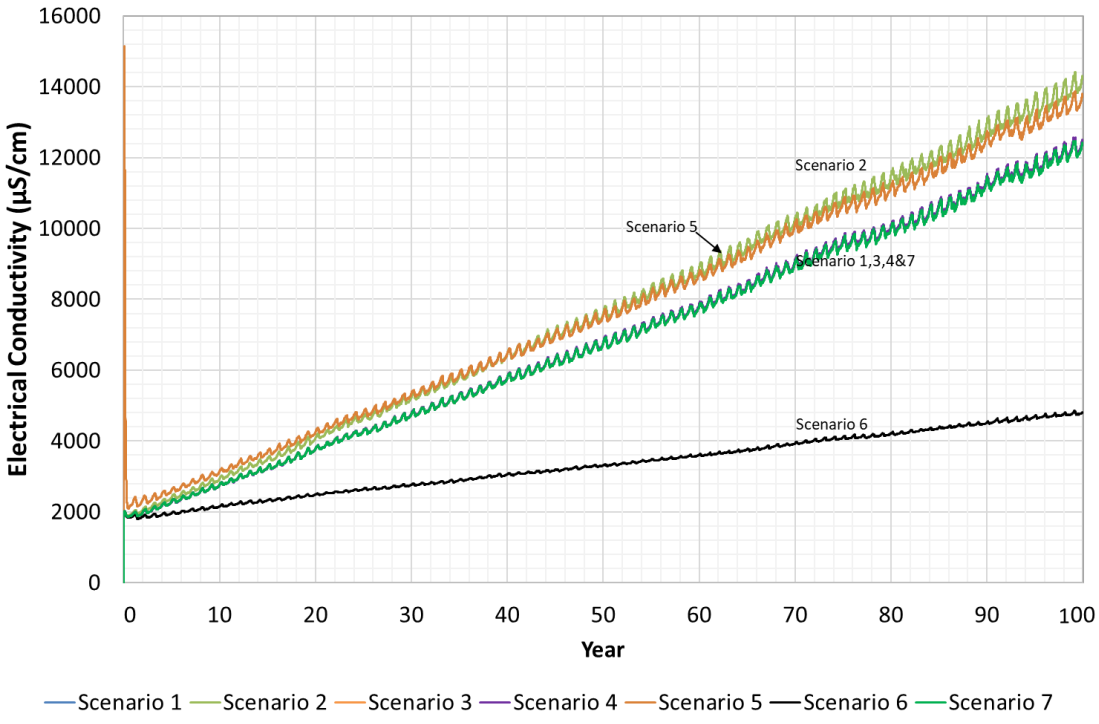


Figure 3.8 Forecast Jax East Pit Void Lake Median EC (Sensitivity)

4. CONCLUSIONS

The key findings from the study are:

- The final void lakes are forecast to fill to equilibrium levels of:
  - Approximately 110 m AHD in Jax Main Pit within a period of approximately 70 to 90 years following cessation of dewatering activities in Jax Main Pit.
  - Approximately 104 m AHD in Jax East Pit within a period of approximately 40 to 50 years following cessation of dewatering activities in Jax East Pit.
  - These levels are approximately 47 m to 58 m below the level at which the void lakes would spill to the receiving waterways. No overtopping of the void lakes to the receiving environment is forecast to occur.

- The pre-mining groundwater level in the vicinity of Jax Main Pit is substantially higher (30 m) than the forecast void lake equilibrium level. Accordingly, the Jax Main Pit final void is expected to remain a sink to groundwater flows, with no reverse flow from the void to groundwater expected to occur.

- The pre-mining groundwater level in the vicinity of Jax East Pit is substantially higher (36 m) than the forecast void lake equilibrium level. Accordingly, the Jax East Pit final void is expected to remain a sink to groundwater flows, with no reverse flow from the void to groundwater expected to occur.

- Due to the future depth of the void lakes and the likely thermal gradient, the lakes are considered to have a high potential for stratification. This is likely to occur on a seasonal cycle with stratification in the warmer summer months followed by mixing in the cooler winter months or under climatic conditions that would promote the turnover of the void lake stratification (e.g. strong winds).

- The salinity of the void lakes is forecast to increase over time as evaporation results in on-going concentration of salts.
  - The void lake EC of both Jax Main Pit and Jax East Pit is forecast to increase at an average rate of approximately 30-100 µS/cm per year. The maximum EC will ultimately be governed by the salt solubility limit.
  - The water in the Jax void lakes is not expected to impact surface water quality in the adjacent drainage features due to the significant difference in elevation between the equilibrium lake level and the surface drainage channels.

5. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

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2 April 2019

QCoal Services Pty Ltd
Level 15, 40 Creek Street
Brisbane QLD 4000

Attention: Julian Dobos

Dear Julian,

RE: LONG TERM WATER QUALITY OF JAX COAL MINE RESIDUAL VOIDS

As per our conversation on Monday 25 March 2019, I understand that you require confirmation of the long term water quality in the planned residual void lakes at the Jax Coal Mine (JCM). This is to inform the post-mining land use.

Previous Study

Engeny Water Management (Engeny) previously prepared the *JCM Final Void Hydrology Study Jax Main Pit and Jax East Pit* (Engeny, Nov 2018). That study utilised a GoldSim water balance model of the planned residual voids to forecast the long term hydrology of the void lakes including equilibrium volumes and water quality trends. Water quality was represented as electrical conductivity (EC) by undertaking a salt mass balance coupled with the water balance to estimate Total Dissolved Solids (TDS) and utilising a conversion factor (1 µS/cm EC = 0.67 mg/L TDS).

The study presented results for a 100 year simulation after cessation of mining, which was long enough to achieve an equilibrium volume in the void lakes. However, the EC was continuing to rise linearly over time. This increase is due to the lack of any significant outflows from the voids (i.e. water leaves the voids through evaporation, but there is no associated transport of salt). Consequently, the concentration of TDS and associated EC continues to increase over time, ultimately governed by the solubility limit.

Review of Livestock Drinking Water Quality

Guidance on drinking water quality limits for livestock is provided in *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, Oct 2000). Tolerance of livestock to TDS in drinking water is summarised in Table 1. The livestock of interest in the locality of JCM is beef cattle, which experiences a loss of production and decline in animal condition for TDS values exceeding 5,000 mg/L (approximately 7,460 µS/cm EC).

Table 1 Tolerance of livestock to TDS in drinking water (ANZECC & ARMCANZ, Oct 2000)

Livestock	Total dissolved solids (mg/L)		
	No adverse effects on animals expected	Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production	Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually
Beef cattle	0–4000	4000–5000	5000–10 000
Dairy cattle	0–2500	2500–4000	4000–7000
Sheep	0–5000	5000–10 000	10 000–13 000[b]
Horses	0–4000	4000–6000	6000–7000
Pigs	0–4000	4000–6000	6000–8000
Poultry	0–2000	2000–3000	3000–4000

a From ANZECC (1992), adapted to incorporate more recent information

b Sheep on lush green feed may tolerate up to 13 000 mg/L TDS without loss of condition or production

Long Term Water Quality

The previous water balance model has been extended to simulate a period of 500 years after cessation of mining. The forecast water quality trends in the Jax Main Pit and Jax East Pit void lakes over this horizon are presented in Figure 1 and Figure 2 respectively.

The results indicate that the previous water quality trends continue over the longer simulation period. The time to exceed the threshold for loss of production in beef cattle is summarised in Table 1 and shown to be within 80 years and 200 years for Jax East Pit and Jax Main Pit respectively. The average rate of increase in EC over the simulation is summarised in Table 3.

Table 2 Time to exceed the threshold for loss of production in beef cattle (years)

Pit Void	5th Percentile	50th Percentile	95th Percentile
Jax Main Pit	196	157	133
Jax East Pit	78	55	40

Table 3 Rate of increase in EC (µS/cm/year)

Pit Void	5th Percentile	50th Percentile	95th Percentile
Jax Main Pit	34	42	50
Jax East Pit	84	119	157

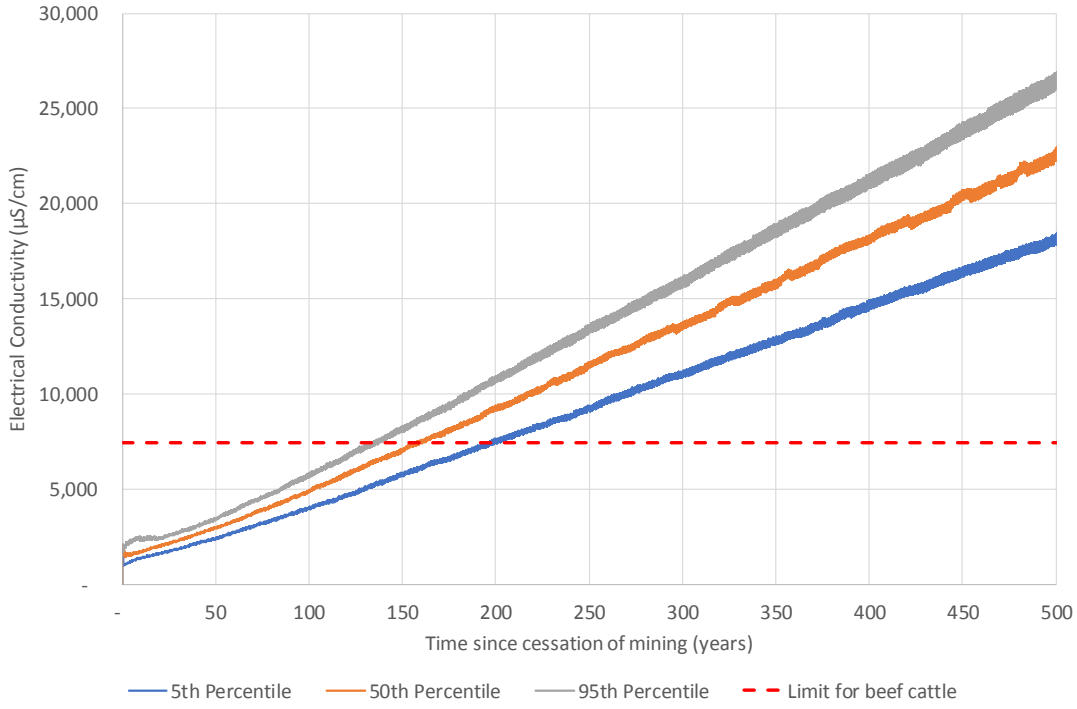


Figure 1 Jax Main Pit void lake EC forecast

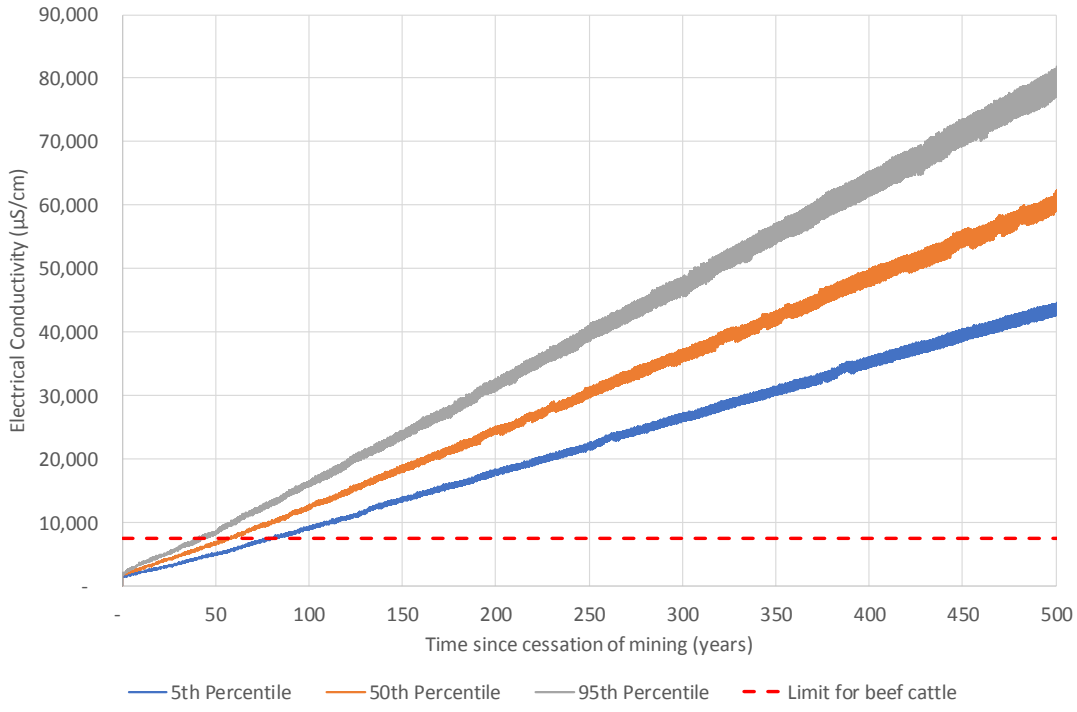


Figure 2 Jax East Pit void lake EC forecast

Please don’t hesitate to contact the undersigned if you have any questions or would like to discuss further.

Yours faithfully



Sean Frazer
Principal Engineer (CPEng, RPEQ)
Associate

APPENDIX B

Residual Void Hydrology Study QCoal Northern Hub Mines April 2020 (Engeny ((2020))

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Residual Void Hydrology Study

QCoal Northern Hub Mines






April 2020

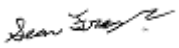
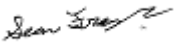
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M4100_041 RESIDUAL VOID HYDROLOGY STUDY						
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REV	**DESCRIPTION**	**AUTHOR**	**REVIEWER**	**PROJECT MANAGER**	**APPROVER (PD)**	**DATE**
Rev 0	Client Issue	Nutan Gothwal	Sean Frazer	Alice Hines	Sean Frazer	27 March 2020
Rev 1	Client Issue	Nutan Gothwal	Sean Frazer	Alice Hines	Sean Frazer	22 April 2020
Rev 2	Client Issue	Nutan Gothwal	Sean Frazer	Alice Hines	Sean Frazer	24 April 2020
Signatures						

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1. INTRODUCTION

Sonoma Coal Mine (SCM), Cows Coal Mine (CCM), Drake Coal Mine (DCM) and Jax Coal Mine (JCM) are four independent but co-located mining operations owned and operated by subsidiaries of QCoal Pty Ltd (QCoal) and are collectively referred to as the QCoal Northern Hub (QNH). The QNH is located south of Collinsville within the Bowen Basin.

Environmental Authorities (EAs) have been issued for each independent mine by the Department of Environment and Science (DES) under the Environmental Protection Act 1994. The EAs associated with the QNH are summarised in Table 1.1. SCM, CCM, DCM and JCM are each authorised to operate under their respective EA.

Table 1.1 Summary of QNH Environmental Authorities

Site	EA Permit Number	EA Date	EA Holder	Locations
SCM	EPML00707713	03/10/2019	Watami (Qld) Pty Ltd JS Sonoma Pty Ltd CSC Sonoma Pty Ltd QCoal Sonoma Pty Ltd	ML10325 ML10326 ML10327
CCM	EPML00334613	03/10/2019	Bowen River Coal Pty Ltd	ML10345
DCM	EPML00393013	03/10/2019	Northern Hub (Drake) Pty Ltd Drake Coal Pty Ltd	ML10349 ML10350 ML10351
JCM	EPML00337613	2020	Jax Coal Pty Ltd	ML10346

QCoal has commissioned Engeny Water Management (Engeny) to undertake a void hydrology study of existing and proposed QNH residual voids. Previous void assessments have been undertaken by Engeny for the QNH as described in Section 2.1.

2. DATA REVIEW

2.1 Previous Studies

Previous studies referred to for this assessment include:

- Water Management Plan 2019/2020 QNH Mines (Engeny, February 2020).
- Drake Coal Project: Environmental Impact Statement (GHD, 2012)
- SCM Final Void Hydrology Study Main Pit (Engeny, November 2015).
- CCM Final Void Hydrology Study Q Pit and B Pit (Engeny, April 2017).
- *JCM Final Void Hydrology Study Jax Main Pit and Jax East Pit (Engeny, November 2018)* – this assessment and the conclusions therein remain applicable as there is no change to the proposed final landform.

2.2 Approved Residual Voids

The EAs for SCM, DCM, CCM and JCM stipulate the approved voids, their size and required wall slopes for each of the specific sites (i.e. Table H1 in each EA), which has been summarised in Table 2.1.

It is noted that not all of the voids may eventuate and/or some approved voids stated as discrete pits in the EA are operationally part of broader complexes comprising multiple in close proximity where the void area is cumulative (this is especially the case for the DCM), as shown in Table 2.1 and detailed further in Section 2.3.

Table 2.1 EA Table H1 for SCM, CCM, DCM and JCM

Residual Void	Void Area	Maximum Slope
Sonoma Coal Mine – EPML00707713		
Sonoma Main Pit	120 ha	High wall – maximum slope of 70° with the top 10m having a maximum slop of 45° including a 1m bund Low wall – 17° – 37°
Sonoma East Pit 1	14 ha	
Sonoma East Pit 2	15 ha	
Sonoma Q-Pit	N/A backfilled	N/A backfilled

Residual Void	Void Area	Maximum Slope
Sonoma B-Pit	N/A backfilled	N/A backfilled
Cows Coal Mine – EPML00334613		
B Seam Pit	Backfilled	N/A
Q Seam Pit	Backfilled	N/A
Drake Coal Mine – EPML00393013		
Drake Pit 5	59 ha	High wall – 65º Low wall – 45º
Drake Pit 1	258 ha	
Drake Pit 2		
Drake Pit 2 Expansion		
Central Pit 3	50 ha	
Central Pit 4	16 ha	
East Pit 1	14 ha	
Drake Pit 3-Q	61 ha	
Drake Pit 3-R		
Jax Coal Mine - EPML00337613		
Jax Main Pit [1]	70 ha	High wall – 60º Low wall – 32º
Jax East Pit [1]	27 ha	

Note 1: Post mining land use of Aquatic Ecosystems

2.3 Voids Modelled for this Assessment

There are currently seven existing open cut mining pits across QNH. There are an additional six open cut pits planned at this time (subject to operational and economically driven changes) which have not yet commenced (i.e. Sonoma East Pit 1, Sonoma East Pit 2, Jax East Pit, Drake Pit 2 Expansion, Drake Pit 4 North and Drake Pit 4 South.

It is clearly noted that as mine planning is subject to change driven by economic factors locally and internationally (notably coal price and demand), the presence of voids as well as their size or shape, is subject to change. As such within the level of design information available, Engeny has undertaken to conservatively asses the layout of final voids provided by QCoal, such that should minor changes to a void or pit complex occur over the life of QNH, this assessment can still be relied upon to inform impact assessments provided key hydrological modelling parameters (e.g. catchment and pit geometry) are maintained (see Section 5.1).

Additionally, the nomenclature for QNH pits and residual voids has changed from approvals through to operation as a result of changes to mine planning.

As such the key document sets used to define the residual void locations and extents were:

- Environmental Impact Statements (EIS) for DCM;
- Later Development Plans (LDP) for SCM, DCM and JCM;
- EAs for SCM, CCM, JCM and DCM; and
- QCoal Life of Mine Planning (LOMP) for SCM, CCM, JCM and DCM

A summary of the residual voids modelled in this assessment, including the various nomenclatures, areas and operational status is provided in Table 2.2, which shows that:

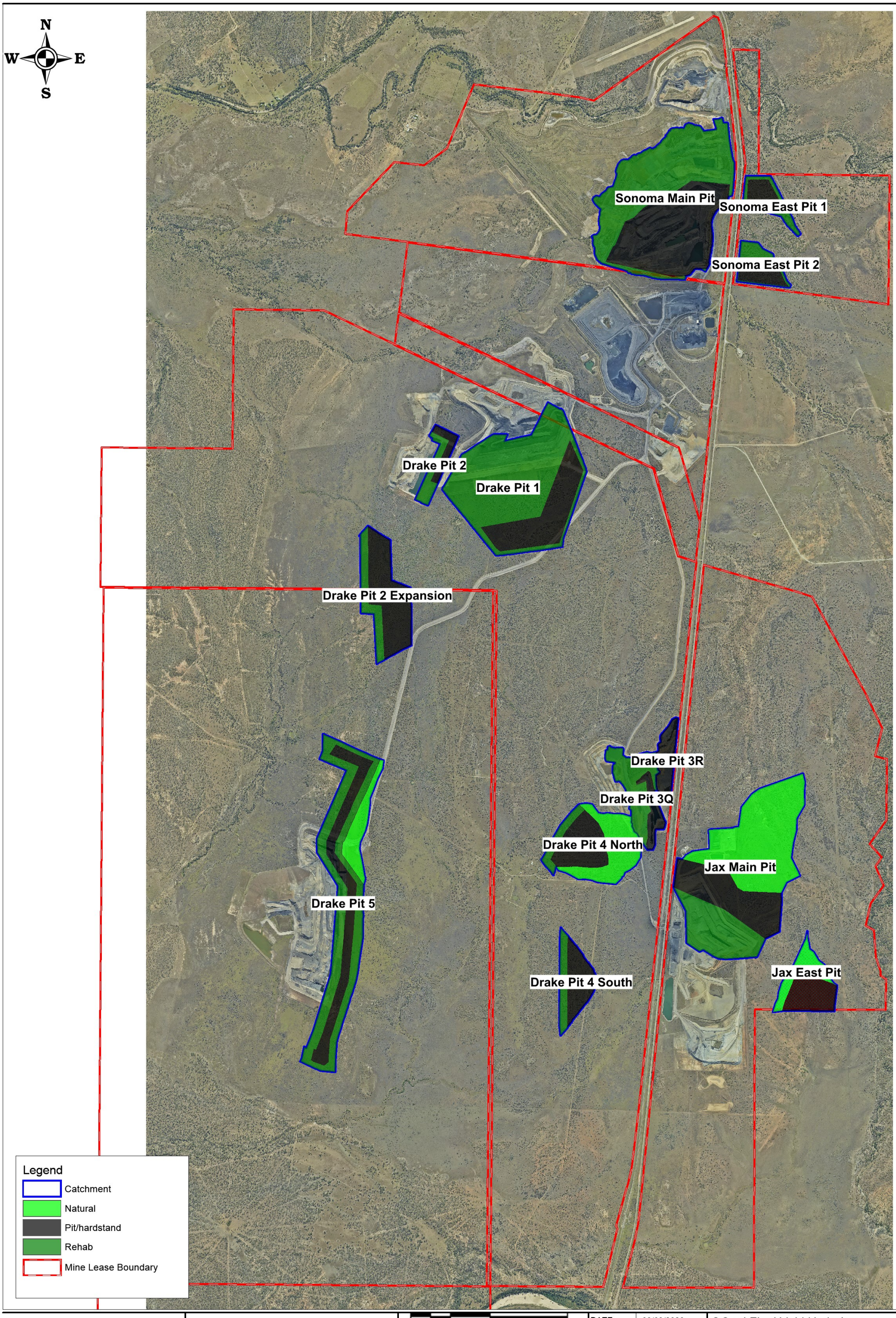
- DCM Central 3 is Drake Pit 4 North;
- DCM Central 4 is Drake Pit 4 South; and
- DCM East Pit 1 void as approved in the EA has not been modelled as a discrete void for the purposes of this assessment as it was considered that any potential development of East Pit 1 would be more likely as a small extension or satellite pit of Drake 1 Pit.

A site layout is presented in Figure 2.1 and identifies the locations of the proposed residual voids modelled in this assessment.

Table 2.2 Summary of Modelled QNH Residual Voids

Mine Site	Report ID	EIS ID	EA ID	Approved Residual Void Surface Area	Modelled Residual Void Surface Area	Current Status
SCM	Sonoma East Pit 1	Sonoma East Pit Complex	Sonoma East Pit 1	14 ha	14 ha	Planned
	Sonoma East Pit 2		Sonoma East Pit 2	15 ha	15 ha	Planned
	Sonoma Main Pit	Sonoma Main Pit	Sonoma Main Pit	120 ha	139 ha	Commenced
DCM	Drake Pit 1	West 2	Drake Pit 1	258 ha	64 ha	Commenced
	Drake Pit 2		Drake Pit 2		9 ha	Commenced
	Drake Pit 2 Expansion		Drake Pit 2 Expansion		60 ha	Planned
	Drake Pit 3Q	East 3	Drake Pit 3Q	61 ha	14 ha	Commenced
	Drake Pit 3R		Drake Pit 3R		21 ha	Commenced
	Drake Pit 4 North	Central 3	Central 3	66 ha	38 ha	Planned
	Drake Pit 4 South	Central 4	Central 4		28 ha	Planned
	Drake Pit 5	West 1	Drake Pit 5	59 ha	59 ha	Commenced
JCM	Jax Main Pit	N/A	Jax Main Pit	70 ha	69 ha	Commenced

Mine Site	Report ID	EIS ID	EA ID	Approved Residual Void Surface Area	Modelled Residual Void Surface Area	Current Status
	Jax Pit East	N/A	Jax East Pit	27 ha	28 ha	Planned



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meters
0 900 1800
Scale in metres (1:45,000 @ A3)
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994 (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

DATE	09/03/2020
DRAWN	NG
CHECKED	AH
JOB NO.	M4100_041

QCoal Final Void Hydrology
QNH Mine Site
Final Void Location and Catchment

A3 | Figure 1.1 | 0

2.4 Residual Void Requirements and Outcomes

The EAs for SCM, DCM, CCM and JCM also stipulate general rehabilitation requirements and outcomes for voids (stated as Condition H13 in each EA):

- Condition H13 Residual Void Outcome (all QNH EAs)

  Residual Voids must comply with the following outcomes:
  a) Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority;
  b) residual voids must comply with Table H1: Residual void outcomes;
  c) At the completion of decommissioning and rehabilitation, all voids must demonstrably have the appropriate level of flood protection from nearby watercourses as approved by the administering authority, such that the protection is sustainable for the foreseeable future.

The JCM EA also includes some more specific detail regarding the outcomes for the two approved voids (stated in JCM EA Table H1), which the SCM, DCM and CCM EAs do not. The JCM EA Table H1 includes the following void outcome statement:

- Table H1 JCM EA

  Void Outcomes for Jax Main Pit and Jax East Pit: Residual Void unable to sustain a Post Mining Land Use.

2.5 Mine Planning and Residual Void Concepts

The residual void locations and extents for current and proposed pits were determined based on the following documents:

- DCM EIS (2012).
- LOMP – outlines the mining operations and extent of disturbance within existing as well as proposed mining pits for the remainder of the mine life. This was used to determine the geographical location of the residual voids.
- LDP – a 5-year plan (FY20 to FY24) developed by QCoal which was used to determine the direction of mining progression within the disturbed extent.
- EAs – for each respective mine site. Approved residual void surface areas for each residual void were used as a guide to delineate void surface area at natural ground level.

An overview of the conceptual final landform for residual voids at each mine site is provided in the following sections.

2.5.1 SCM Residual Voids

- Sonoma Main Pit is located centrally within the SCM ML. Design final landforms including in-pit co-disposal have been provided by QCoal (August 2019) for two final scenarios. Option 1 involved in-pit co-disposal with a rejects embankment and Option 2 involved in-pit co-disposal without rejects embankment. Option 2 (refer Figure 2.2) has been assumed for this assessment. Both options remain under review by QCoal at the time of this assessment. Results presented in this document are for Option 2. It is noted that the landform provided to Engeny was for year 20 of in-pit co-disposal deposition and it is understood that the ultimate final landform of rejects deposition is estimated to be an additional 20m higher. Forecast void lake water levels determined in this assessment need to be translated up by a similar amount but remain representative of the final higher final landform surface.

- Sonoma North Pit is located in the north-east of the SCM ML. QCoal propose to backfill this pit and it will therefore will not remain as a residual void post-mine closure.

- Sonoma East Pit 1 and Sonoma East Pit 2 are planned for commencement within the next five years. It is not proposed to backfill either pit and therefore both are expected to remain as residual voids.

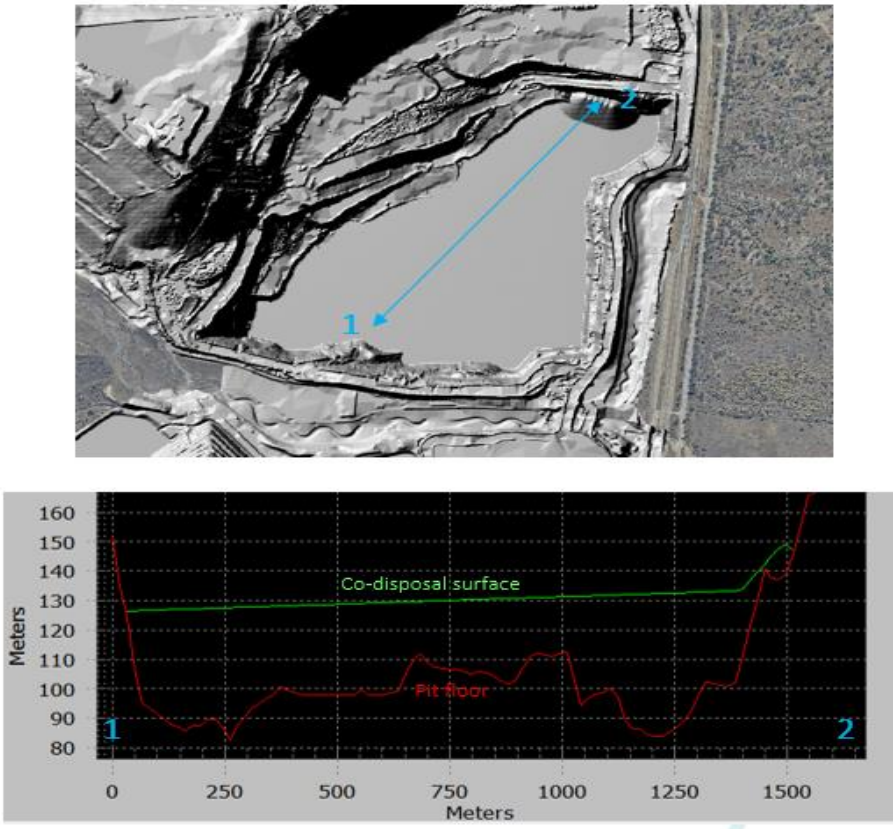


Figure 2.2 Year 20 Proposed Sonoma Main Pit Residual Void Landform (Option 2)

2.5.2 CCM Residual Voids

- Q Pit was in the south-east corner of the SCM/CCM mines and spanned the SCM and CCM MLs. Q Pit has been fully backfilled. A small sediment dam (Q Pit Sediment Dam) has since been constructed on the SCM ML portion of the backfilled void.

- B Pit operation (referred to as the Cows Pit in various other documents) spans the SCM and CCM MLs, and transitions into the Drake 1 Pit to the south on the DCM ML. B Pit void on the SCM and CCM MLs has been backfilled.

There are no residual voids proposed on the CCM mine lease.

2.5.3 DCM Residual Voids

- Drake Pit 1 void is located at the northern extent of the DCM abutting the CCM ML boundary and is the southern progression from B Pit into the north of DCM.

- Drake Pit 2 is immediately to the west of Drake 1 Pit.

- Drake Pit 2 Expansion is a proposed residual void to the south-west of Drake 1.

- Drake Pit 3R is located on the eastern boundary of the mine lease approximately 5 km south of Q Pit.

- Drake Pit 3Q is located on the eastern boundary of the mine lease immediately south of Drake 3 R Pit.

- Drake Pit 4 North and Drake Pit 4 South are two additional proposed residual voids within DCM.

- Drake Pit 5 is located in the south- western portion of DCM.

- East Pit 1 remains an approved void but as describe in Section 2.3 is likely to be amalgamated as part of the broader Drake Pit 1, Drake Pit 2 and Drake Pit 2 Expansion complex.

It is not currently planned to backfill any of the DCM pits and therefore all above mentioned DCM pits will remain as residual voids. It is noted that a new pit called Drake Pit 3Q South is included in the DCM life of mine plan, however it has not been included in the residual void hydrology assessment. As advised by QCoal, there is not sufficient planning data to inform an assessment of Drake 3Q South Pit at this time. It may be assessed at a future date when planning has further progressed.

2.5.4 JCM Residual Voids

- The JCM Main Pit void is located centrally within the JCM mine lease. QCoal is not planning to backfill the JCM Main Pit and it is planned to remain as a residual void.

- Jax East Pit has not yet commenced, and the timing of mining commencement has not yet been confirmed. It is planned to remain as a residual void.

A residual void hydrology assessment for Jax Coal Mine was previously undertaken *(Engeny, November 2018).* The proposed final landform has not changed since that study was undertaken. Minor changes to groundwater levels and recovery curves were reported in the updated groundwater assessment (AGE, 2020) however these changes were not material to residual void outcomes. Consequently, the previous Jax pits void assessment outcomes remain suitable and have not been updated.

2.6 Storage Characteristics

It has been assumed that existing storage curves of operational pits at their current layout is suitable to represent pit geometry of their respective residual voids. Storage curves for pits which have not yet commenced were estimated based on the geometry of existing pits of similar size. The process for adapting storage curves to new locations involved the following steps:

- Comparison of approved residual void areas to the surface area (at crest level) of existing pit voids to identify an appropriate pit to represent the future residual void storage characteristics.

- Transpose the adopted storage curve vertically such that the crest level corresponds to the natural ground level at the location of the planned residual void.

The assumed final landform storage curves of existing and proposed residual voids along with their respective storage capacities are summarised in Table 2.3. Plots of adopted storage curves are provided in Appendix A. Storage curves for any final void planning or assessment are an area of uncertainty as actual final storage curves will not be possible to determine until mining has been completed, and any low-wall/high-wall rehabilitation requirements have also been completed. The adopted curves are the best available estimate of the residual void storage characteristics based on currently available mine planning information and are considered suitable for the purposes of this assessment.

Table 2.3 Assumed Residual Void Storage Curves

Residual Void	Adopted Storage Curve	Storage Capacity (ML)
Sonoma Main Pit	In-pit co-disposal without reject wall (Design)	45,151
Sonoma East Pit 2	Jax Pit (survey 2013)	2,009
Sonoma East Pit 1	Jax Pit (survey 2013)	1,788
Drake Pit 1	Drake Pit 1 (survey 2019)	18,323

Residual Void	Adopted Storage Curve	Storage Capacity (ML)
Drake Pit 2	Drake Pit 2 (survey 2019)	1,711
Drake Pit 2 Expansion	Drake Pit 1 (survey 2019)	15,824
Drake Pit 3Q	Drake Pit 3Q (survey 2019)	2,326
Drake Pit 3R	Drake Pit 3R (survey 2019)	1,254
Drake Pit 4 North	Jax Pit (survey 2019)	6,160
Drake Pit 4 South	Jax Pit (survey 2019)	3,708
Drake Pit 5	Drake Pit 1 (survey 2019)	13,996

2.7 Catchment Delineation

The contributing catchment to each residual void has been determined using the following data:

- Drone survey dated August 2019.
- LOMP polygons (supplied by QCoal 11/10/2019).
- EA conditions determining maximum residual void footprints (refer Table 2.1).
- Site wide aerial survey dated July 2014.
- Aerial photography dated June 2019.

It has been assumed that all out-of-pit spoil areas will be rehabilitated following the cessation of mining. The adopted catchments for QNH residual voids are presented in Figure 2.1. Based on the final landform criteria defined in the site EAs (refer Table 2.1) and the anticipated maximum landform heights (LOMP), it is estimated that approximately a 100 m width of the low wall batter will drain to the residual void while all remaining rehabilitated catchment will be diverted by grading the dump away from the void.

Where diversion of upslope natural catchment can be achieved with minor drainage works (i.e. shallow drains and bunds) it has been assumed that these works would be incorporated into the final landform. Where more significant infrastructure would be required to divert upslope catchment, it has been conservatively assumed to report to the residual void in the base case scenario with an optimised catchment scenario discussed in Section 2.7.1.

A summary of the contributing catchment areas for the base scenarios is provided in Table 2.4

Table 2.4 Contributing Catchment Area for Residual Voids (Base Case)

Mine Site	Residual Void	Catchment Area (ha)
SCM	Sonoma East Pit 1	25
	Sonoma East Pit 2	27
	Sonoma Main Pit	280
DCM	Drake Pit 1	240
	Drake Pit 2	22
	Drake Pit 2 Expansion	80
	Drake Pit 3Q	55
	Drake Pit 3R	21
	Drake Pit 4 North	97
	Drake Pit 4 South	42
	Drake Pit 5	191
JCM	Jax Main Pit	264
	Jax East Pit	49

2.7.1 Optimisation of Catchment

Catchment area is one of the key driving variables for residual void hydrology outcomes. Void catchment area was investigated as a driver in the equilibrium lake level, which informs a voids potential for seepage into the regional groundwater. For example, the conceptual Drake Pit 4 North residual void was identified during this assessment as a void where sections of the upslope catchment defined in the LOMP could be diverted around the void as an alternative to directing it into the void, thereby reducing the void lake level. The diversion concept is illustrated in Figure 2.3 and involves an excavated drain along the north-eastern side of Drake Pit 4 North to divert approximately 48 ha of undisturbed catchment.

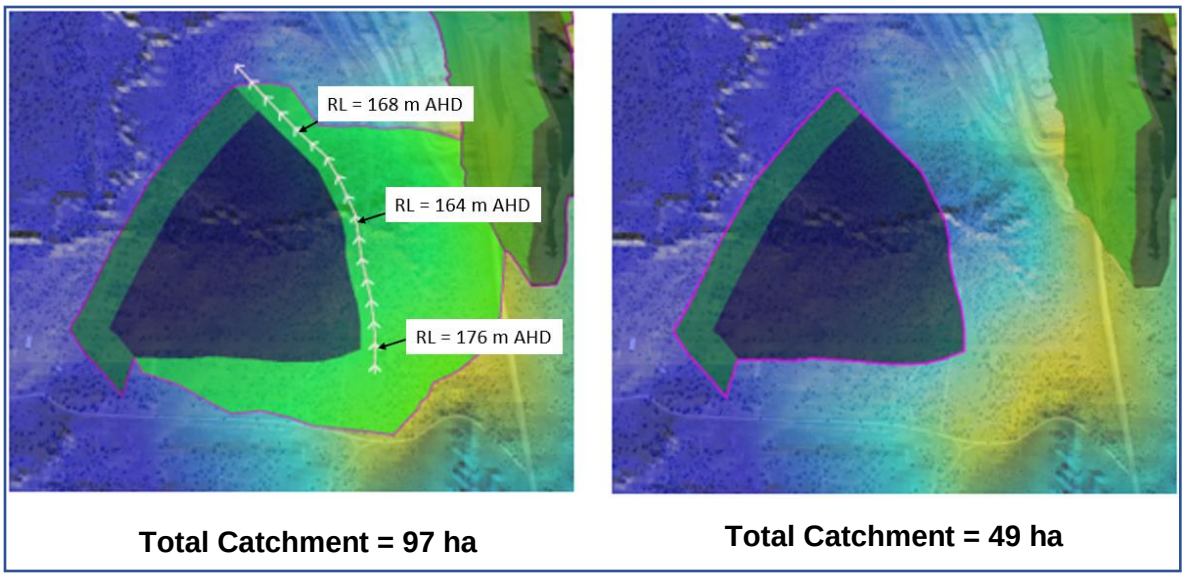


Figure 2.3 Drake Pit 4 North diversion concept (left) and mitigated catchment (right)

3. GROUNDWATER CONTRIBUTION

3.1 Groundwater Quantity and Interaction

Numerical groundwater modelling of the design residual voids was undertaken by AGE (March 2020) to predict groundwater recovery after the cessation of mining. From the model, a rating curve of groundwater inflow versus pit water level for each residual void was developed (Refer to Appendix B). It is noted that the range of the groundwater recovery curves is limited by the water levels simulated in the groundwater model. Where required, the final value of the groundwater recovery curves have been conservatively maintained for the remainder of the adopted void storage curves.

Negative flows shown in the groundwater recovery curve figures indicate the elevation of water level within the lake at which point a net outflow from the void lake can potentially occur. **Any modelled outflows from a void lake resulting from these portions of the groundwater recovery curves need to be interpreted with care and may not necessarily indicate flows to the surrounding regional groundwater system**. In particular, through discussion with AGE, it is understood that the adopted groundwater recovery curves are impacted by the following processes:

- Interaction between residual void lakes located in close proximity such as hydraulic gradients between void lakes resulting in flow from one void lake to another **which is not considered to be flow into the surrounding regional groundwater** (e.g. between Sonoma East 1 and Sonoma East 2 and between Drake 3Q and Drake 3R). It is noted that the modelled flow rates in these situations are generally of very small magnitude.

- Outflows from the void lakes into the surrounding spoil material. The numerical model makes no distinction between outflows from the void lake into the low-wall backfill waste rock material and outflows into the regional groundwater system. As such a modelled outflow as determined by the model may be associated with the saturation period of the low-wall wast rock until such time as steady state equilibrium is reached. This primarily occurs during the initial recovery period when the spoil material is first becoming saturated.

The interaction between the residual void lake and surrounding regional groundwater (be it net inflow or outflow) considers a range of indicators including:

- Base of Weathering – the threshold between highly weathered material and less permeable hard rock. The Base of Weathering provides an indication of areas where seepage from a void lake into the surrounding geology might occur if lake levels are forecast to exceed this threshold. Again such seepage is not immediately representative of a groundwater source into regional groundwater.

- Regional Groundwater Level – when the regional groundwater level exceeds the forecast void lake level then there is a hydraulic gradient into the void and the void is considered to act as a groundwater sink. Alternatively, a void lake level that is forecast

to be above the regional groundwater level may result in a hydraulic gradient out of the void into the surrounding geology (a net outflow). However, localised outflow from a source pit has the potential to be captured by a down-gradient pit acting as a global sink in which case would not be representative of a source to the regional groundwater. This process can be identified through hydrogeological modelling.

- Net Zero Flow Level – This level has been extracted from the groundwater recovery curves described in Section 3.1 and provides an indication of the direction of water fluxes to the void lake. As previously stated, outflows resulting from these recovery curves need to be interpreted with care as they may represent movement from one void (an net outflow) to an adjacent void which is a groundwater sink (a net inflow) thus containing void water from both voids (considered as movement within a groundwater sink system), or movement of water into unsaturated low wall spoil material, as opposed to an actual flow into the regional groundwater system.

AGE (2020) has provided a summary of these indicator levels for each of the residual voids as summarised in Table 3.1.

Table 3.1 Base of Weathering and Regional Groundwater Levels

Mine Site	Residual Void	Base of Weathering (mAHD)	Pre- mining Regional Groundwater Level (mAHD)	Net Zero Flow Level (mAHD)
SCM	Sonoma East Pit 1	155.80	156.30	Inflows at all levels
	Sonoma East Pit 2	156.92	155.53	Outflows at all levels
	Sonoma Main Pit	153.02	155.67	8.23
DCM	Drake Pit 1	169.07	146.57	Inflows at all levels
	Drake Pit 2	153.4	147.23	100.11
	Drake Pit 2 Expansion	163.99	144.24	Inflows at all levels
	Drake Pit 3Q	161.28	142.55	Inflows at all levels
	Drake Pit 3R	156.72	141.78	83.15
	Drake Pit 4 North	126.96	139.50	Inflows at all levels
	Drake Pit 4 South	146.72	136.71	Inflows at all levels
	Drake Pit 5	144.39	137.42	Inflows at all levels

3.2 Groundwater Quality

Monitoring of groundwater quality across a number of monitoring bores at QNH is undertaken on a quarterly basis. The groundwater quality data has previously been assessed as part of the *SCM Final Void Hydrology Study Main Pit* (Engeny, 2015) and *CCM Final Void Hydrology Study Q Pit and B Pit* (Engeny 2017). Both studies determined a representative groundwater inflow quality of 2,000 µS/cm. A consistent quality was been adopted for the *JCM Final Void Hydrology Study Jax Main Pit and Jax East Pit (Engeny, November 2018)* is considered suitable for the purposes of this assessment.

4. WATER BALANCE MODEL DEVELOPMENT

4.1 Overview

Engeny has previously developed a water balance model of the QNH mines using the GoldSim software. The development of the model, input parameters and calibration are detailed in *Water Management Plan QNH Mines* (Engeny, 2020). The existing model has been adopted as a basis for this assessment.

4.2 Residual Void Inflows and Outflows

The water balance of the residual voids will be governed by the following water inflows and outflows:

- Inflows:
  - Surface runoff inflows from rehabilitated spoil areas that drain to the void.
  - Surface runoff inflows from the walls and ramps of the void.
  - Inflows from incident rainfall on the void lake.
  - Groundwater inflows to the void (if the void lake level is lower than the regional groundwater level) (refer to Section 3).
- Continuous Outflows:
  - Outflows due to evaporation losses from the surface area of the void lake.
- Potential Outflows (conditional on void lake level):
  - Seepage outflows from the void lake – either to an adjacent groundwater sink void, into the unsaturated low-wall waste rock dump or into the regional groundwater (if the void lake level is higher than the regional groundwater level).
  - Discharges to surface water (only if the void fills to spill level).

4.2.1 Runoff Generation

Catchment runoff has been simulated using the Australian Water Balance Model (AWBM). The model represents the catchment using three conceptual surface stores to simulate partial areas of runoff. The water balance of each surface store is calculated independently of the others. The model calculates the water balance of each partial area at daily time steps. At each time step, rainfall is added to each of the three surface stores and evapotranspiration is subtracted from each store. If the value of water in the store exceeds the capacity of the store, the excess water becomes runoff. Part of this runoff becomes recharge of the baseflow store if there is a baseflow component to the stream flow.

AWBM parameters were adopted from the existing QNH operational water balance model (as for *Water Management Plan QNH Mines* (Engeny, 2020)). These parameters are as summarised in Table 4.1.

Table 4.1 Adopted AWBM Runoff Parameters

Parameter	Natural	Hardstand & Pits	Rehabilitated Spoil
C1 (mm)	23.0	5.0	10.0
C2 (mm)	125.0	20.0	120.0
C3 (mm)	180.0	40.0	180.0
A1	0.134	0.134	0.134
A2	0.433	0.433	0.433
A3	0.433	0.433	0.433
BFI	0.05	0.00	0.35
Kb	0.87	0.60	0.60
Ks	0.30	0.10	0.10
Average Soil Store (mm)	135	27	131
Average Annual Runoff Coefficient	14%	36%	16%

4.2.2 Climate Data

Long-term daily rainfall data at the QNH was obtained from the SILO climate database facility hosted by the Queensland Department of Environment and Science (DES). SILO includes both Patched Point Data and Data Drill. The Data Drill utilises grids of data interpolated from point observations by the Bureau of Meteorology to provide climate statistics for a specified location. Patched Point Data is only available at selected rainfall stations and utilises grids of data to 'patch' any data gaps in the climate record at that site.

A SILO Patched Point Data climate series was obtained for the nearby Collinsville Post Office (33013) covering the period January 1889 to September 2019. A composite data set was obtained by merging the SILO data with SCM site rainfall to obtain a continuous record from January 1889 to September 2019 (130 years of data).

Table 4.2 Residual void Hydrology Assessment Climate Data

Month	Mean Rainfall (mm)	Mean Morton's Lake Evaporation (mm)	Mean Evapotranspiration (mm)
January	156	198	195
February	144	170	162
March	99	171	164
April	37	139	133
May	31	110	107
June	32	89	89
July	20	100	100
August	17	127	127
September	15	158	162
October	24	196	199
November	55	205	207
December	98	214	212
Total	727	1875	1857

Corrections to the lake evaporation rates were applied in the residual void water balance model to reflect the reduction to the freshwater evaporation rate that occurs for a saline water body. Morton's method for adjusting evaporation rates has been adopted as presented in *Hydrological Recipes: Estimation Technique in Australian Hydrology (1996)* as follows:

- Evaporation reduction factor = 1 / [1+TDS (mg/L)/10^6]

This equation predicts a relatively small evaporation correction for salinity of approximately 1% reduction per 10,000 mg/L total dissolved solids (TDS) for TDS values up to 50,000 mg/L (i.e. 5% reduction for 50,000 mg/L TDS).

4.3 Water Quality

4.3.1 Salinity EC Conversion

Electrical conductivity (EC) and Total Dissolved Solids (TDS) are key indicators of water quality and can be simulated within the residual voids water balance model. The model directly simulates TDS using a salt mass balance and converts to EC via a constant conversion factor (1 mg/L TDS = 1.49 µS/cm EC) (ANZECC & ARMCANZ, 2000). Water quality inputs to the water balance model have been reviewed and are summarised in the following sections.

4.3.2 Rainfall Dependent Salt Mass Inputs

Salinity of runoff generated in the water balance is determined based on land use type. Surface water runoff TDS characteristics have previously been calibrated for certain land use types as documented in *Water Management Plan QNH Mines* (Engeny, 2020). These runoff TDS characteristics have been adopted for the modelling of all voids in this void hydrology study and are summarised in Table 4.3.

Table 4.3 Water Source TDS Concentration (mg/L)

Source	Salinity (mg/L)
Pit wall runoff	1300 (1,931 µS/cm EC)
Rehabilitated Spoil runoff	700 (1,040 µS/cm EC)
Natural catchment runoff	700 (1,040 µS/cm EC)
Direct rainfall	5 mg/L, based on latitude and distance from the coast (DNR, 1997)

4.3.3 Potential for Stratification

Due to the depths of the residual void lakes and the likely thermal gradients, the lakes are considered to have a potential for stratification which is a well understood hydrological occurrence. This is likely to occur on a seasonal cycle with stratification in the warmer summer months followed by mixing in the cooler winter months or under climatic conditions that would promote the turnover of the void lake stratification (e.g. strong winds).

For the purpose of the model, runoff entering the residual voids was assumed to be fully mixed with the existing stored water. This does not account for the potential stratification of water quality within voids. Assuming complete mixing of the void lake contents will provide an average salinity in the void lake over the simulation period and is considered suitable for the purposes of this assessment.

4.4 Model Assumptions

The following key assumptions were applied in the water balance modelling:

- Water outflows associated with the saturation of the spoil in the backfilled voids (typically during first filling conditions) are indirectly captured in the groundwater recovery curves and as such not explicitly represented in the water balance model. The model results are indicative of void lake behaviour after the backfill material becomes saturated.
- All residual voids were assumed empty at the start of simulation.
- The void lakes are fully mixed (i.e. no stratification). Water quality results indicate the average salt concentration of the entire void lake.
- The salinity of runoff from rehabilitated spoil was assumed to be consistent with undisturbed natural runoff.
- Storage curves and catchment areas have been inferred from the best available mine planning information. Adopted storage curves are assumed to be representative of proposed residual voids.
- All spoil stockpiles, backfilled areas and regraded pit walls were assumed to have the runoff quantity and quality characteristics of rehabilitated spoil.

5. MODEL RESULTS

The residual void hydrology water balance model was simulated for a period of 200 years. The historical climate data set has been used to assess 130 potential realisations of the void lake behaviour under different climate sequences. The residual void hydrology assessment was completed for two scenarios as described below:

- Base Case Scenario - The base case has been adopted using catchment delineation methodology described in Section 2.7 and Table 2.4.
- Mitigated Case Scenario - The mitigated scenario has been modelled where there is an opportunity to reduce the catchment area reporting to the residual voids beyond what was provided in the LOMP designs – which are not intended to be to such a detailed level of drainage design (Refer to Section 2.7.1).

Forecast void lake performance indicators are defined in section 5.1 while an example of typical void lake behaviour is provided in section 5.2. Detailed model output plots are provided in Appendix C and Appendix D. A discussion of the key outcomes of the assessment is provided in Section 5.3.1 and Section 5.3.2.

5.1 Void Lake Performance Indicators

The key indicators of the hydrological behaviour of the void lakes for this assessment include:

- Void lake equilibrium level - The equilibrium level is defined as the forecast median level (50th percentile) after the rapid filling period. This is considered to be the level at which the void lake is most likely to sit with periodic fluctuations above and below. Equilibrium level is relatively stable in the long term following the initial rapid filling period.
- Void lake equilibrium volume – The equilibrium volume is defined as the volume corresponding to equilibrium level.
- Void lake maximum level – The maximum level is defined as the highest void lake level forecast during the simulation.
- Void lake filling time – The void filling time is defined as the initial period of filling of the void after cessation of mining until the lake reaches its equilibrium volume.
- Ponded area at equilibrium – Equilibrium level is determined by the balance between lake inflows (primarily catchment runoff) and outflows (primarily evaporation). The evaporation is governed by the ponded area of the lake based on the adopted storage curve. The ponded area at equilibrium has been reported to inform the suitability of the forecast results following more detailed refinement of the mine plan (i.e. the results presented are applicable when the contributing catchment, equilibrium level and ponded area at equilibrium are maintained), allowing for potential changes to void designs as per Section 2.3.

- Void lake water quality (EC) 200 years after cessation of operations – Void lake salinity has been reported at the end of the simulation to indicate the general trend of EC over time. The concentration of salts is forecast to increase beyond simulation period as there are negligible outflows of the salts from the residual voids.

- Residual void outcome - The void equilibrium and maximum level results have been compared with the groundwater interaction indicator levels (refer Section 3.1) to determine whether the void is likely to act as a groundwater 'sink' or a 'source'.

  - Sink - A groundwater 'sink' refers to a void which has modelled equilibrium and/or maximum levels lower than the regional groundwater level. The hydraulic gradient generated by this change in levels would result in groundwater ingress to the pit. It has been identified where lake levels are in close proximity to the regional groundwater level (within 2 m) or above the base of weathering as these outcomes may be impacted by uncertainties in model inputs.

  - Source - A groundwater 'source' refers to a void which has a net outflow of water from the void lake into the surrounding geology (generally identified by a water level above the regional groundwater level) where such outflow is not into the low-wall backfill material. In these cases, the hydraulic gradient would result in water within the pit seeping into groundwater systems.

A summary of the key void lake hydrology performance indicators are provided in Table 5.1 for the base case and mitigated catchment scenarios respectively.

5.2 Typical Void Lake Forecast Behaviour

An example of the void lake hydrology assessment results is provided in Figure 5.1 for level and Figure 5.2 for quality, for a typical residual void (i.e. Drake Pit 1).

Figure 5.1 presents the following key results for void lake water level:

- Minimum value on each day of the simulation period.

- Median (i.e. 50th percentile) value on each day of the simulation period. The median is indicative of the most likely value at any point in time (i.e. half the results are higher and half the results are lower) and has been used to define the equilibrium level.

- Maximum value on each day of the simulation period.

The information provided on Figure 5.1 provides the results of Drake 1 Pit void as n example of the typical behaviour of the void lake levels. The graph also features the key levels such as pit floor and pit crest level indicating the total depth of the pit and providing context for the void lake depth. The base of weathering level and pre-mining regional groundwater level (defined in Section 3.1) are also presented to assess the potential pit behaviour. The pre-mining regional groundwater level is a key level compared against the maximum pit lake level to demonstrate if the residual void will act as a "sink" or a "source", whereas, the base

of weathering level is used a secondary indicator to determine seepage through weathered material. Such a scenario can be when maximum void lake level is below pre-mining regional groundwater level but above the base of weathering level.

Key features illustrated on Figure 5.1 include:

- Void lake level will steadily rise over initial years following the cessation of mining (approximately 40 years in this example).
- The void lake levels are forecast to fluctuate over time as a result of prevailing climate conditions. The lake level fluctuates around an equilibrium level, which has been defined as the median lake level (approximately 126 m AHD in this example). The minimum and maximum forecast levels indicate the potential range of fluctuation in lake levels over time (120 m AHD to 134 m AHD in this example).
- The depth of the forecast lake levels relative to the groundwater interaction levels. In this example, the maximum void lake level (134 m AHD) is 12.6 m below the pre-mining regional groundwater level (146.6 mAHD) and 35.1 m below the base of weathering level (169.1 m AHD). This example residual void is therefore forecast to behave as a groundwater sink.

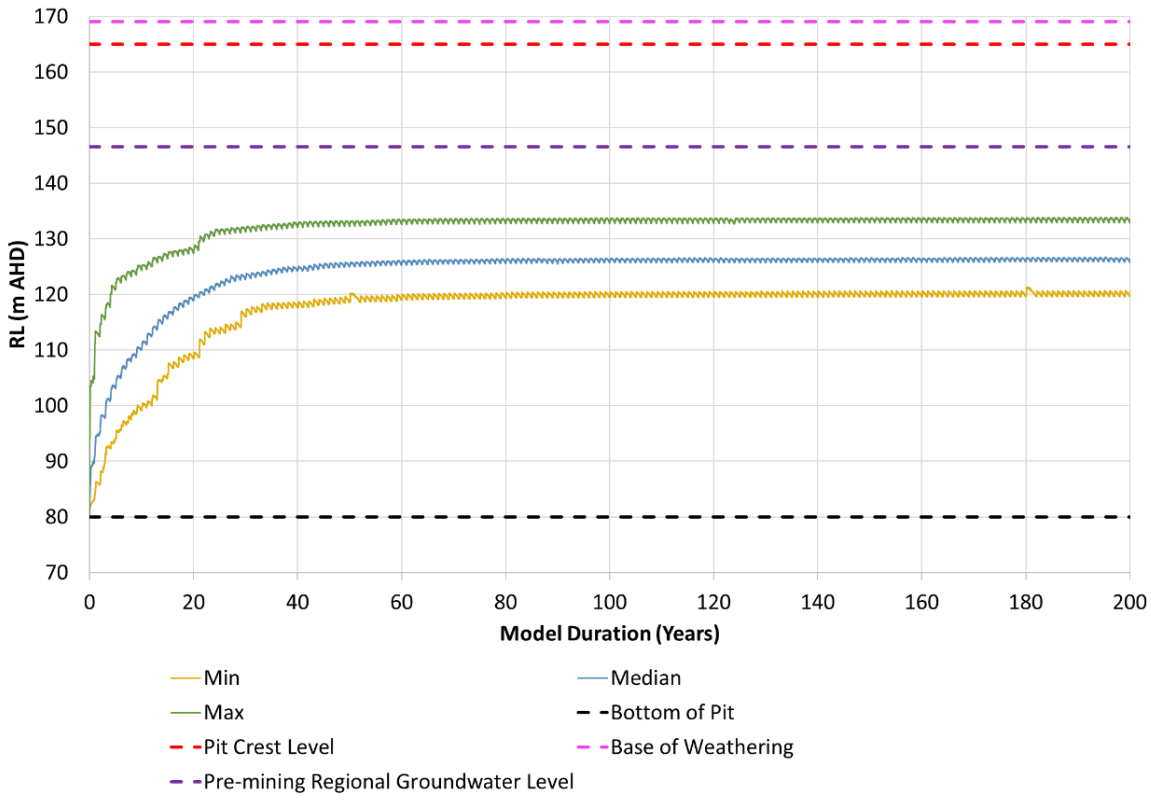


Figure 5.1 Example Void Lake Level Forecast

Figure 5.2 provides the results of water quality modelling for the Drake 1 Pit as an example of typical water quality behaviour of the void lakes. Key features illustrated include:

- The void lake salinity (EC) increases over the simulation period. This is a result of evaporation being the only significant outflow from the void lakes, which results in ongoing concentration of salts. In this example, the equilibrium void lake EC (i.e. the median value) at the end of simulation period is approximately 12,900 µS/cm.

- The forecast indicates an ongoing linearly increasing trend in void lake salinity. In this example, the equilibrium void lake EC is continuing to increase at a rate of approximately 130 µS/cm per year. **Ultimately salts will continue to concentrate with the maximum EC limited by solubility of the constituent salts within the lake – this is conceptually the case for any comparable water body which experiences an inflow where evaporation is the only outflow and occurs at a rate exceeding the inflow.**

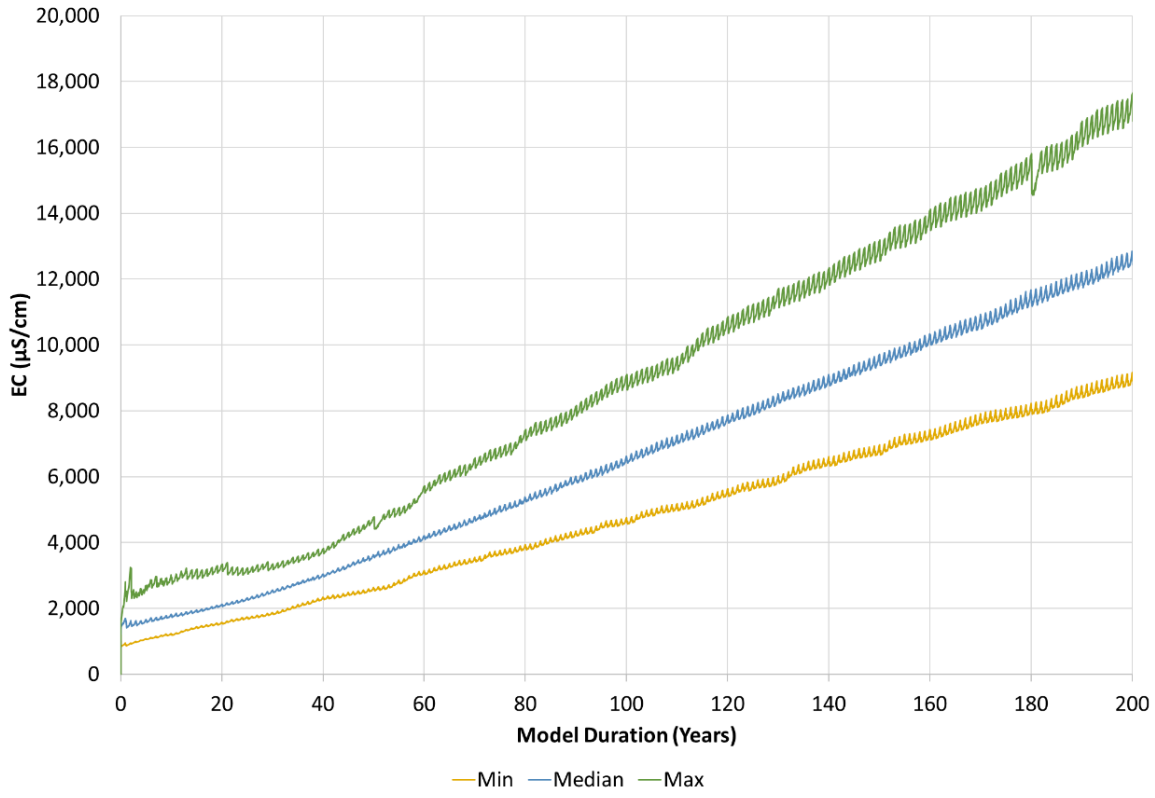


Figure 5.2 Example Void Lake Salinity (EC) Forecast

5.3 Modelling Results

The key model outputs for all QNH modelled voids are summarised in Table 5.1 for level and quality. A graphical representation of the forecast void lake level, volume and salinity for all QNH modelled voids are provided in Appendix C for base cases and Appendix D for mitigated cases.

Table 5.1 Residual Void Lake Results Summary (Base Case and Mitigated Case for Selected Voids)

Residual void	Catchment Area (ha)	Void Equilibrium Water Level (m AHD)	Maximum Water Level (m AHD)	Void Spill Elevation (m AHD)	Pre-mining Groundwater Level (m AHD)	Base of Weathering Level (m AHD)	Void Equilibrium Volume (ML)	Ponded area at Equilibrium (ha)	Void Equilibrium EC at 200 years (µS/cm)	Rate of Increase in EC (µS/cm/year)	Initial Void Filling Period (Years)
Sonoma East Pit 1 (Base Case)	25	158	164	176	156.30	155.80	322	4.6	46,352	493	20
Sonoma East Pit 2 (Base Case)	27	154	161	176	155.53	156.92	214	3.8	47,635	380	20
Sonoma Main Pit (Base Case)	280	150[1]	154[1]	171	155.67	153.02	587	49.2	266,030	1,787	5
Drake Pit 1 (Base Case)	240	126	134	165	146.57	169.07	5,245	27.3	12,896	130	40
Drake Pit 2 (Base Case)	22	139	145	164	147.23	153.40	74	2.3	12,282	15	10
Drake Pit 2 Expansion (Base Case)	80	124	131	168	144.24	163.99	1,601	13.0	33,008	310	30
Drake Pit 3Q (Base Case)	55	150	157	172	142.55	161.28	434	3.6	36,812	334	15
Drake Pit 3R (Base Case)	21	165	169	172	141.78	156.72	66	2.4	9,284	9	5
Drake Pit 4 North (Base Case)	97	133	140	155	139.50	127.96	961	11.7	37,665	394	20

Residual void	Catchment Area (ha)	Void Equilibrium Water Level (m AHD)	Maximum Water Level (m AHD)	Void Spill Elevation (m AHD)	Pre-mining Groundwater Level (m AHD)	Base of Weathering Level (m AHD)	Void Equilibrium Volume (ML)	Ponded area at Equilibrium (ha)	Void Equilibrium EC at 200 years (µS/cm)	Rate of Increase in EC (µS/cm/year)	Initial Void Filling Period (Years)
Drake Pit 4 North (Mitigated Case)	49	125	130				608	6.1	55,775	594	20
Drake Pit 4 South (Base Case)	42	131	136	152	136.71	146.72	401	6.6	62,509	606	20
Drake Pit 5 (Base Case)	191	111	119	138	137.42	144.39	4,237	21.6	14,007	140	60
Jax Main Pit [4] (Base Case)	264	110	118	165	140.8[2]/140[3]	149.78	7,999	28.4	4,940	30-100	80
Jax Main Pit [4] (Mitigated Case)	143	98	105				4,794	19.4	7,271	60	80
Jax East Pit [4] (Base Case)	47	104	112	165	135.2[2]/140[3]	146.72	1,086	6.9	12,547	30-100	80
Jax East Pit [4] (Mitigated Case)	41	103	110				923	6.6	14,415	130	45

Note 1: Levels have been shifted up 20m to represent additional 20m of co-disposal deposition

Note 2: Level as provided by AGE (2020)

Note 3: Level used in previous assessment (Engeny, 2018)

Note 4: JCM Final Void Hydrology Study (Engeny 2018)

Legend

	Void lake level is below the pre-mining regional groundwater level and base of weathering
	Void lake level is above pre-mining regional groundwater level

5.3.1 Levels

The key level findings for each residual void are summarised as follows:

- Sonoma East Pit 1 - The void lake equilibrium level (158 m AHD) and maximum void lake level (164 m AHD) are 1.7 m and 7.7 m above the pre-mining regional groundwater level (156.30 m AHD) respectively. The residual void is forecast to have ongoing net outflows to the local geology or regional groundwater.
    - The Sonoma East Pit 1 void lake level is forecast to be above the regional groundwater level and therefore may result in a hydraulic gradient out of the void into the surrounding geology (a net outflow). However, localised outflow from Sonoma East Pit 1 has the potential to be captured by a down-gradient pit acting as a global sink (for example, Sonoma Main Pit) and would therefore not be representative of a source to the regional groundwater. This process can be identified through hydrogeological modelling.
- Sonoma East Pit 2 - The void lake equilibrium level (154 m AHD) and maximum void lake level (161 m AHD) are 1.5 m below and 5.5 m above the pre-mining regional groundwater level (155.53m AHD) respectively. The residual void is forecast to have ongoing net outflows to the local geology or regional groundwater.
    - The Sonoma East Pit 2 void lake level is forecast to be above the regional groundwater level and therefore may result in a hydraulic gradient out of the void into the surrounding geology (a net outflow). However, localised outflow from Sonoma East Pit 2 has the potential to be captured by a down-gradient pit acting as a global sink (for example, Sonoma Main Pit) and would therefore not be representative of a source to the regional groundwater. This process can be identified through hydrogeological modelling.
- Sonoma Main Pit - The void lake equilibrium level (130 m AHD) and maximum void lake level (134 m AHD) are 25.7 m and 21.7 m below the pre-mining regional groundwater level (155.67 m AHD) respectively. These outcomes are based on the design landform surface at year 20. It is expected the final co-disposal surface will be as much as 20m higher than this level. The conservative addition of a further 20 vertical metres of rejects material can be expected to result in an equilibrium level of 150 mAHD and a maximum level of 154 mAHD which remain below the regional groundwater level.
    - As such the Sonoma Main Pit is expected to act as a groundwater sink; however as it will be subject to in-pit co-disposal of rejects it will behave differently to the other voids modelled and further consideration is recommended in the detailed mine planning for this void based on the in-pit co-disposal plan.
    - In addition, due the placement of rejects material within the void, the Sonoma Main Pit residual void geometry included a large predominantly flat surface. The void is forecast to behave as an evaporation pan and therefore periodically dries out to very minimal volumes.

- Drake Pit 1 - The void lake equilibrium level (126 m AHD) and maximum void lake level (134 m AHD) are 20.6 m and 12.6 m below the pre-mining regional groundwater level (146.57 m AHD) respectively. Therefore, the residual void is forecast to act as a sink.

- Drake Pit 2 - The void lake equilibrium level (139 m AHD) and maximum void lake level (145 m AHD) are 8.2 m and 2 m below the pre-mining regional groundwater level (147.23 m AHD) respectively. The residual void is forecast to act as a sink.

- Drake Pit 2 Expansion - The void lake equilibrium level (124 m AHD) and maximum void lake level (131 m AHD) are 20.2 m and 13.2 m below the pre-mining regional groundwater level (144.24 m AHD) respectively. Therefore, the residual void is forecast to act as a sink.

- Drake Pit 3Q - The void lake equilibrium level (150 m AHD) and maximum void lake level (157 m AHD) are 7.5 m and 14.5 m above the pre-mining regional groundwater level (142.55 m AHD) respectively. Therefore, the residual void is forecast to have ongoing net outflows to the local geology or regional groundwater.

  - The Drake Pit 3Q void lake level is forecast to be above the regional groundwater level and therefore may result in a hydraulic gradient out of the void into the surrounding geology (a net outflow). However, localised outflow from Drake Pit 3Q has the potential to be captured by a down-gradient pit acting as a global sink (for example, Jax Main Pit) and would therefore not be representative of a source to the regional groundwater. This process can be identified through hydrogeological modelling.

- Drake Pit 3R - The void lake equilibrium level (165 m AHD) and maximum void lake level (169 m AHD) are 23.2 m and 27.2 m above the pre-mining regional groundwater level (141.78 m AHD) respectively. Therefore, the residual void is forecast to have ongoing net outflows to the local geology or regional groundwater

  - The Drake Pit 3R void lake level is forecast to be above the regional groundwater level and therefore may result in a hydraulic gradient out of the void into the surrounding geology (a net outflow). However, localised outflow from Drake Pit 3R has the potential to be captured by a down-gradient pit acting as a global sink (for example, Jax Main Pit) and would therefore not be representative of a source to the regional groundwater. This process can be identified through hydrogeological modelling.

- Drake Pit 4 North – Using the catchment layout from the LOMP (the base case), the void lake equilibrium level (133 m AHD) and maximum void lake level (140 m AHD) are 6.5 m below and 0.5 m above the pre-mining regional groundwater level (139.50 m AHD) respectively. The equilibrium and maximum void lake level sit above the base of weathering (127.96 m AHD) which has been used as a secondary indicator for potential seepage out of the void lake. As such the base case modelling results indicate that this void may alternate between periods of net outflow and periods of acting as a sink, as the lake levels fluctuate over time.

- As discussed in Section 2.7.1 and Section 5, the LOMP is not optimised to consider catchment reduction or completed to a level of detail sufficient to consider specific drainage solutions. Accordingly, a review of catchment reduction options was undertaken which resulted in reduced catchment reporting the Drake 4 North Void (referred to as the mitigated option). The catchment mitigation is discussed in Section 2.7.1.
- The key outcomes for the mitigated case are summarised in Table 5.1. The mitigated void lake equilibrium level (125 m AHD) and maximum void lake level (130 m AHD) are 14.5 m below and 9.5 m below the pre-mining regional groundwater level (139.50 m AHD) respectively. Therefore, based on the primary indicator of void lake and groundwater interaction, the mitigated residual void is forecast to act as a sink.

- Drake Pit 4 South - The void lake equilibrium level (131 m AHD) and maximum void lake level (136 m AHD) are 5.7 m and 0.7 m below the pre-mining regional groundwater level (136.71 m AHD) respectively. The residual void is forecast to act as a sink.

- Drake Pit 5 - The void lake equilibrium level (111 m AHD) and maximum void lake level (119 m AHD) are 26.4 m and 18.4 m below the pre-mining regional groundwater level (137.42 m AHD) respectively. Therefore, the residual void is forecast to act as a sink.

- Jax Main Pit – Using the catchment layout for the LOMP (the base case) the void lake equilibrium level (110 m AHD) and maximum void lake level (118 m AHD) are 30.8-30 m and 22.8-22 m below the pre-mining regional groundwater level (140.8-140 m AHD) respectively. Therefore, the residual void is forecast to act as a sink.

  - As a measure of comparison a potential mitigated scenario was also modelled for a reduced catchment. The key outcomes for the mitigated case are also summarised in Table 5.1.. The mitigated void lake equilibrium level (98 m AHD) and maximum void lake level (105 m AHD) are 42.8-42 m below and 35.8-35 m below the pre-mining regional groundwater level (140.8-140 m AHD) respectively.
  - Conclusions as per JCM Final Void Hydrology Study Jax Main Pit and Jax East Pit (Engeny, November 2018).

- Jax East Pit – The void lake equilibrium level (104 m AHD) and maximum void lake level (112 m AHD) are 31.2-23.2 m and 36-28 m below the pre-mining regional groundwater level (135.2-140 m AHD) respectively. Therefore, the residual void is forecast to act as a sink. Conclusions as per *JCM Final Void Hydrology Study Jax Main Pit and Jax East Pit (Engeny, November 2018).*

  - As a measure of comparison a potential mitigated scenario was also modelled for a reduced catchment. The key outcomes for the mitigated case are also summarised in Table 5.1. The mitigated void lake equilibrium level (103 m AHD) and maximum void lake level (110 m AHD) are 32.2-25.2 m below and 37-30 m below the pre-mining regional groundwater level (135.2-140 m AHD) respectively.
  - Conclusions as per JCM Final Void Hydrology Study Jax Main Pit and Jax East Pit (Engeny, November 2018).

5.3.2 Quality

The salinity of all residual voids modelled as part of this assessment is forecast to continue to increase over time due to the ongoing concentration resulting from evaporation with no significant outflow of salts from either net outflows seepage or overflows. It should be noted that pits with net outflow to the regional groundwater were still shown to accumulate salts throughout the model duration (refer Appendix C). The flow rates to groundwater at all levels of rating curves for all pits (refer Appendix B) were significantly smaller in magnitude that flows associated with rainfall, runoff, and evaporation. This resulted in accumulation of salt in net outflow pits despite salt losses through groundwater mechanisms.

The results presented in Table 5.1 indicate significant variation in the EC of the different voids as a result of differing rates of concentration. However, all void lakes are forecast to exceed 10,000 µS/cm after 200 years (with the exception of Jax Main Pit). The overall water quality outcome is consistent for all void lakes (i.e. high levels of salinity that continue to increase over time).

The water quality forecast for the Sonoma Main Pit residual void exhibits characteristics not evident in other residual voids modelled at QNH in that modelled salinity at 200 years is an order of magnitude higher than any other modelled void. The proposed residual void for Sonoma Main Pit has a large, relatively flat surface produced by the co-disposal of tailings and rejects within the pit. Therefore, any ponding within Sonoma Main Pit is subject to very large evaporation surface areas. The void behaves much like an evaporation pan, with the volume of water within the void regularly reaching very low quantities. During drying periods, the remaining water in the void becomes highly saline as the void does not have any mechanisms (net outflow to groundwater or spills) for salt mass reduction.

The time for the void lakes to reach their equilibrium levels varies based on the ratio of catchment area to void volume. The shortest filling time is seen to be Sonoma Main Pit (5 years) while the longest is Jax Main Pit (80 years).

5.3.3 Ongoing Reliability of Results

It has been necessary to make a number of assumptions associated with the LOMP, which itself is expected to change as the QNH progresses (as discussed in Section 2.3). The accuracy of the results presented is inherently dependent upon the input data and assumptions. In particular, the relationship between contributing catchment area, equilibrium level relative to regional groundwater levels and ponded area at equilibrium level determines the residual void modelling results (i.e. sink or net outflow).

As noted previously in Section 2.3, Engeny has undertaken to conservatively asses the layout of final voids provided by QCoal, such that should minor changes to a void or pit complex occur over the life of QNH, this assessment can still be relied upon to inform impact assessments provided key hydrological modelling parameters are maintained (see Section 5.1).

6. UNCERTAINITY ASSESSMENT

The outcomes of numerical models are inherently dependent upon the quality of the inputs in addition to the modelling process itself. A qualitative uncertainty assessment has been completed on key input data that impacts the outcomes of the residual void lake hydrology and is presented in Table 6.1. Each data input has been assigned a quality rating based on confidence in the data, and whether the data is measured or estimated:

- High – measured data with a high level of confidence.
- Medium – measured data with a low level of confidence or estimated from data with a high level of confidence.
- Low – Estimated from data with a low level of confidence, or incomplete measured data.

Data inputs with a 'Low' quality rating and a 'High' impact rating are the greatest sources of uncertainty in the assessment. As seen in Table 6.1, the data input items with this Low/High combination are the pit geometry of residual voids that are yet-to-commence which is to be expected of any mining operation and the pre-mining regional groundwater level.

Table 6.1 Uncertainty Assessment – Residual Void Hydrology

Input	Primary Data Source	Data Quality Rating	Impact on Residual Void Results
130 years of climate data	SILO climate database facility hosted by Science Division of DES.	High	High
Catchment areas for storages	Based on mine plan polygons, survey dated 2014 and August 2019 provided by QCoal	High	High
Pit geometry: storage curves and maximum storage capacities for residual voids of existing pits	Based on existing pit geometry and survey dated August 2019 or design surfaces (e.g. SCM Main Pit). Residual void inferred to be similar to existing geometry.	Medium	High
Pit geometry: storage curves and maximum storage capacities for residual voids that are yet-to-commence	Based on comparison with existing pit geometry and void surface area	Low	High
Pre-mining regional groundwater level	Supplied by AGE from monitoring and numerical modelling	Low	High

Input	Primary Data Source	Data Quality Rating	Impact on Residual Void Results
Location of residual voids	Based on mine plan polygons provided by QCoal	Medium	Medium
Base of Weathering	Supplied by AGE from exploration data	Medium	Medium
Groundwater recovery curves	Supplied by AGE from numerical modelling	Low - Medium	Low

Pit geometry is critical for identifying the equilibrium level (i.e. the level at which the evaporative outflow from the ponded surface area balances the catchment inflows). The depth at which the equilibrium level and associated ponded area occur in relation to the regional groundwater level determines whether the residual void is expected to act as a sink or a source. However, it is understood that the final void geometry for an open cut coal mine pit which has yet to commence will always be an estimate, due to the changes which occur during the life of pit, in the economic which govern the pit activities (Section 2.3). As such the uncertainty level in this parameter is a normal expectation in void modelling of this kind.

The pre-mining regional groundwater level, as described in sections 3 and 5, is the primary reference level for determining whether a pit is a sink or source. The uncertainty associated with this input originates from the model and has been quantified with input from AGE.

The results of this assessment are considered suitable for determining overall final void hydrology outcomes (i.e. whether a void is a groundwater sink) for the purposes of assessing potential environmental impacts associated with the presence of the final voids.

All model outputs are improved with more accurate inputs and should further modelling of voids be required, additional refining of the inputs would assist in improving the model.

7. CONCLUSIONS

The residual void assessment has demonstrated the following key outcomes:

- None of the void lakes assessed were modelled to overtop to the receiving environment in any climate scenarios.
- The salinity of the residual void lakes is forecast to increase over time as evaporation results in on-going concentration of salts. Water quality in all voids is expected to continue to worsen beyond the 200 year modelled time frame with solubility being the limit on increasing salinity.
- Four (4) residual voids were forecast to have ongoing net outflows to surrounding geology:
  - Sonoma East Pit 1
  - Sonoma East Pit 2
  - Drake Pit 3Q
  - Drake Pit 3R
- Nine (9) residual voids were forecast to act as groundwater sinks:
  - Sonoma Main Pit
  - Drake Pit 1
  - Drake Pit 2
  - Drake Pit 2 Expansion
  - Drake Pit 4 North (mitigated scenario)
  - Drake Pit 4 South
  - Drake Pit 5
  - Jax Main Pit
  - Jax East Pit
- Key areas of uncertainty were identified to be the pit geometry for voids which have not yet commenced as well as with the reported regional groundwater levels.

The residual void forecast outcome in ascending order of depth below regional groundwater are presented in Table 7.1.

Table 7.1 Residual Void Forecast Outcome

Residual void	Modelling outcome	Maximum lake level comparison to pre-mining groundwater level
Jax Main Pit	Sink	35.8 m below pre-mining GW Level
Jax East Pit	Sink	25.2 m below pre-mining GW Level

Residual void	Modelling outcome	Maximum lake level comparison to pre-mining groundwater level
Drake Pit 5	Sink	18.4 m below pre-mining GW Level
Drake Pit 2 Expansion	Sink	13.4 m below pre-mining GW Level
Drake Pit 1	Sink	12.6 m below pre-mining GW Level
Drake Pit 4 North (mitigated)	Sink	9.5 m below pre-mining GW Level
Drake Pit 2	Sink	2 m below pre-mining GW Level
Sonoma Main Pit	Sink	1.7m below pre-mining GW Level
Drake Pit 4 South	Sink	0.7 m below pre-mining GW Level
Sonoma East Pit 2	Net outflow	5.4 m above pre-mining GW Level
Sonoma East Pit 1	Net outflow	7.7 m above pre-mining GW Level
Drake Pit 3Q	Net outflow	14.4 m above pre-mining GW Level
Drake Pit 3R	Net outflow	27.2 m above pre-mining GW Level

8. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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g. This report does not provide legal advice.

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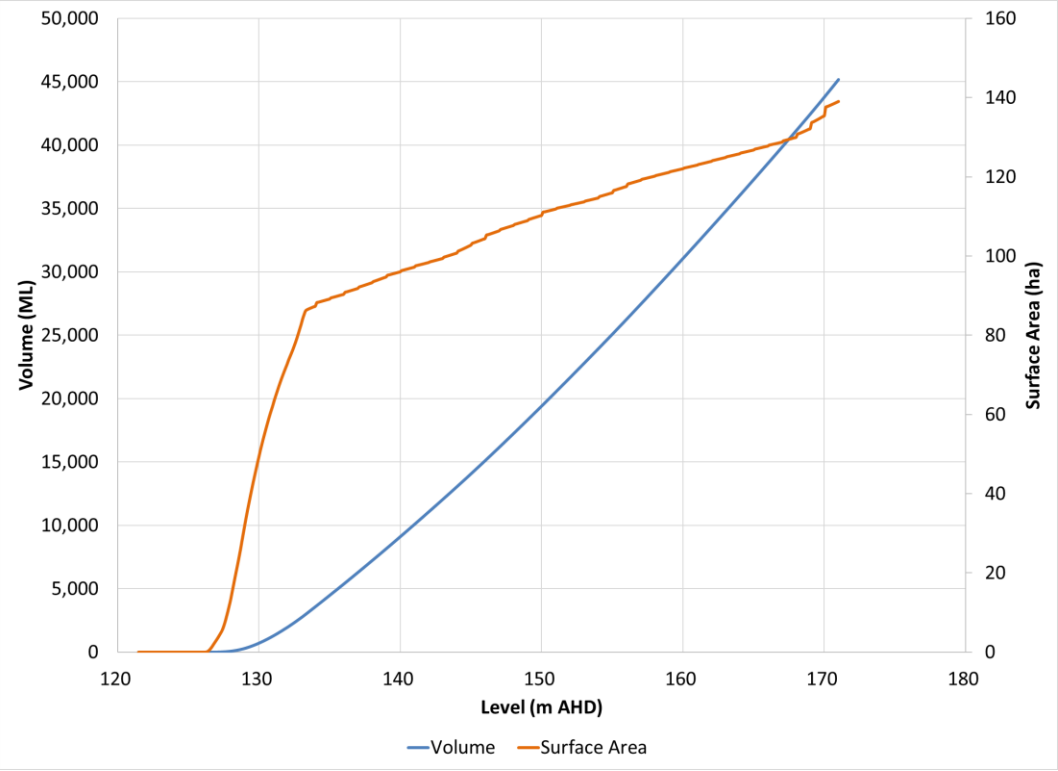
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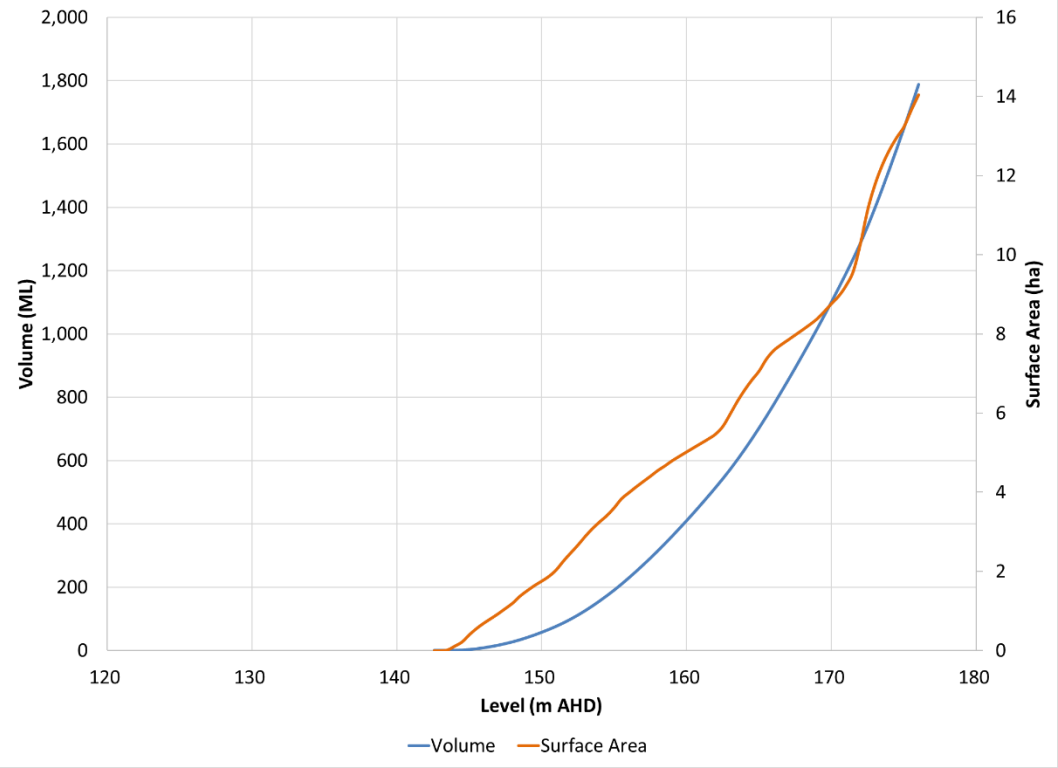
Appendix A

Residual Void Storage Curves

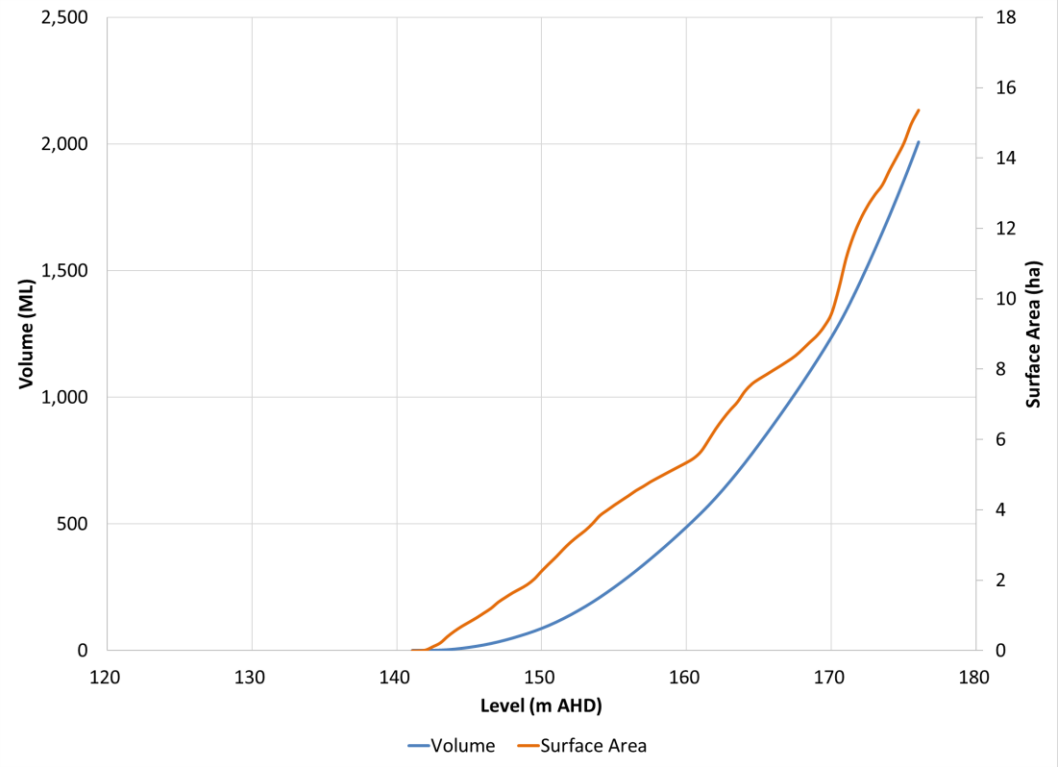
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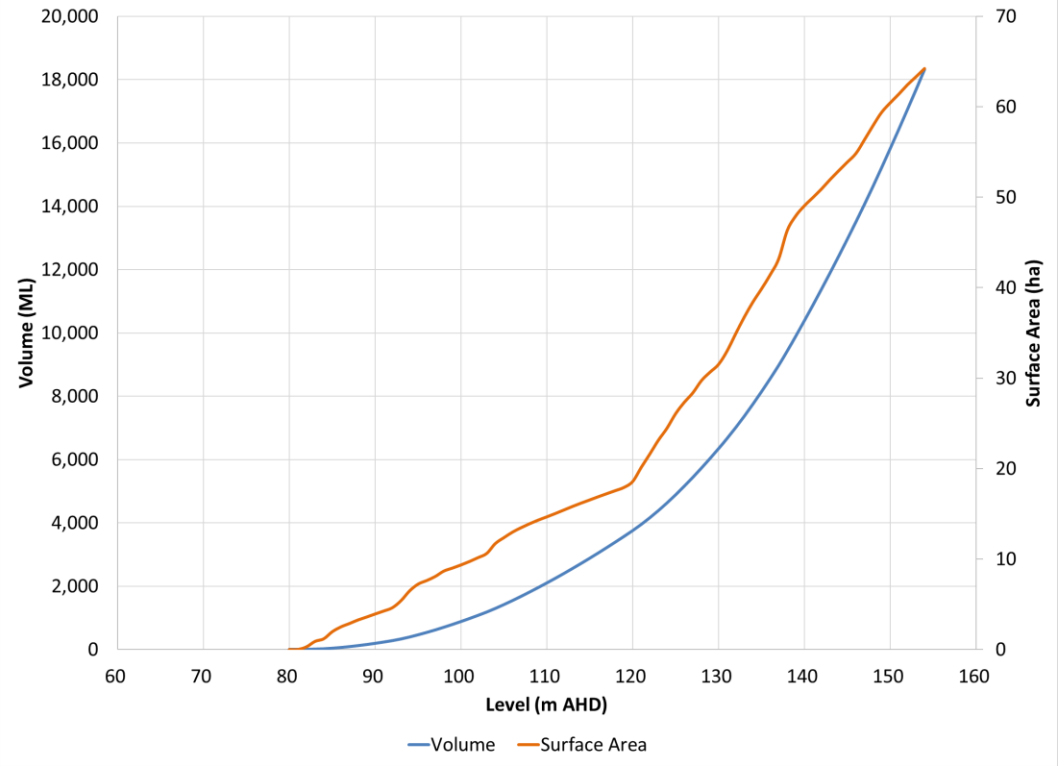
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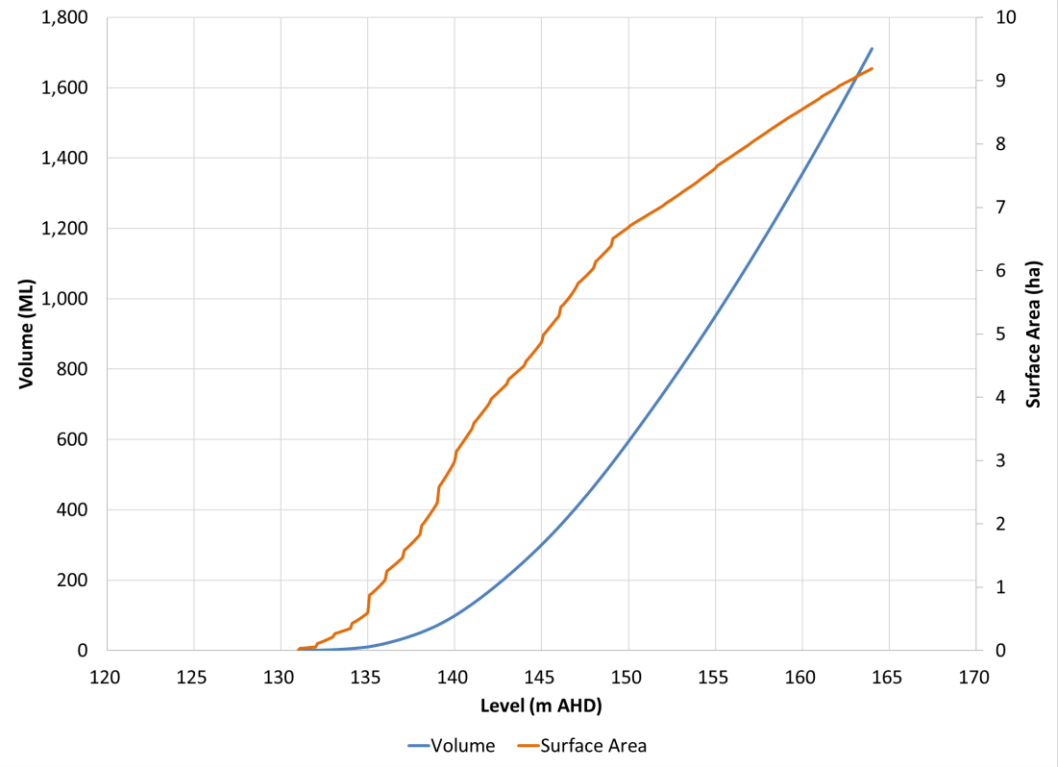
Sonoma East Pit 2



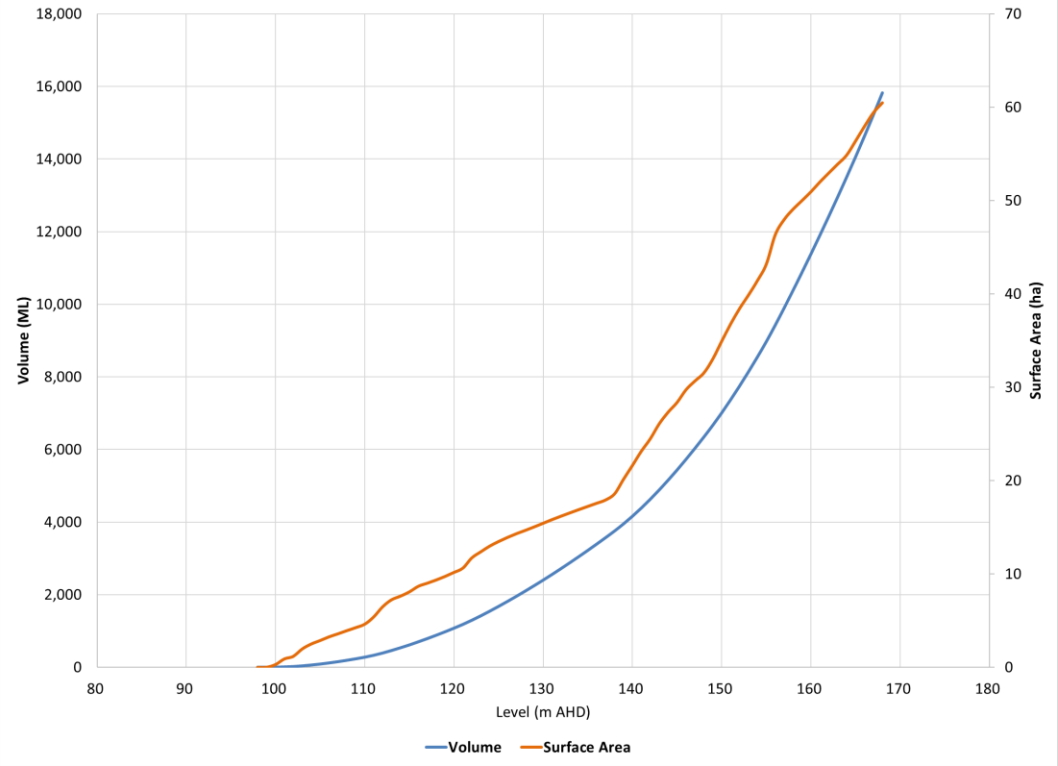
Drake Pit 1



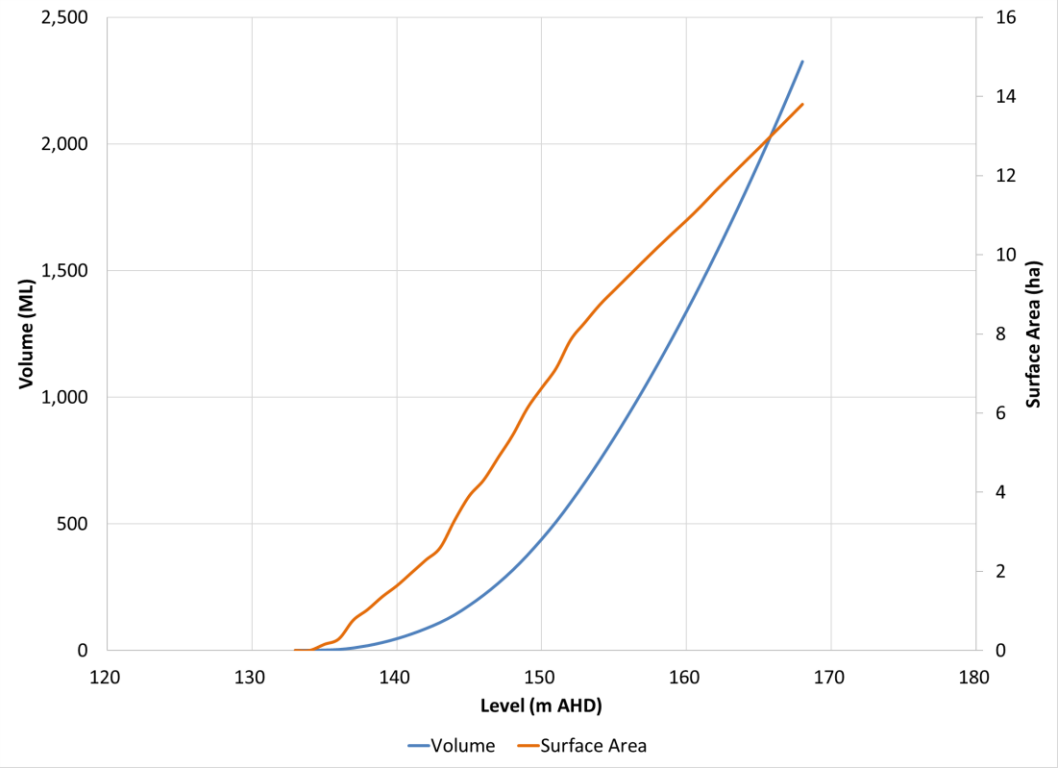
Drake Pit 2



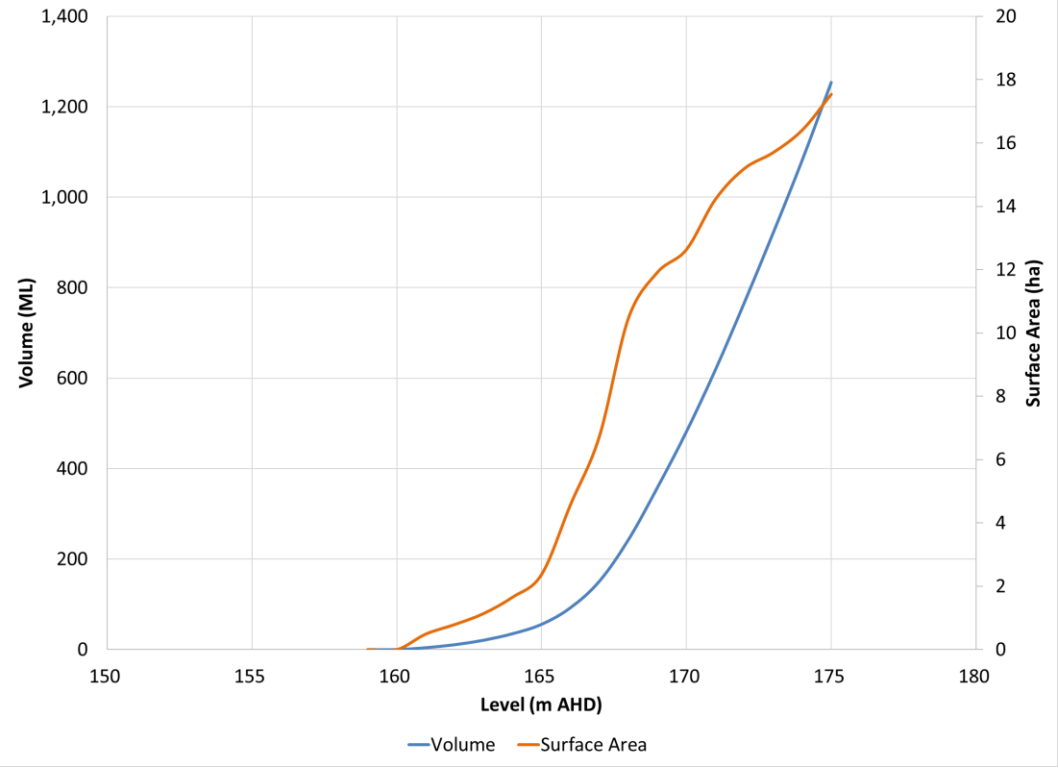
Drake Pit 2 Expansion



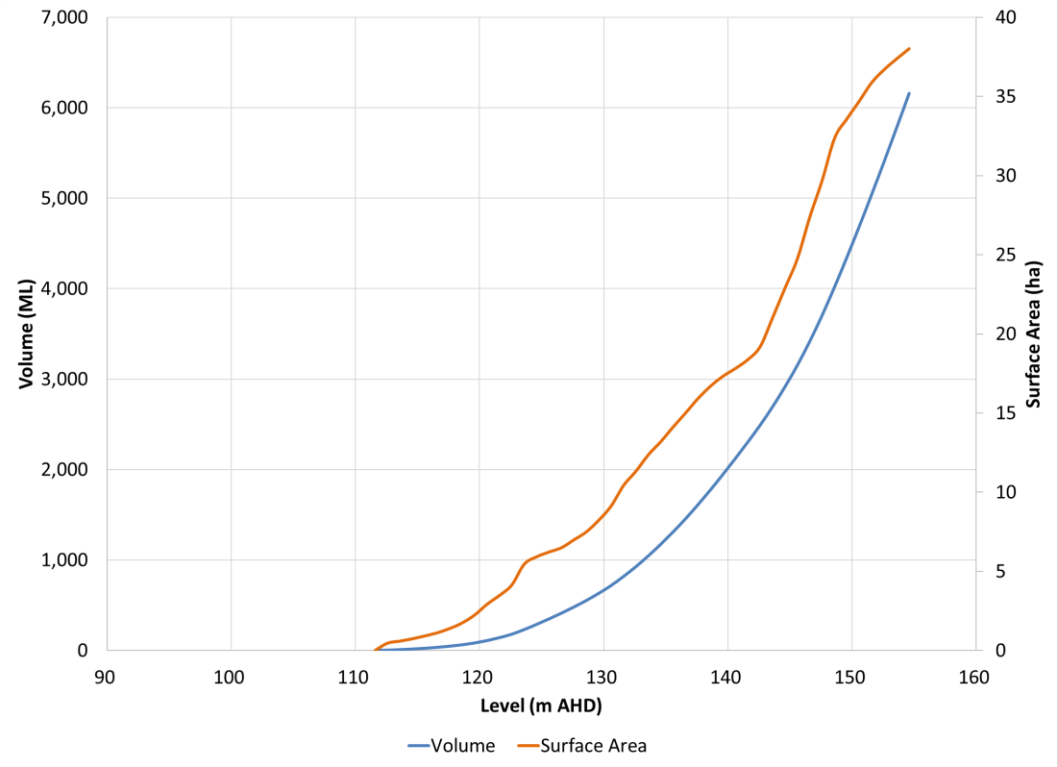
Drake Pit 3Q



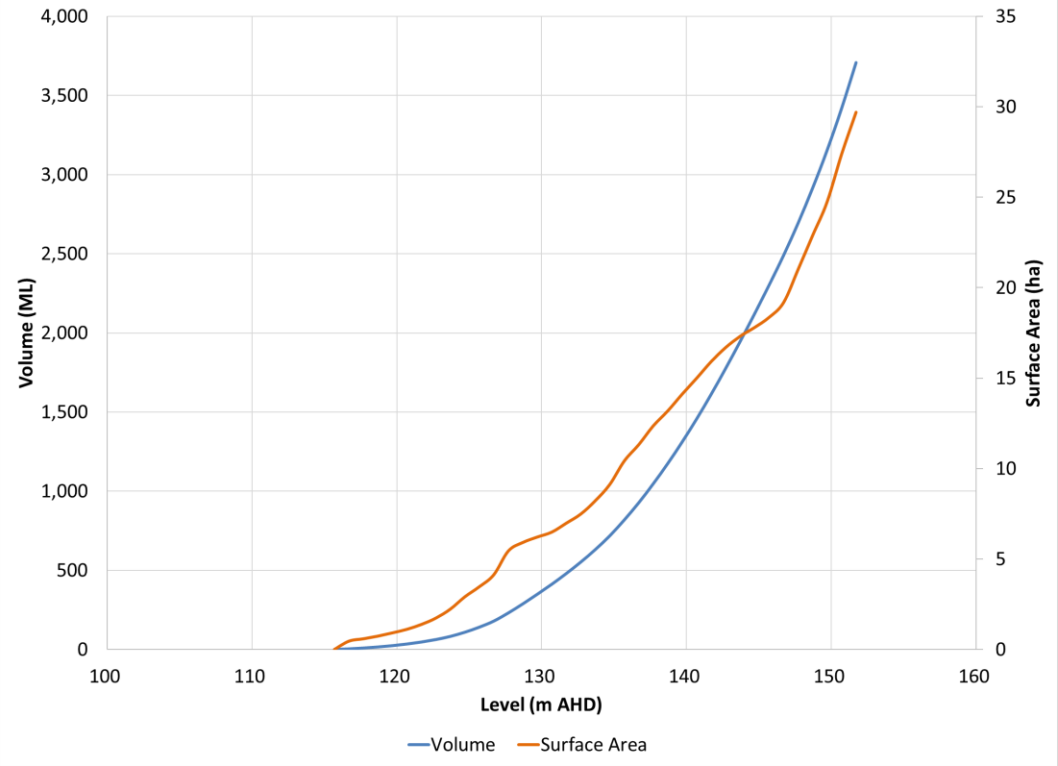
Drake Pit 3R



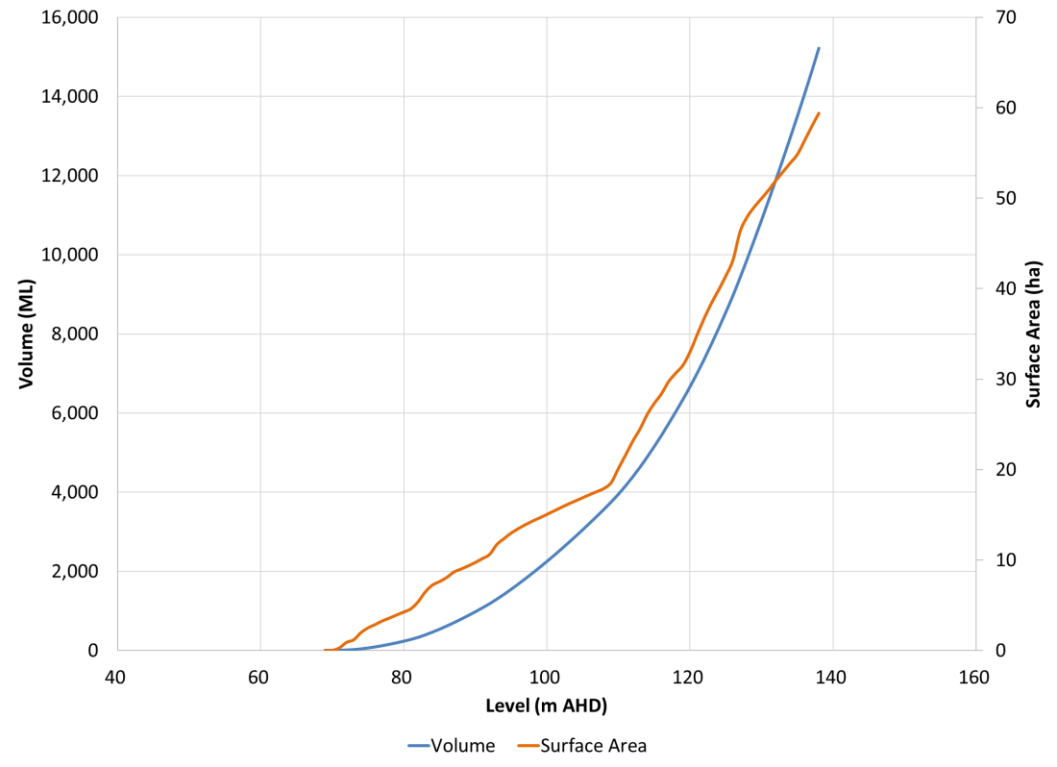
Drake Pit 4 North



Drake Pit 4 South



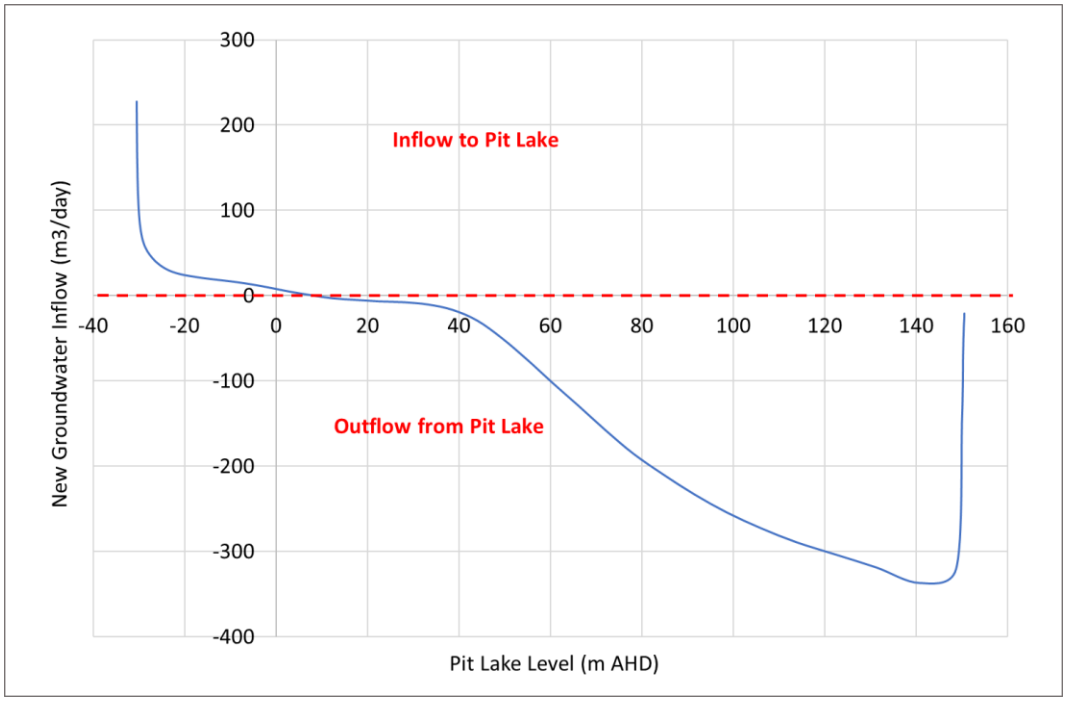
Drake Pit 5


16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume (ML)
70
60
50
40
30
20
10
0
Surface Area (ha)
40
60
80
100
120
140
160
Level (m AHD)
Volume
Surface Area

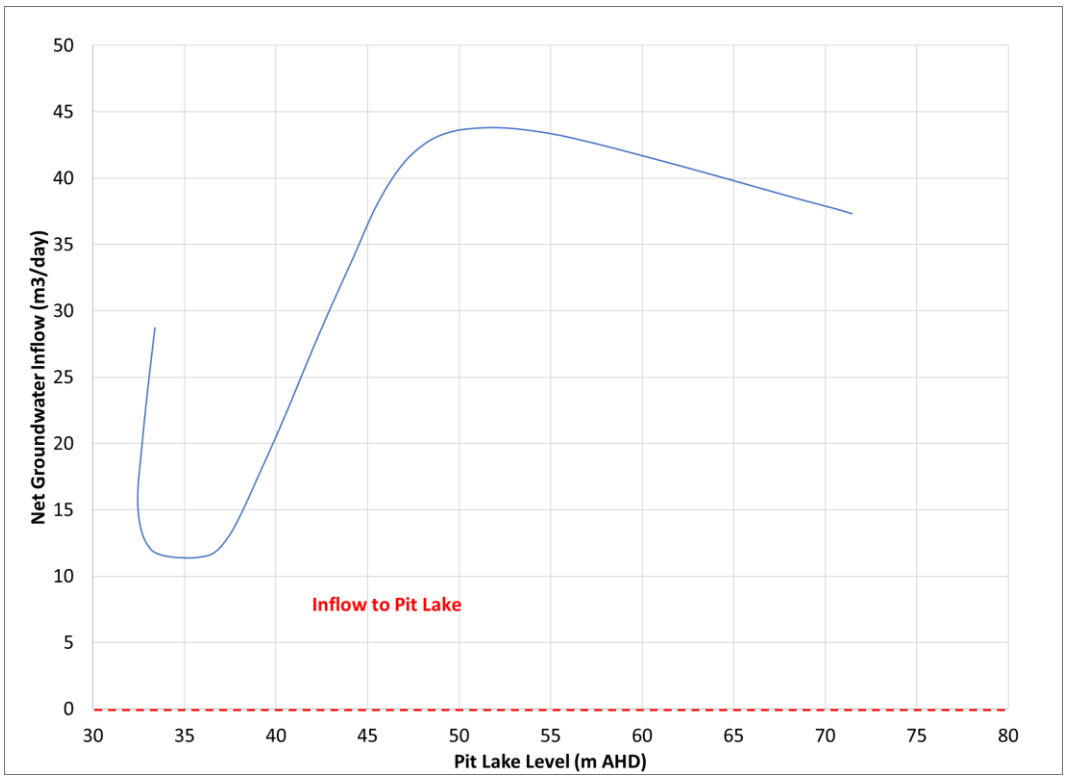
Appendix B

Groundwater Recovery Curves

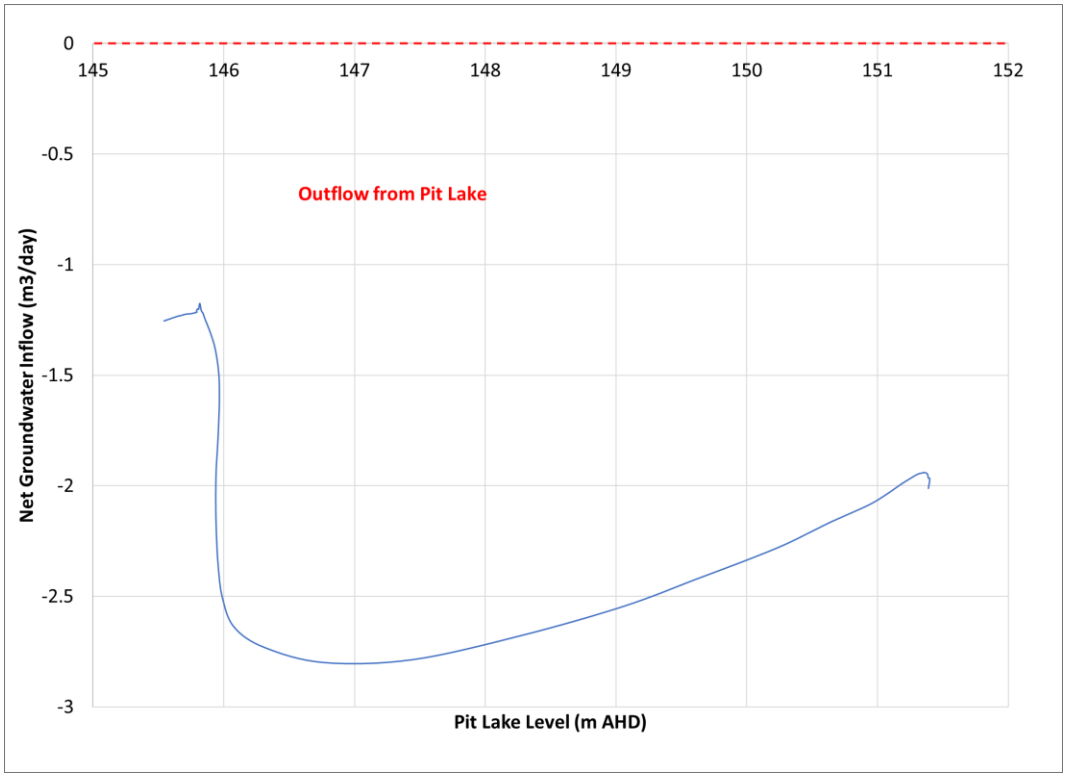
Sonoma Main Pit



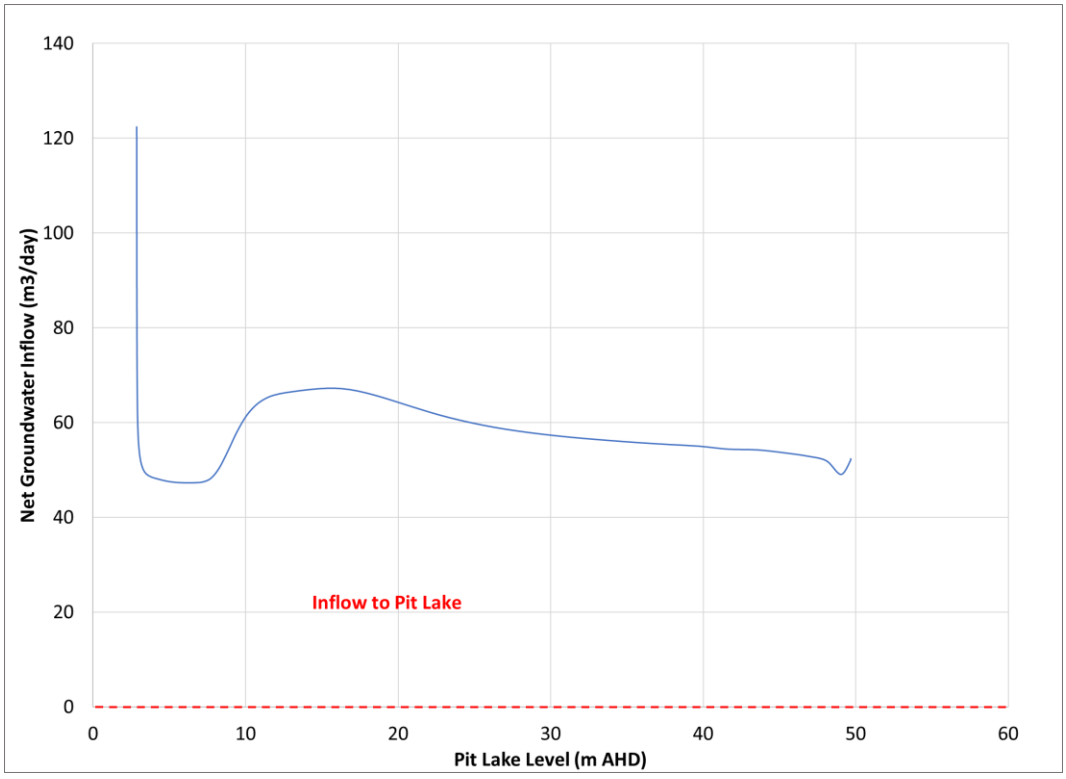
Sonoma East Pit 1



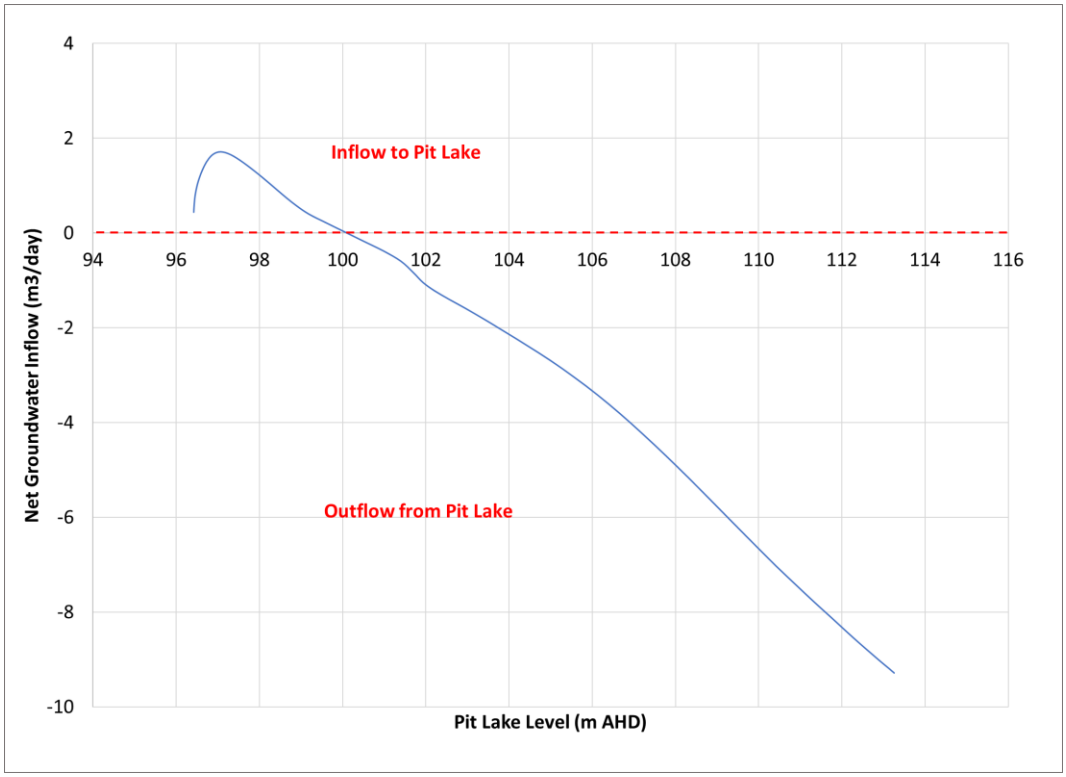
Sonoma East Pit 2



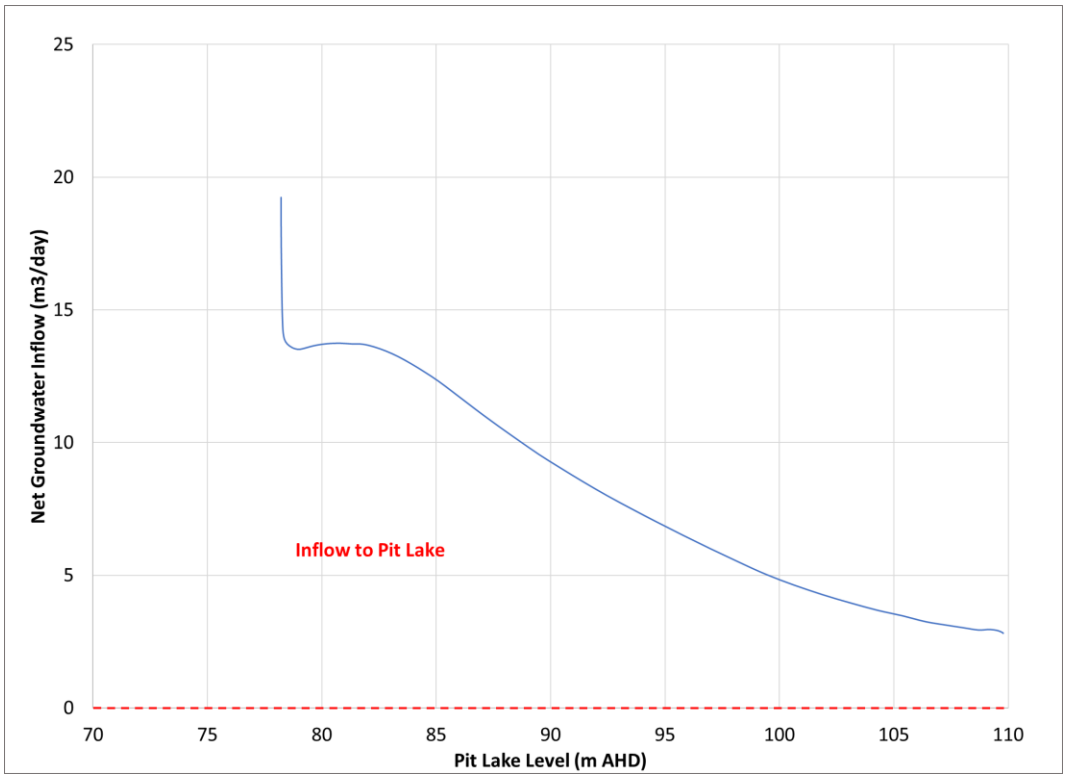
Drake Pit 1



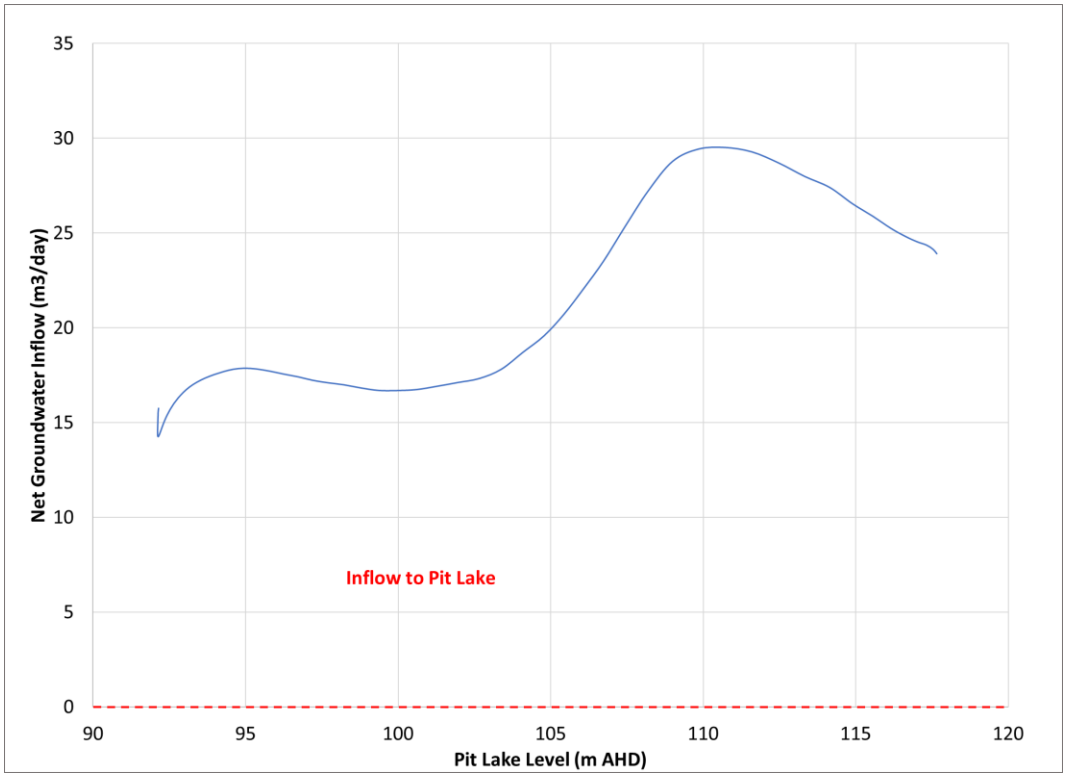
Drake Pit 2



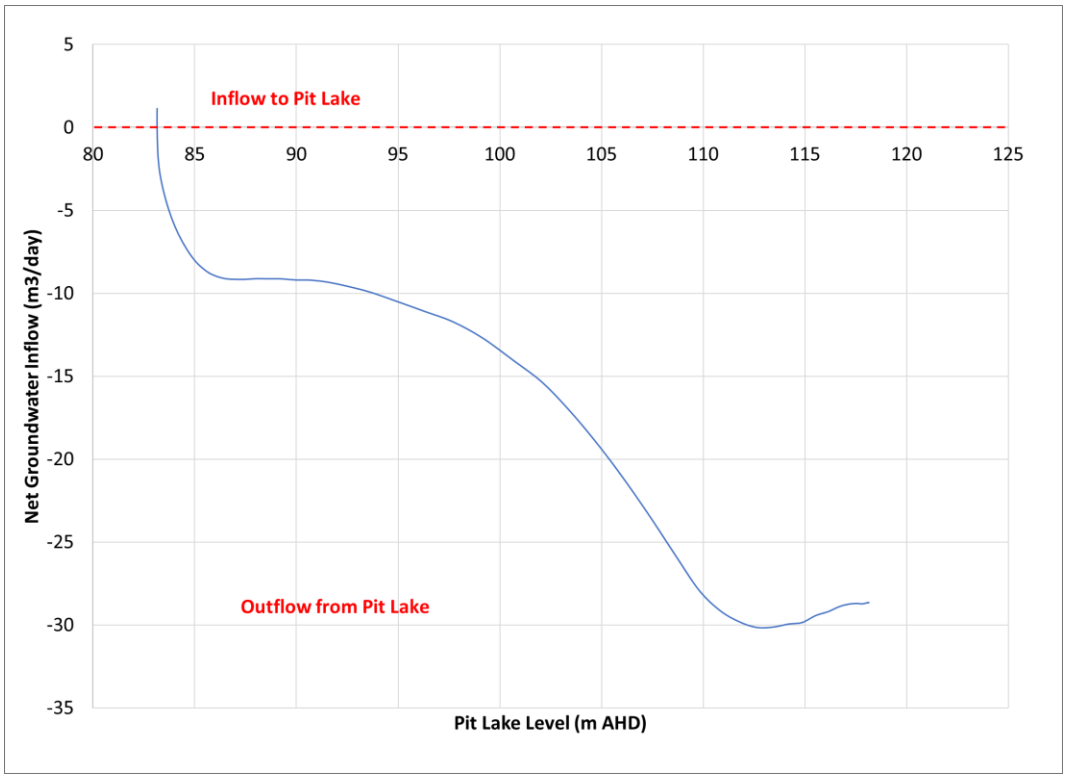
Drake Pit 2 Expansion



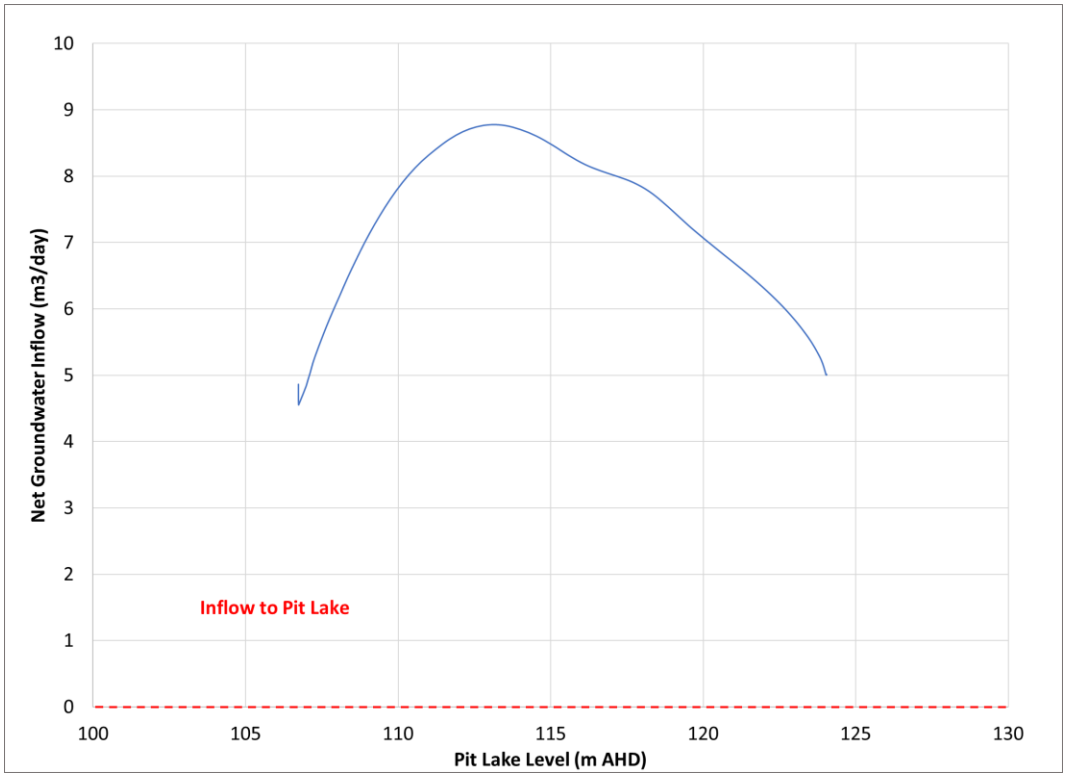
Drake Pit 3Q



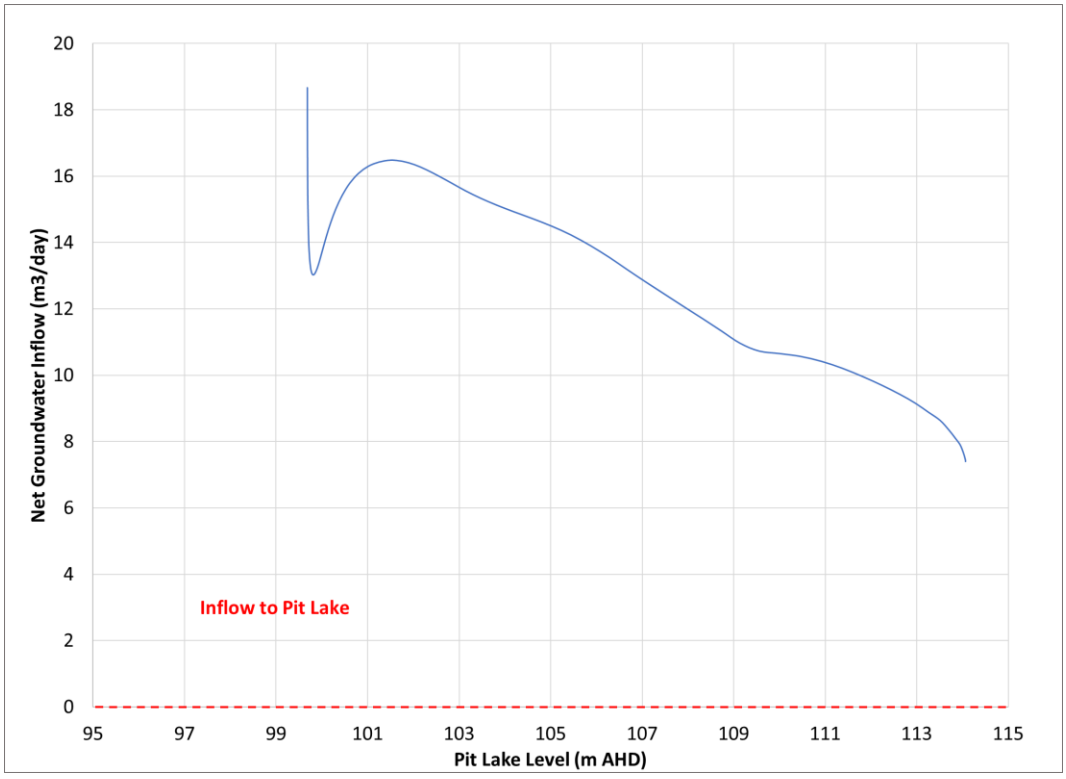
Drake Pit 3R



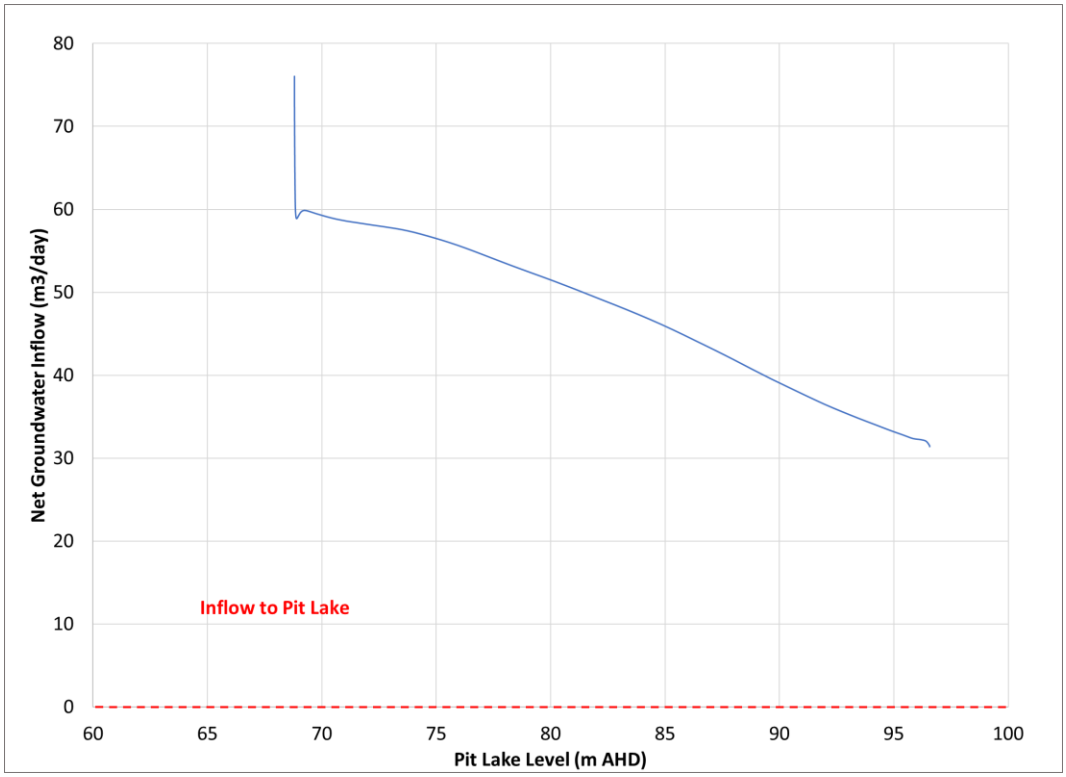
Drake Pit 4 North



Drake Pit 4 South



Drake Pit 5

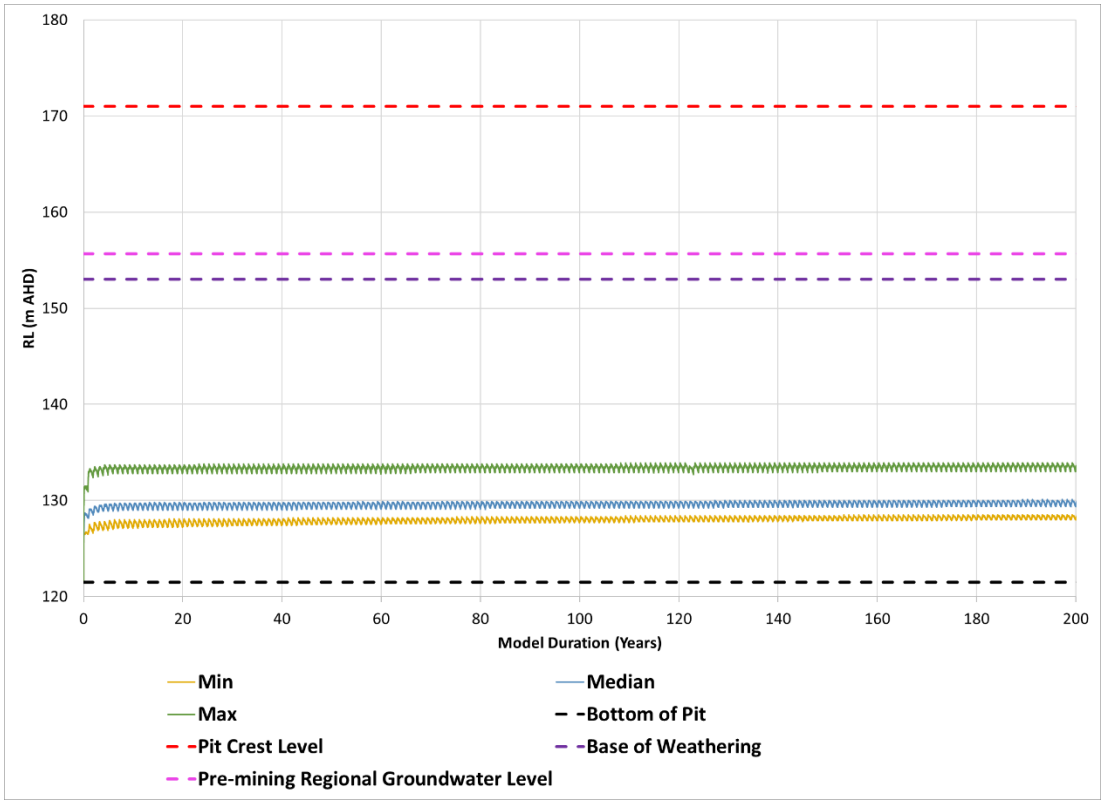

80
70
60
50
40
30
20
10
0
Net Groundwater Inflow (m3/day)
Inflow to Pit Lake
60
65
70
75
80
85
90
95
100
Pit Lake Level (m AHD)

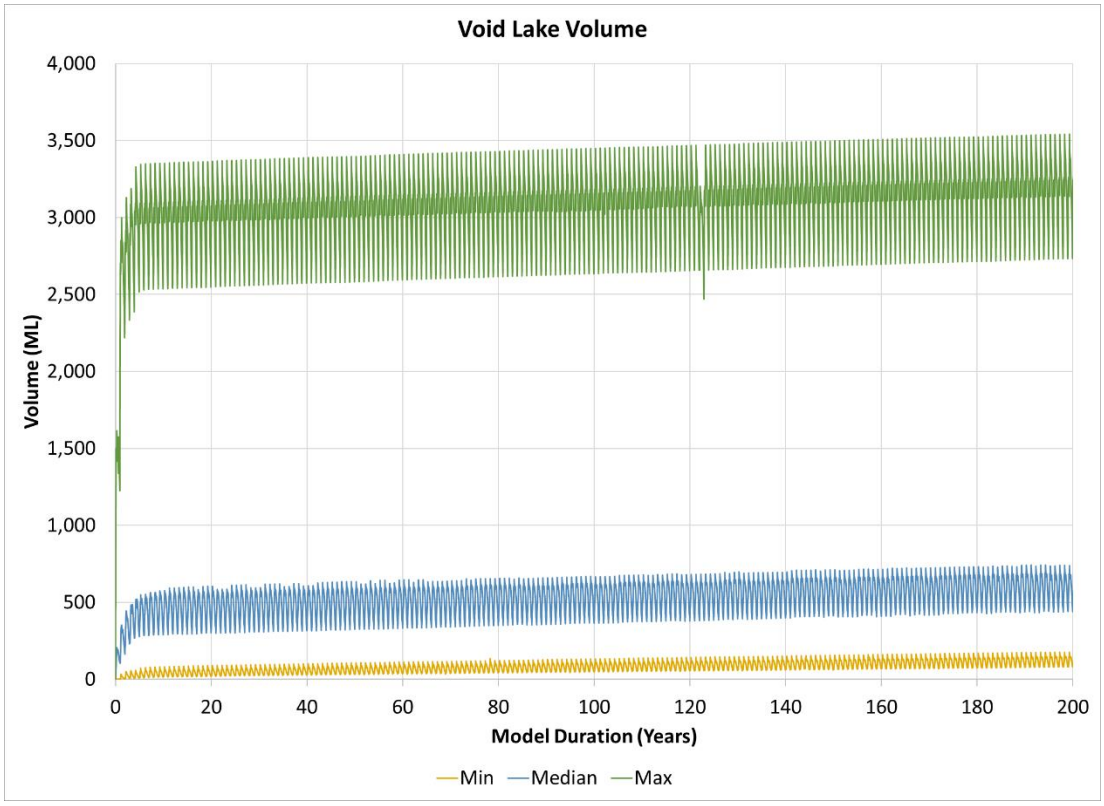
Appendix C

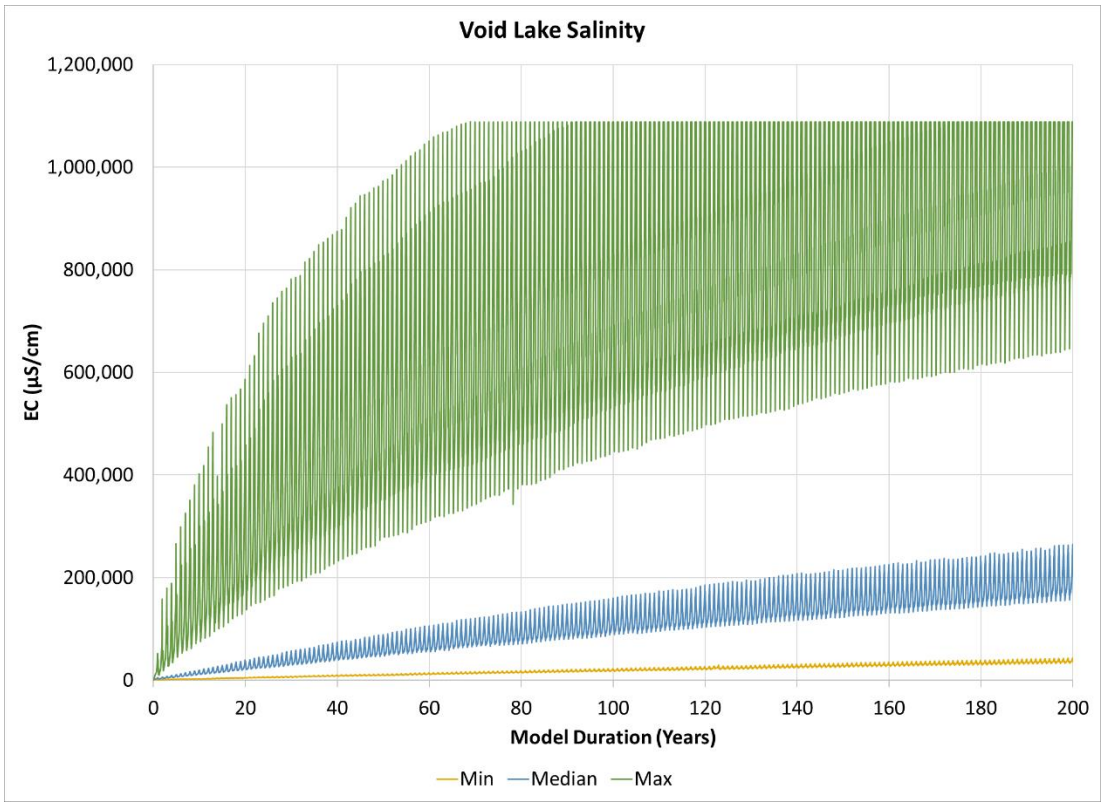
Void Hydrology Model Results

Base Case Scenario

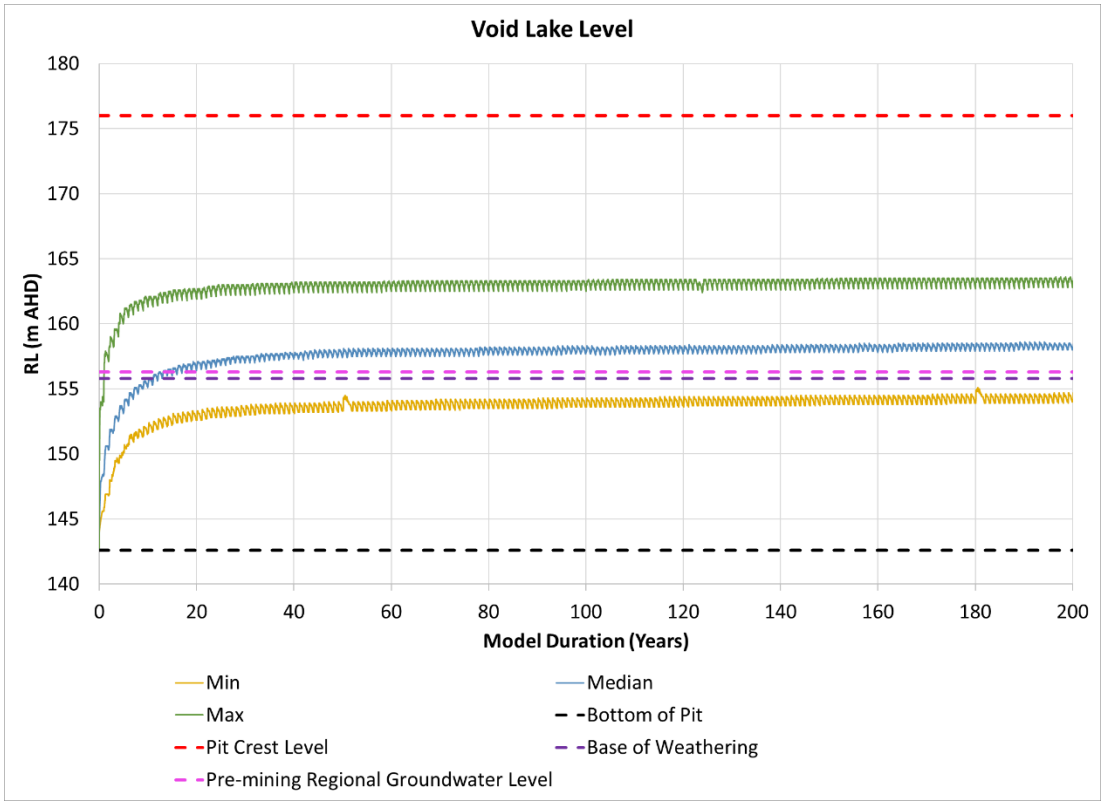
Sonoma Main Pit

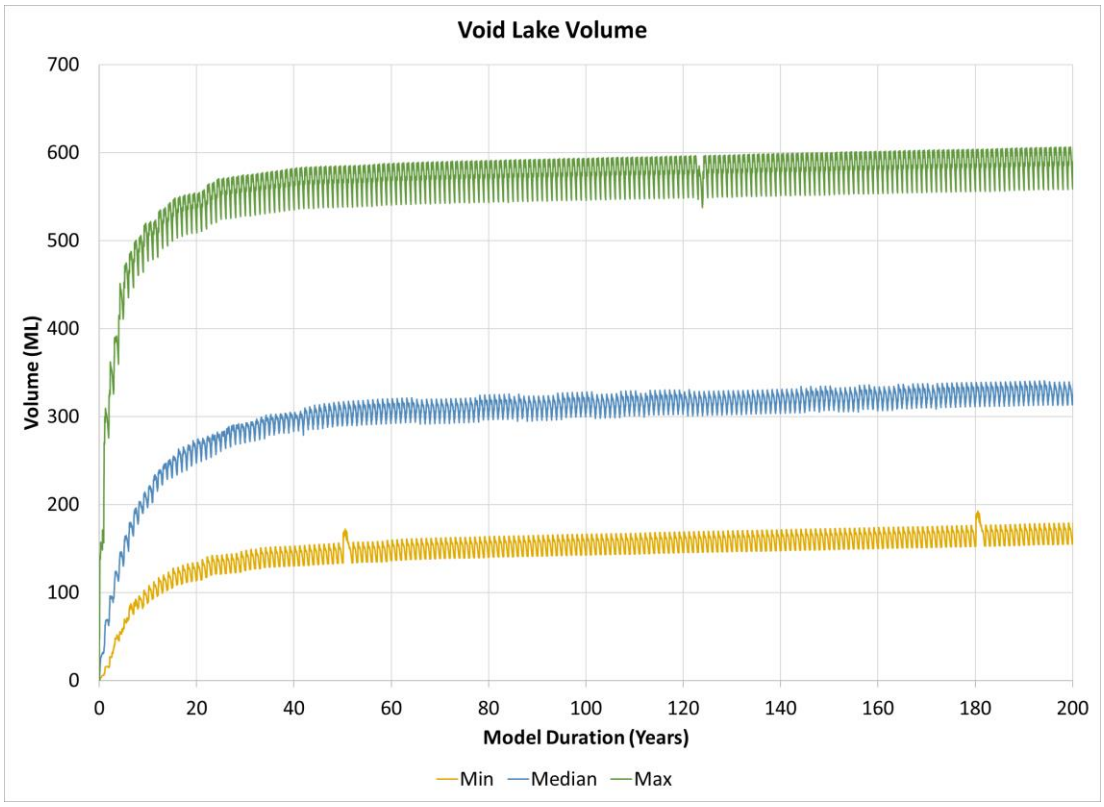


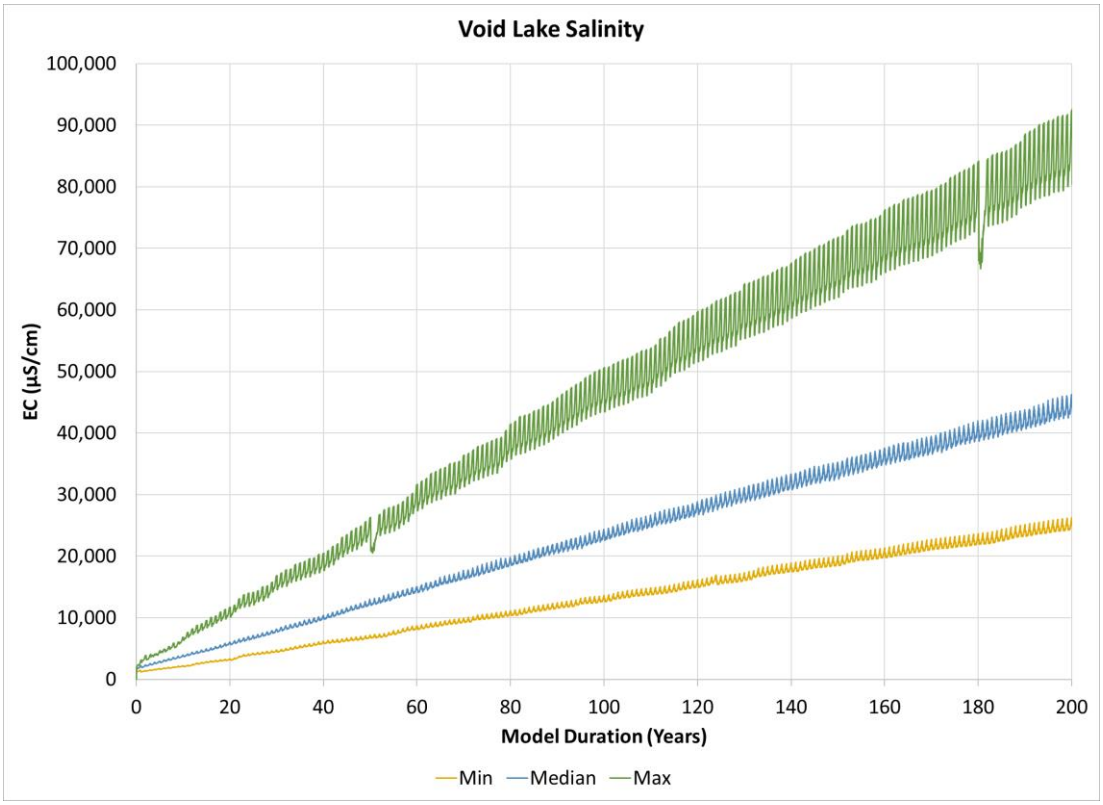



Void Lake Salinity
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

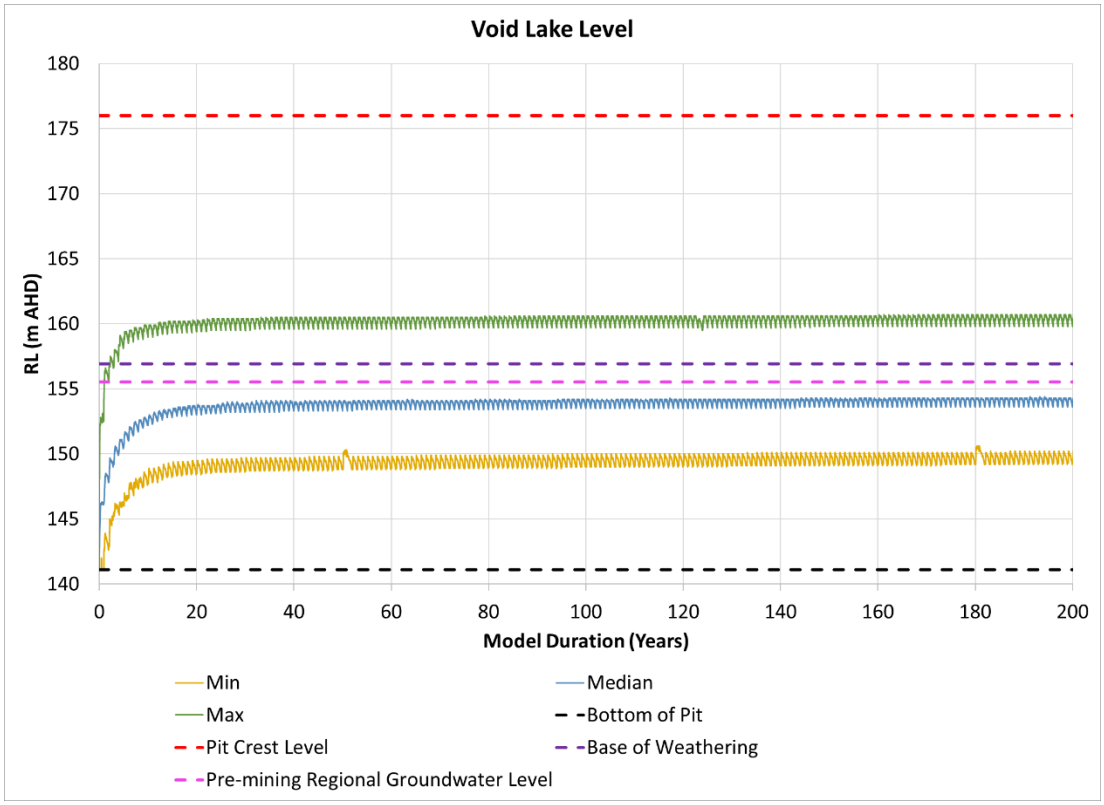
Sonoma East Pit 1

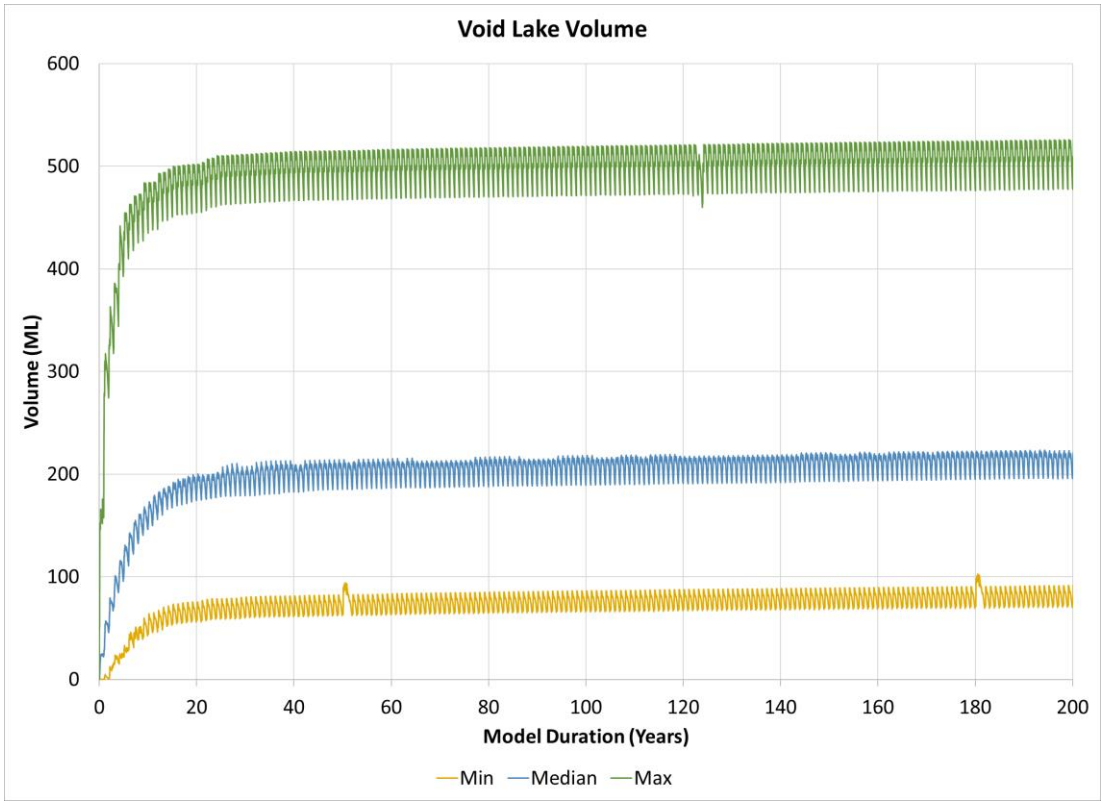


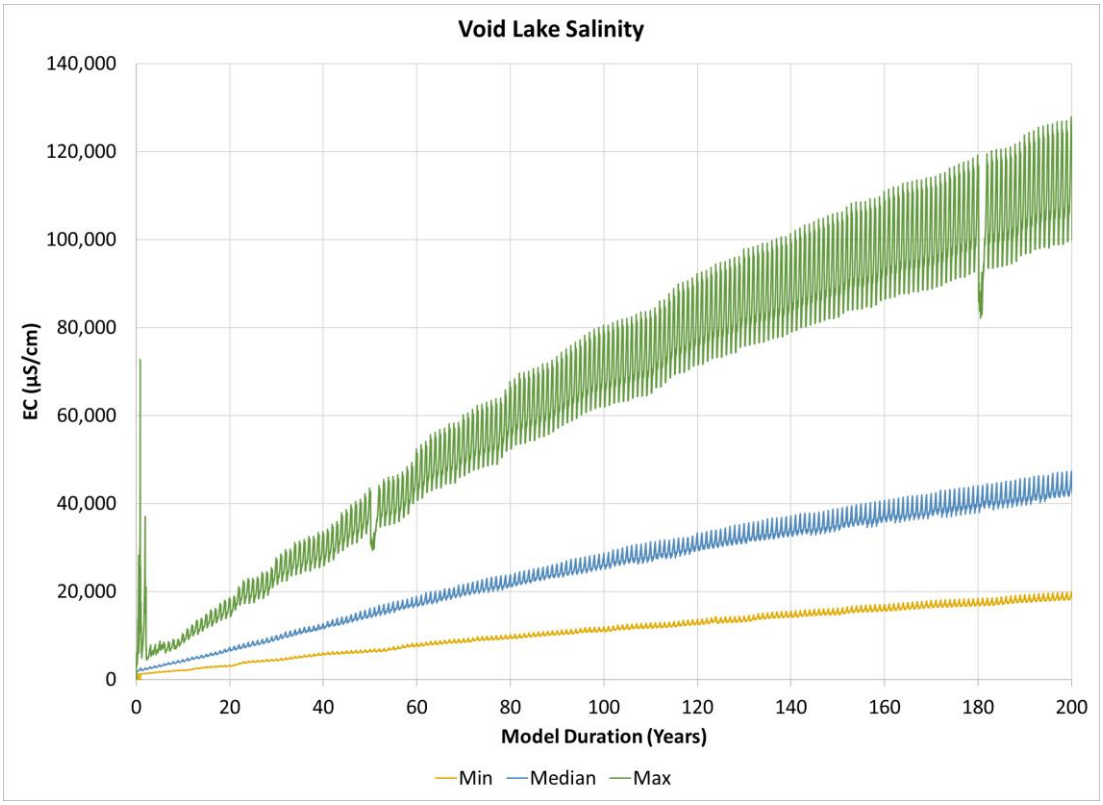



Void Lake Salinity
EC (µS/cm)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

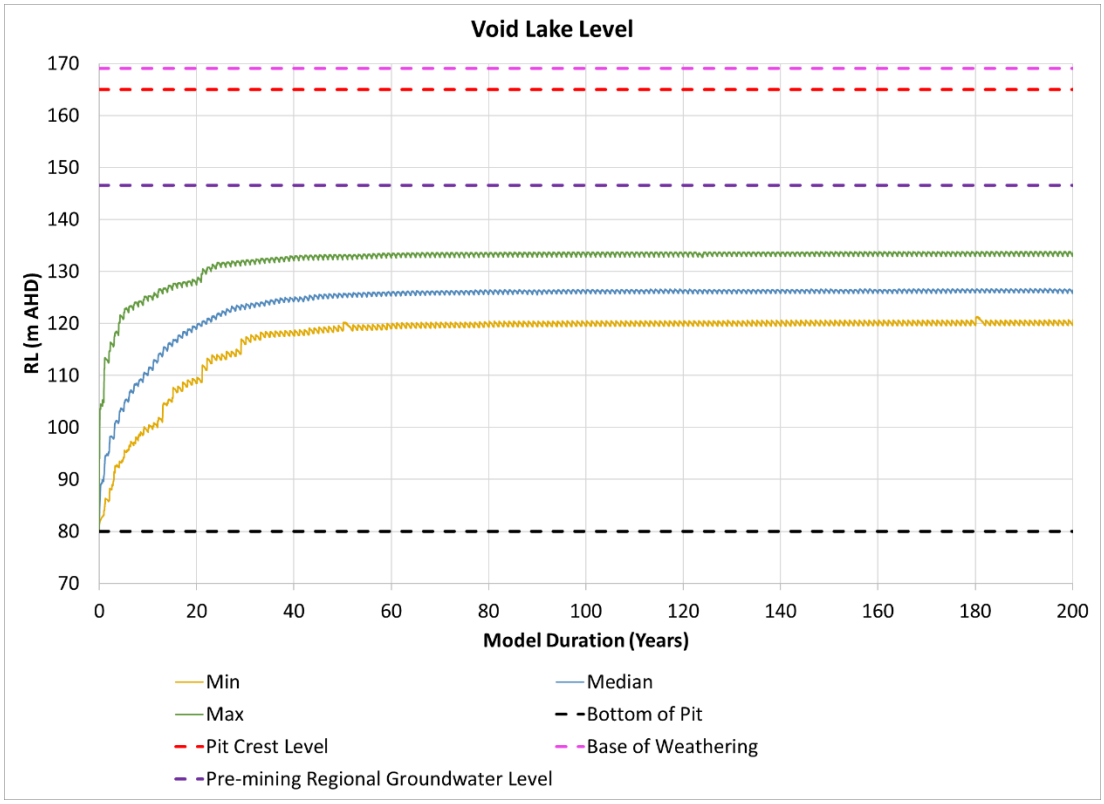
Sonoma East Pit 2

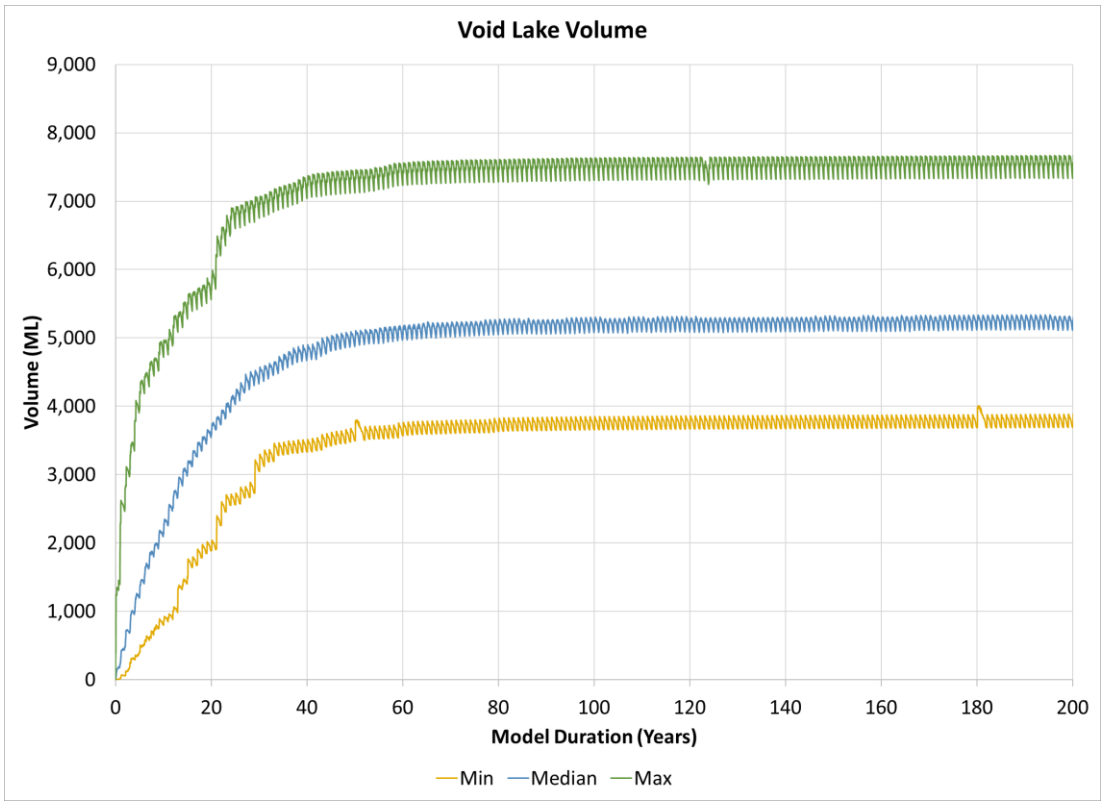


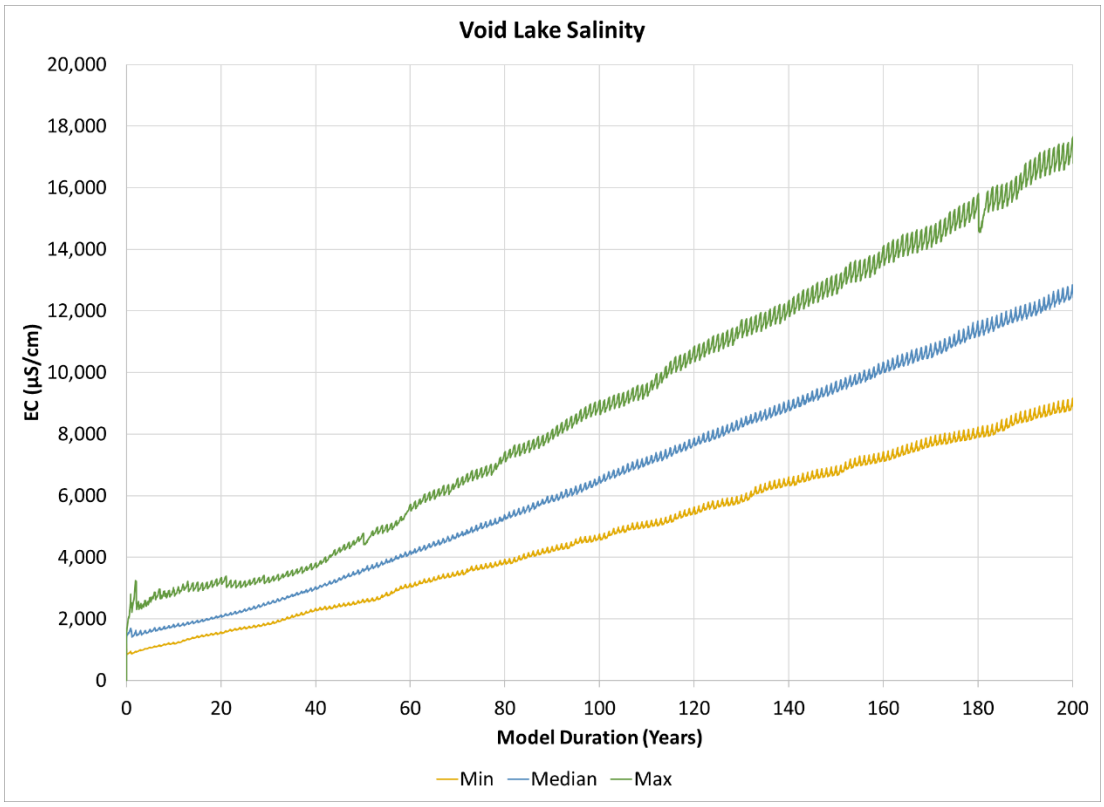



Void Lake Salinity
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

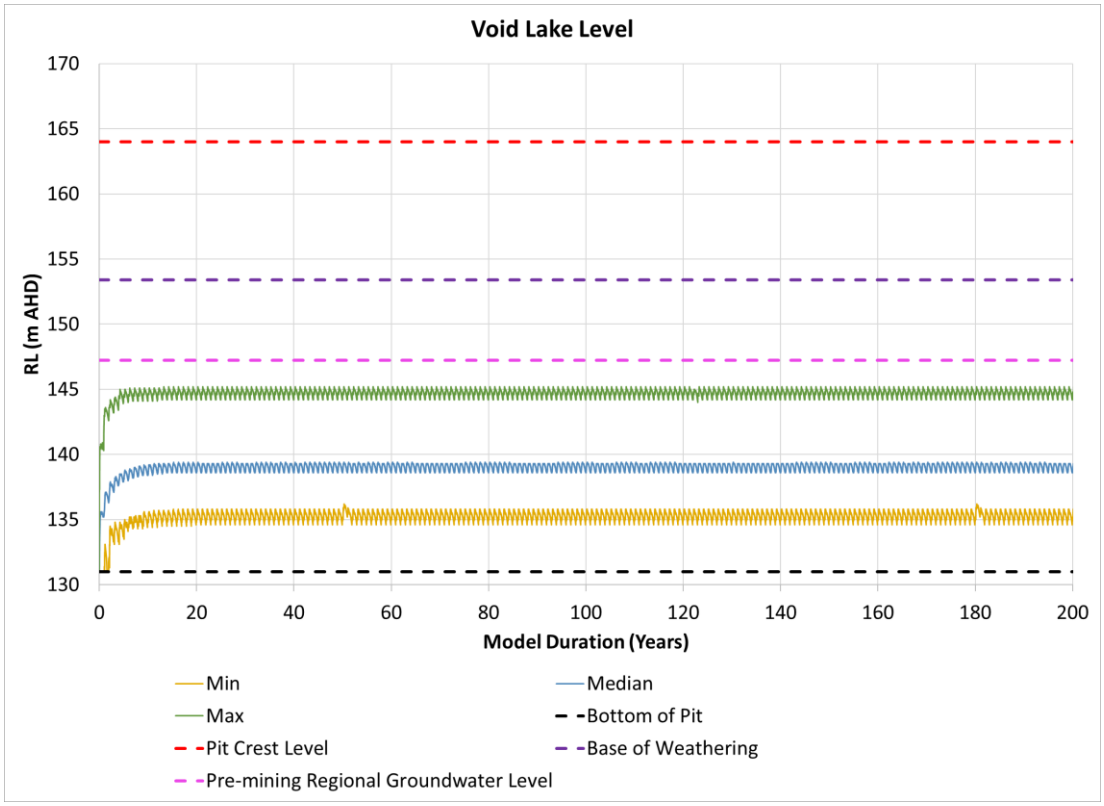
Drake Pit 1

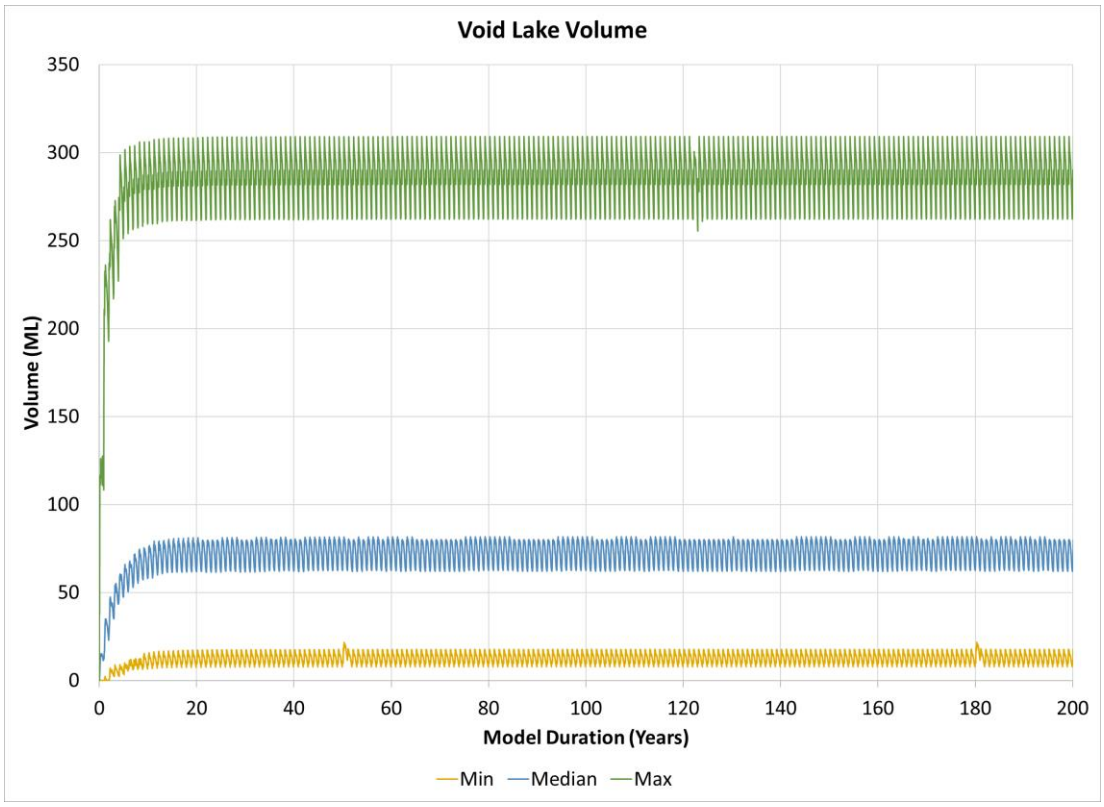

Void Lake Level
RL (m AHD)
170
160
150
140
130
120
110
100
90
80
70
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max
Bottom of Pit
Pit Crest Level
Base of Weathering
Pre-mining Regional Groundwater Level

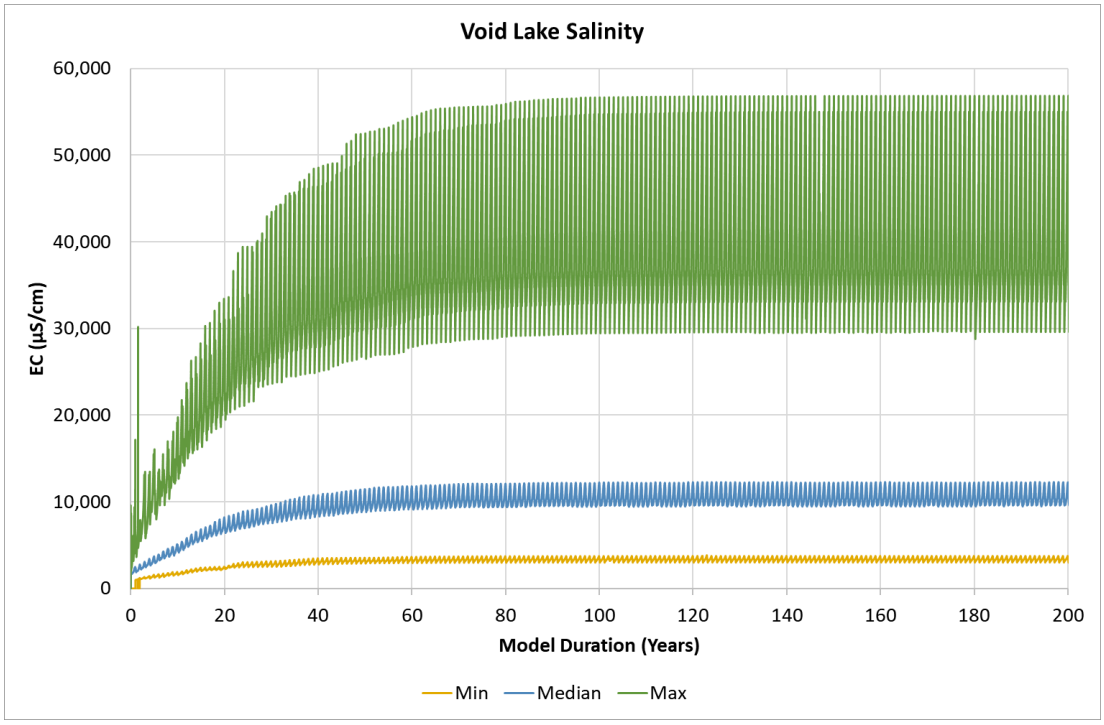

Void Lake Volume
Volume (ML)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max


Void Lake Salinity
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

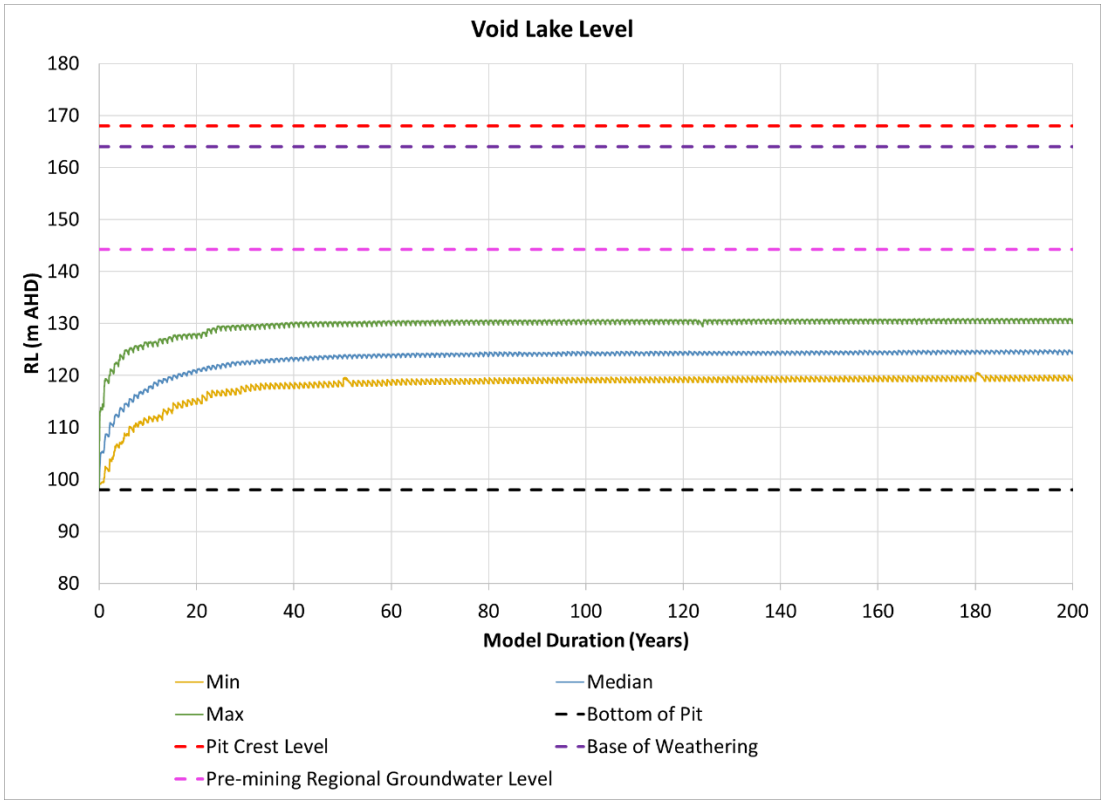
Drake Pit 2

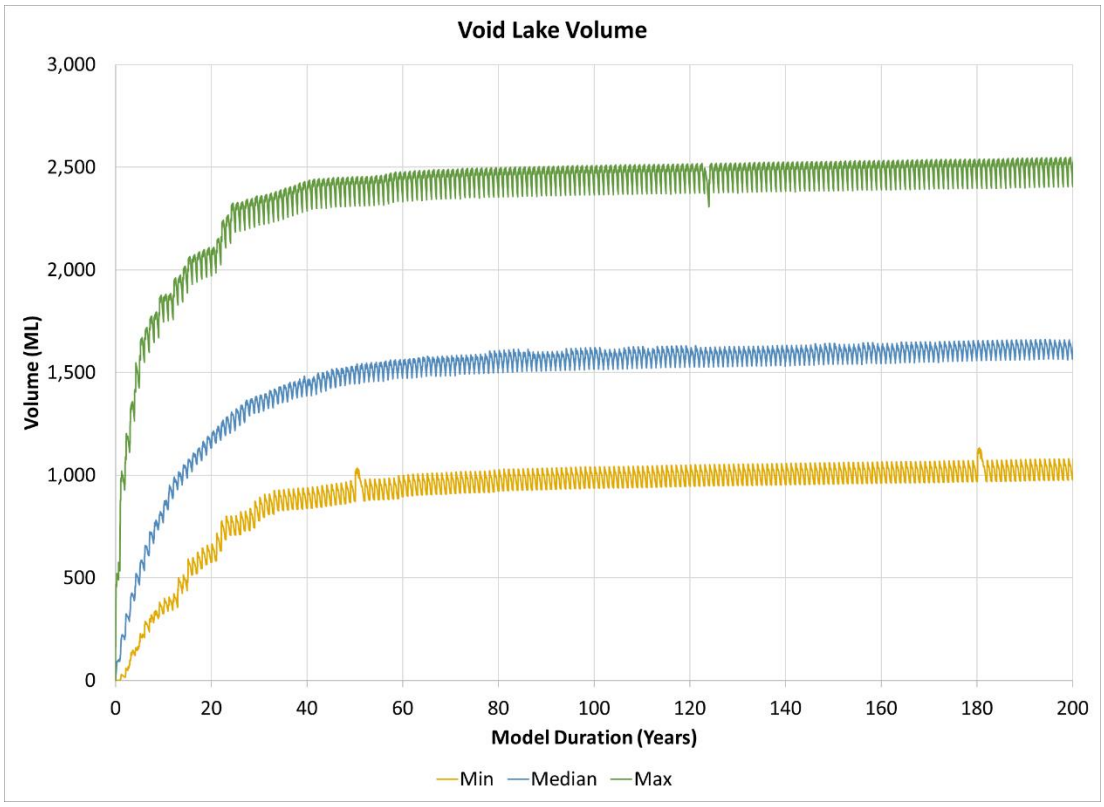

Void Lake Level
RL (m AHD)
170
165
160
155
150
145
140
135
130
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max
Bottom of Pit
Pit Crest Level
Base of Weathering
Pre-mining Regional Groundwater Level

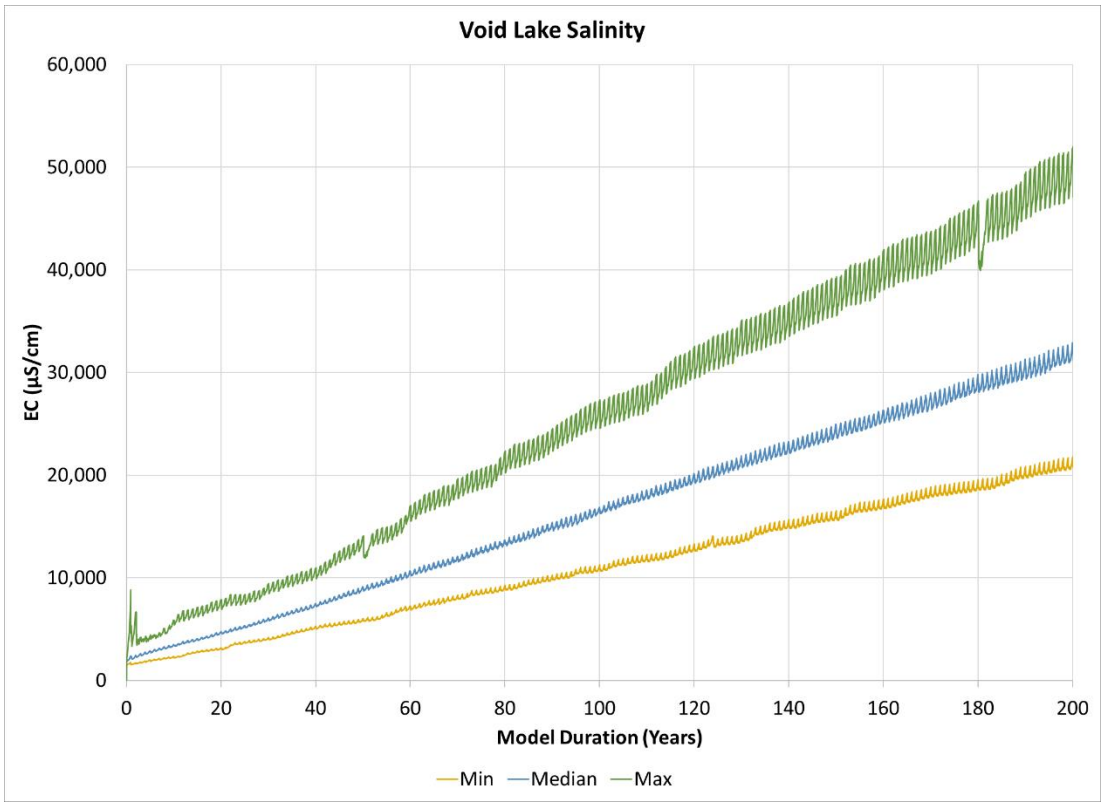

Void Lake Volume
Volume (ML)
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max


Void Lake Salinity
60,000
50,000
40,000
30,000
20,000
10,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

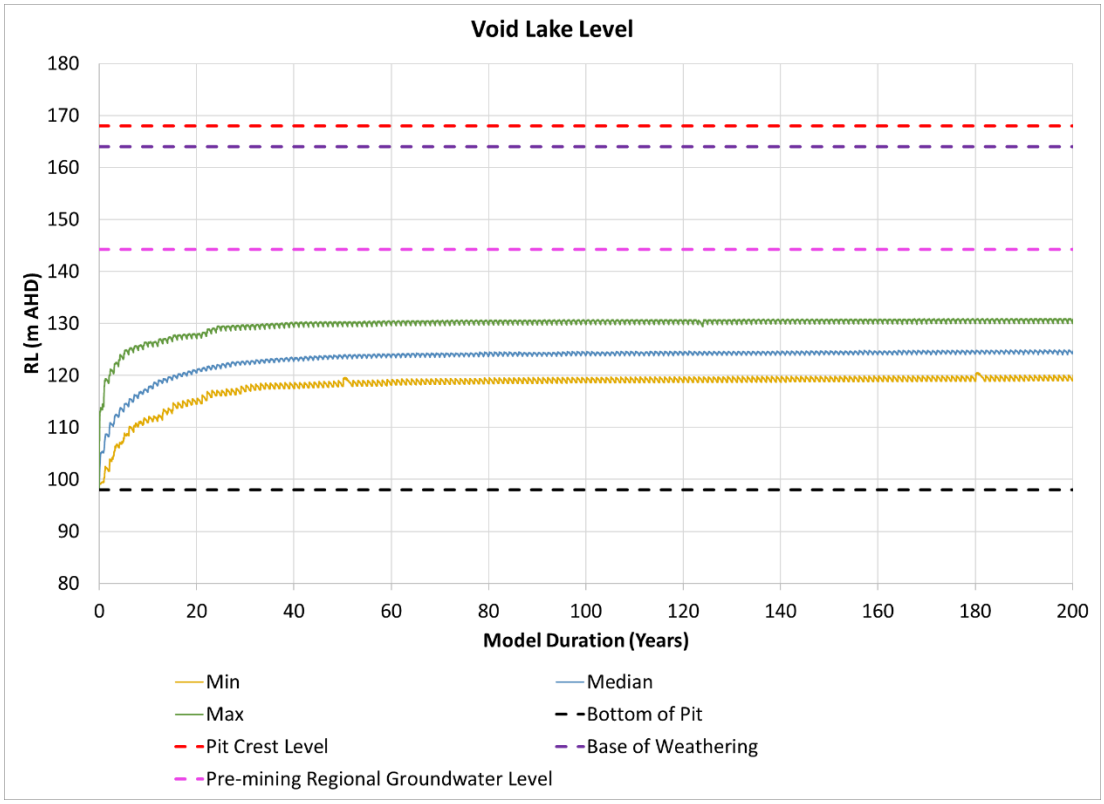
Drake Pit 2 Expansion

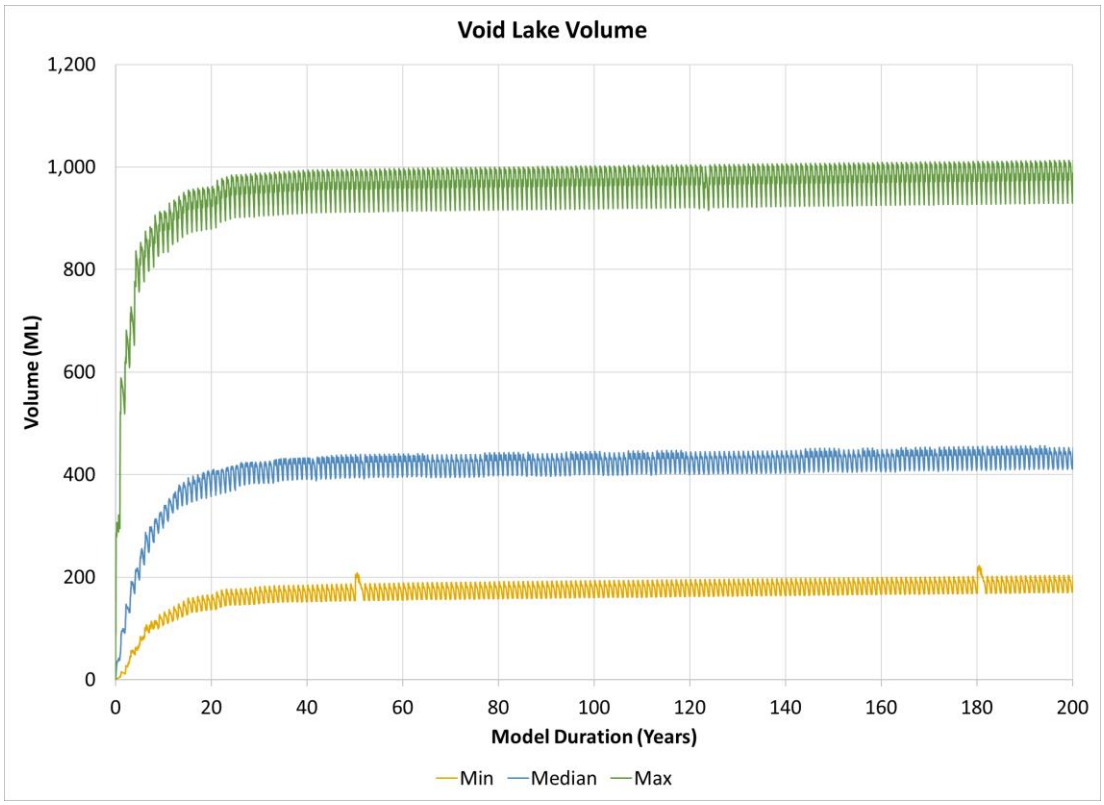


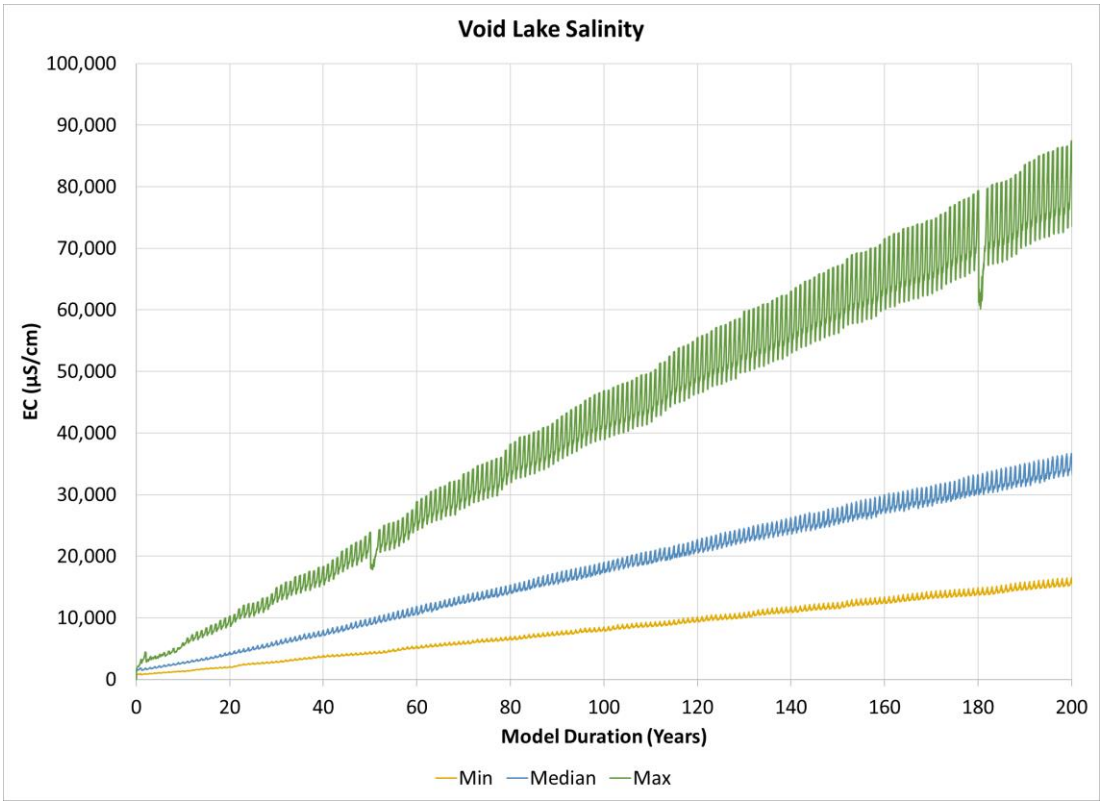



Void Lake Salinity
60,000
50,000
40,000
30,000
20,000
10,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

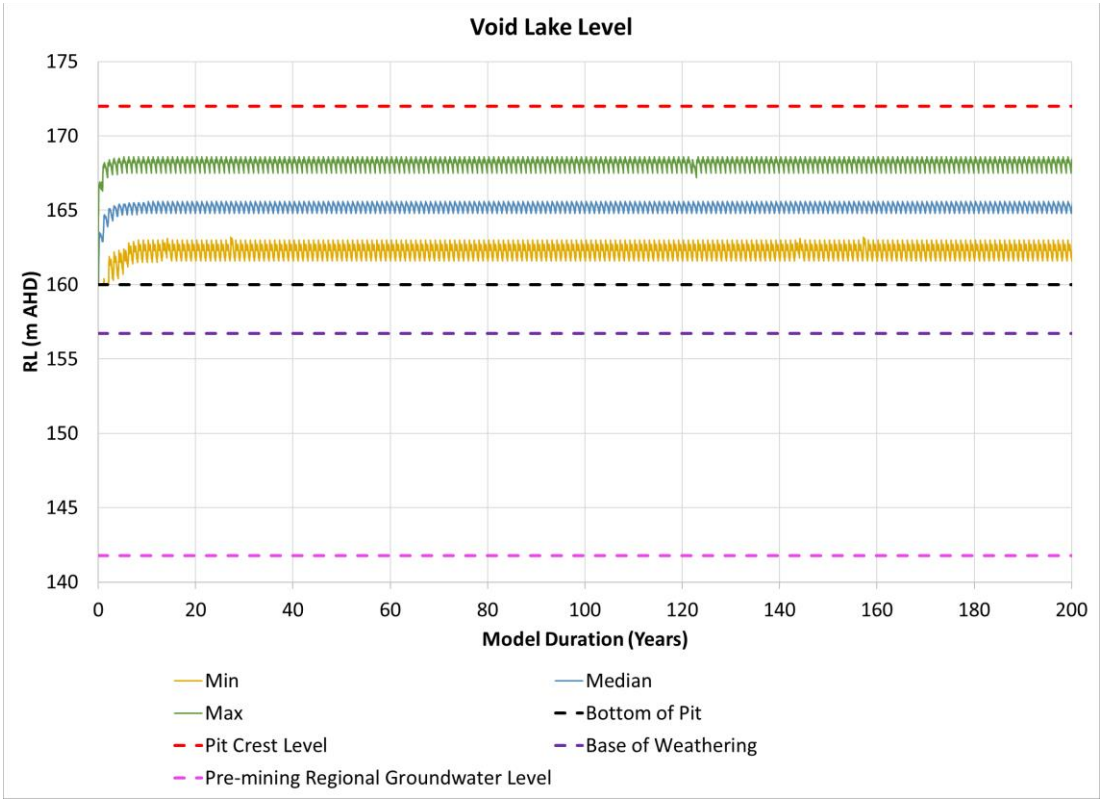
Drake Pit 3Q

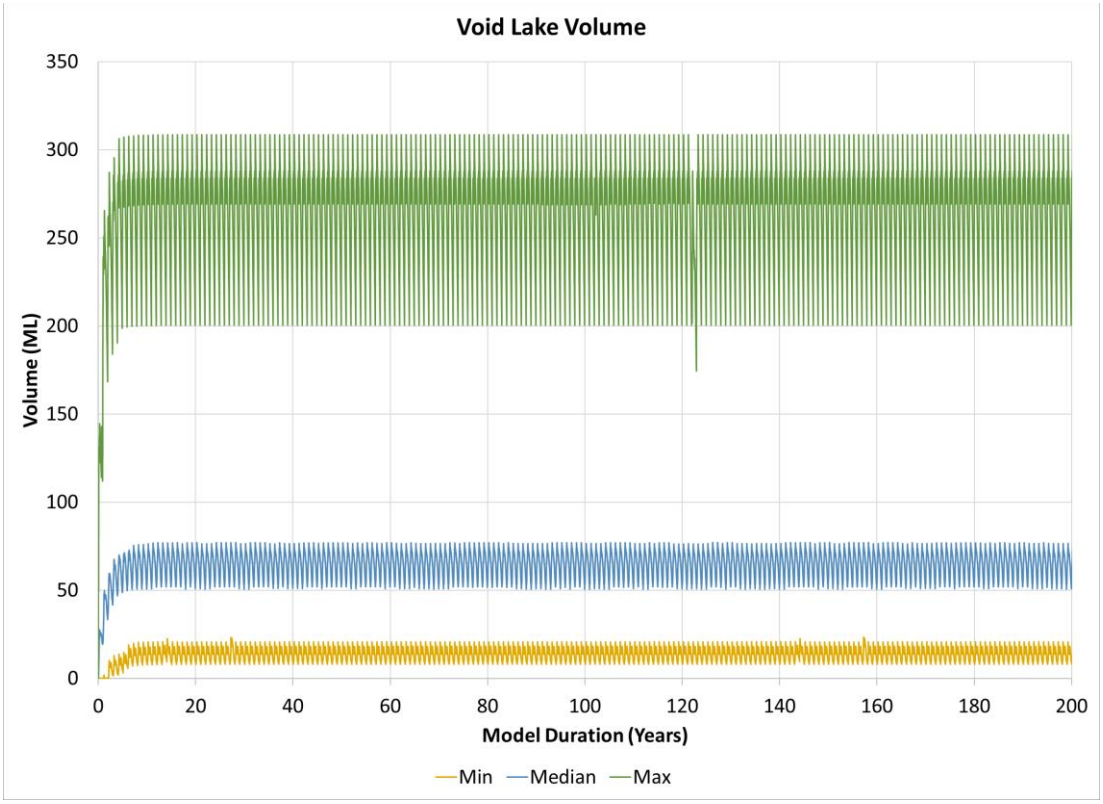

Void Lake Level
RL (m AHD)
180
170
160
150
140
130
120
110
100
90
80
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max
Bottom of Pit
Pit Crest Level
Base of Weathering
Pre-mining Regional Groundwater Level

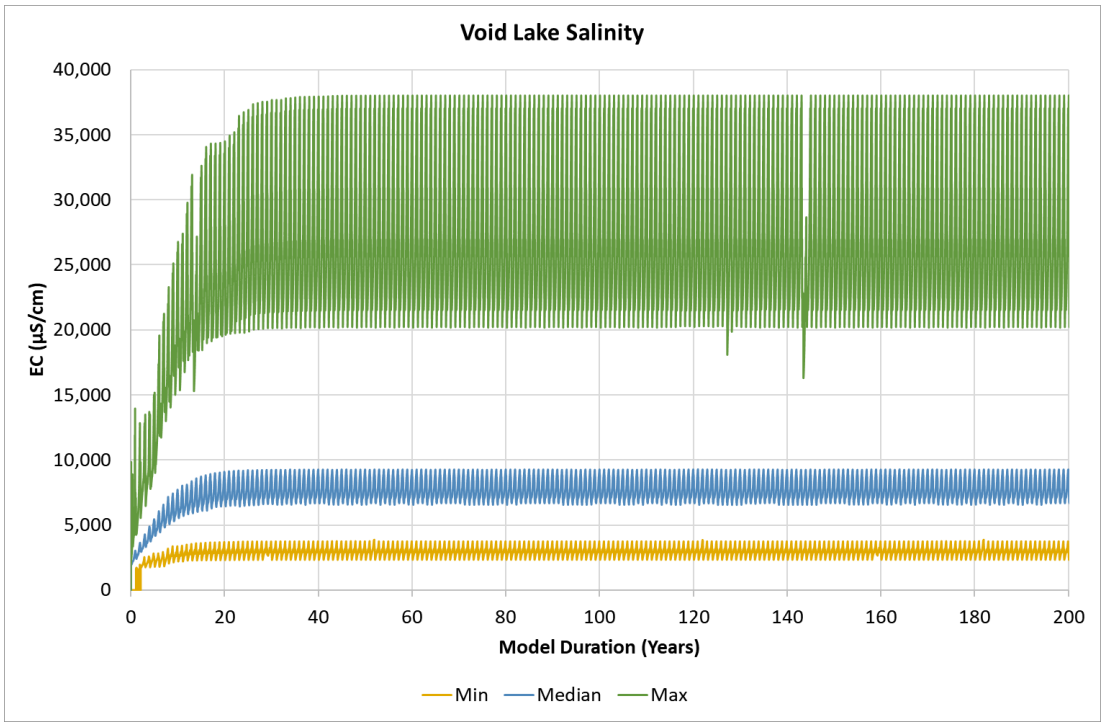

Void Lake Volume
Volume (ML)
1,200
1,000
800
600
400
200
0
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max


Void Lake Salinity
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

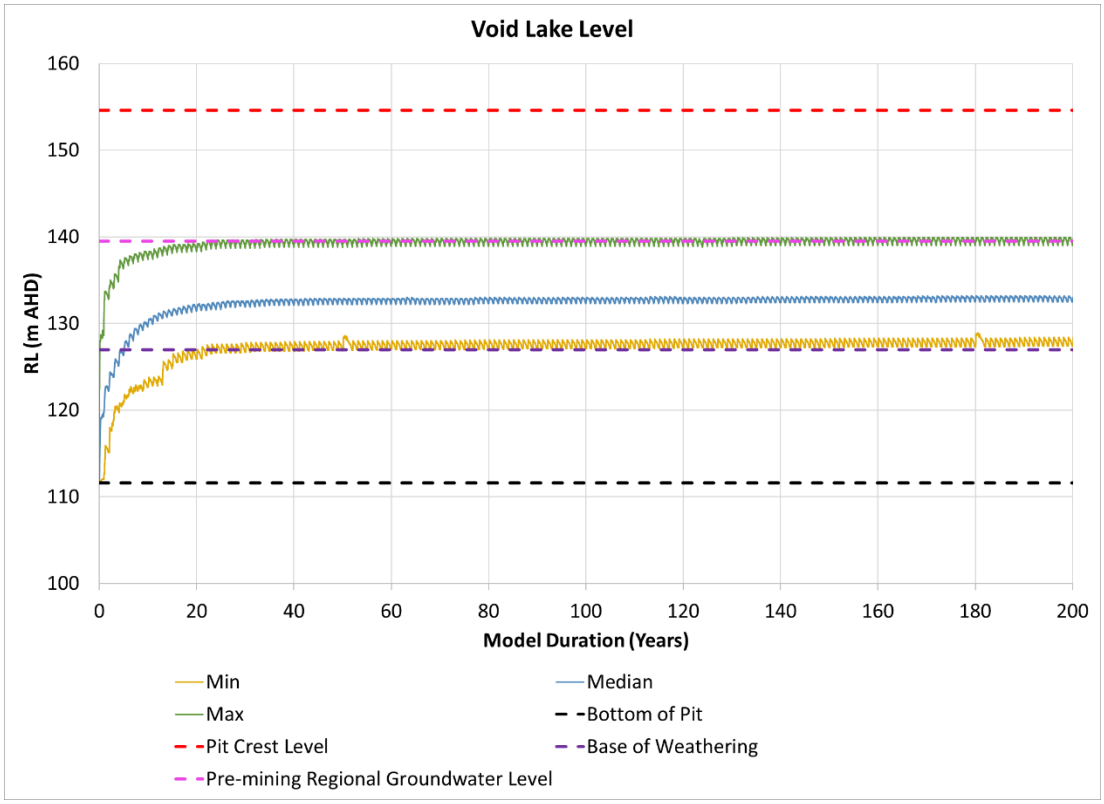
Drake Pit 3R

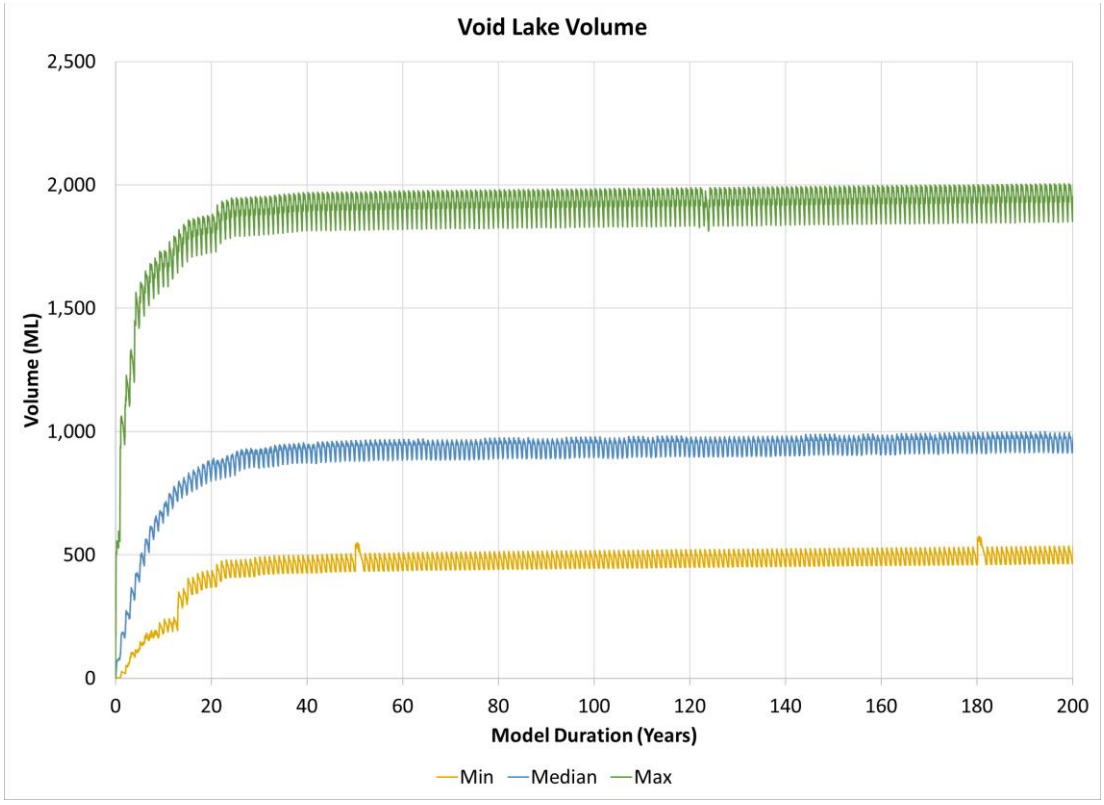

Void Lake Level
RL (m AHD)
175
170
165
160
155
150
145
140
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max
Bottom of Pit
Pit Crest Level
Base of Weathering
Pre-mining Regional Groundwater Level

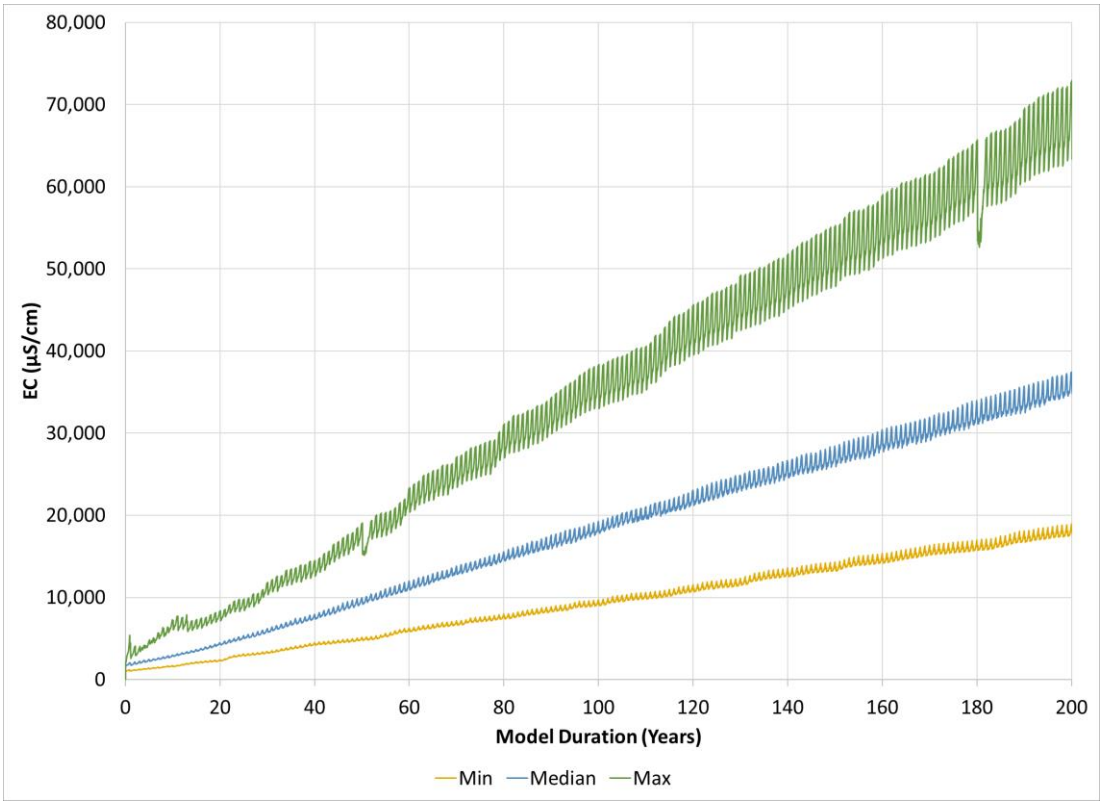

Void Lake Volume
Volume (ML)
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max


Void Lake Salinity
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

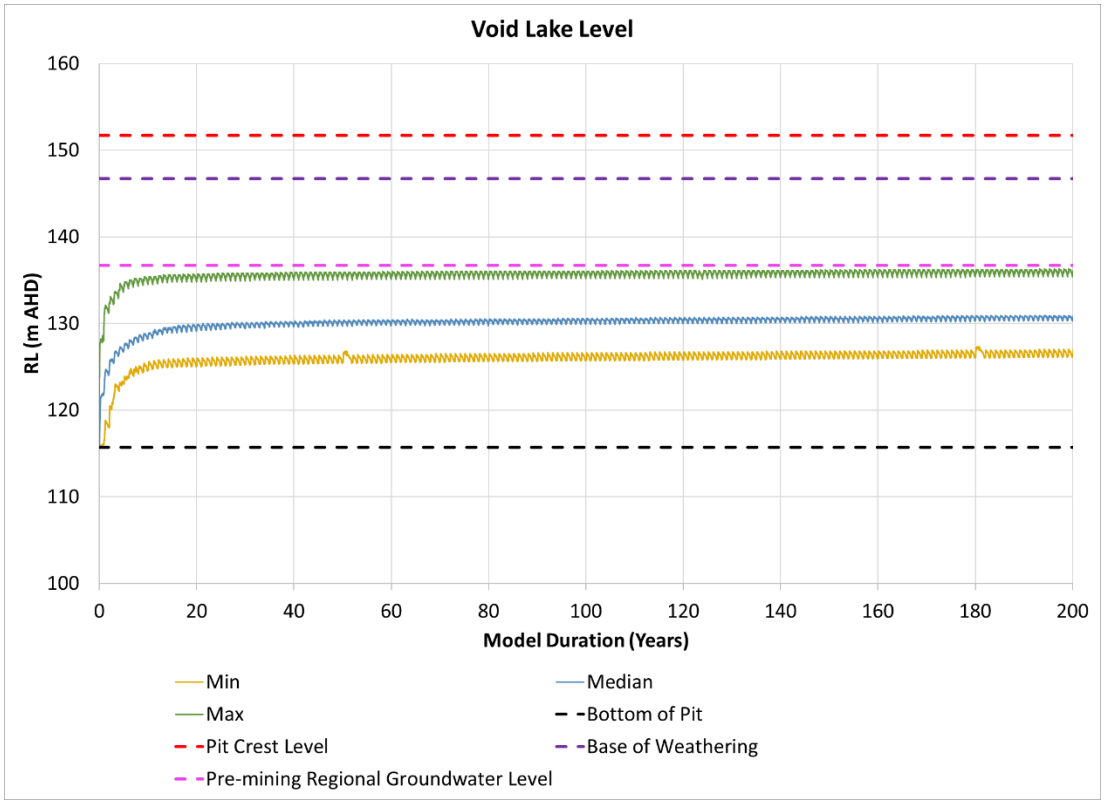
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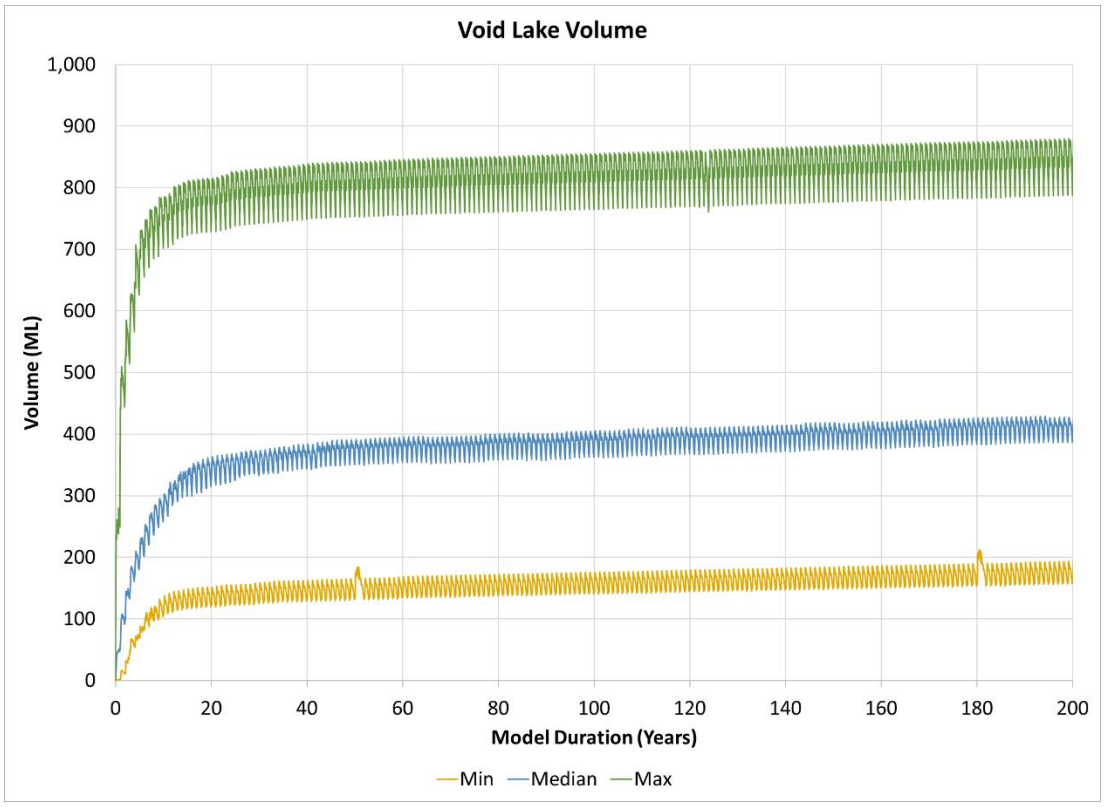


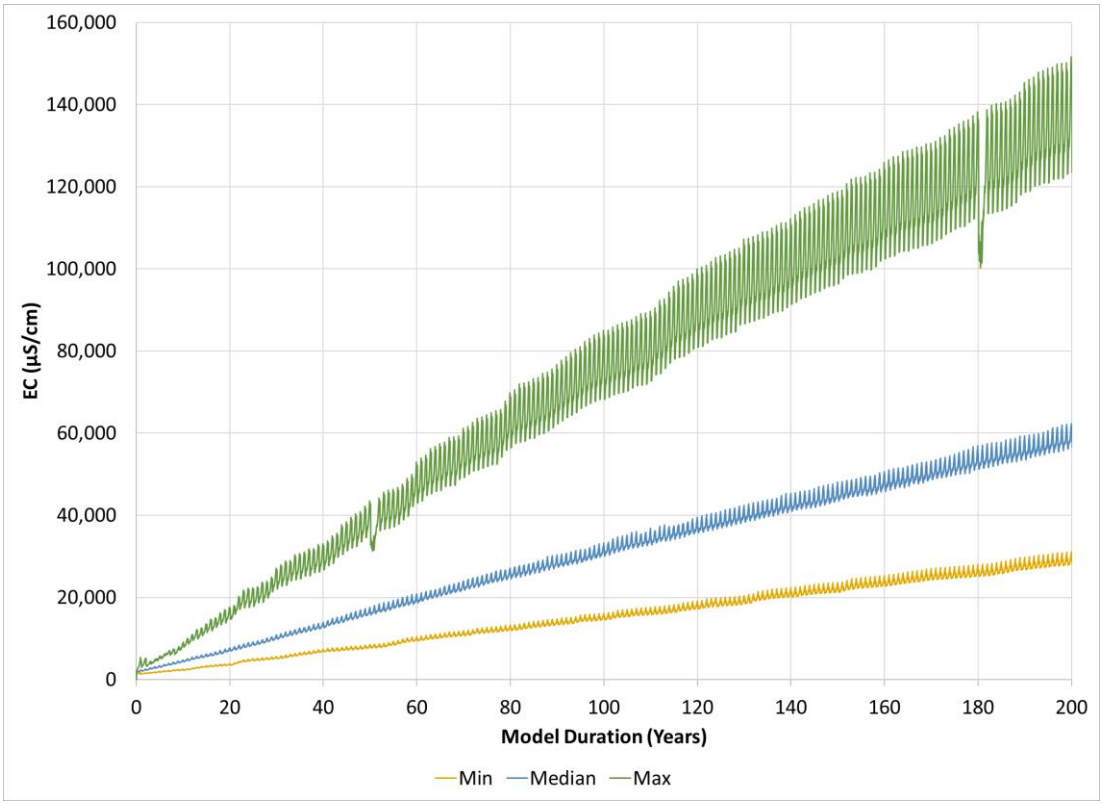



80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

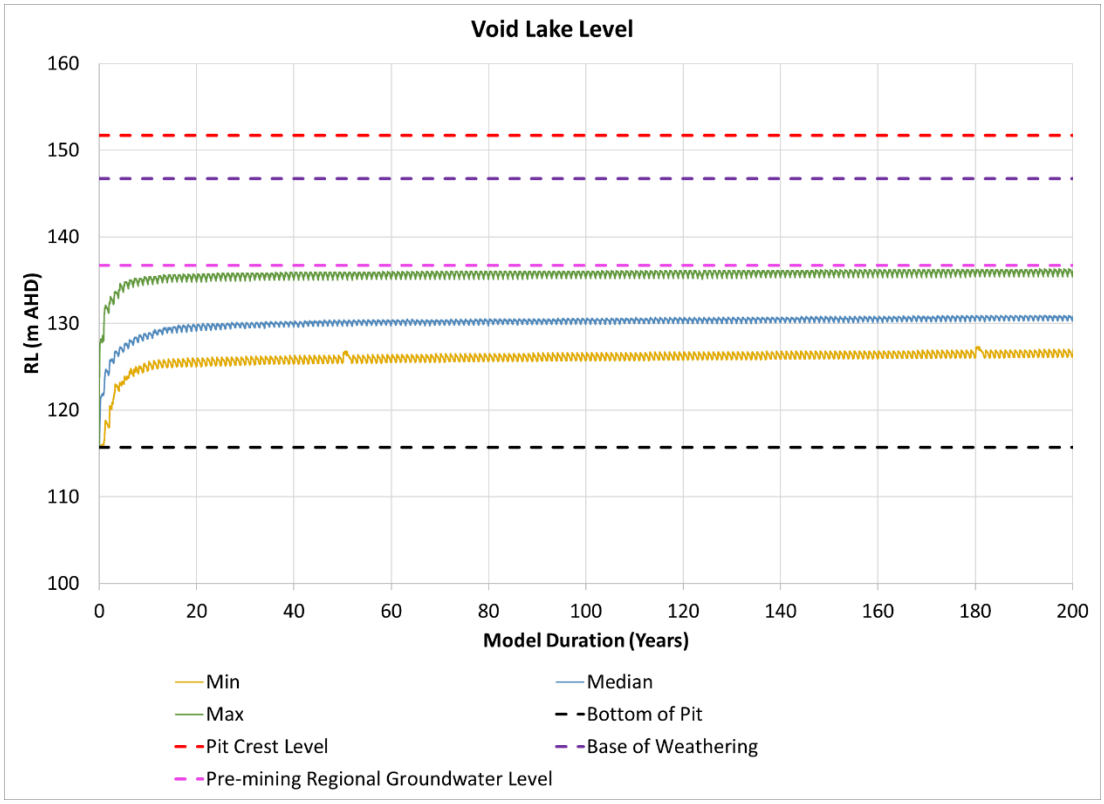
Drake Pit 4 South

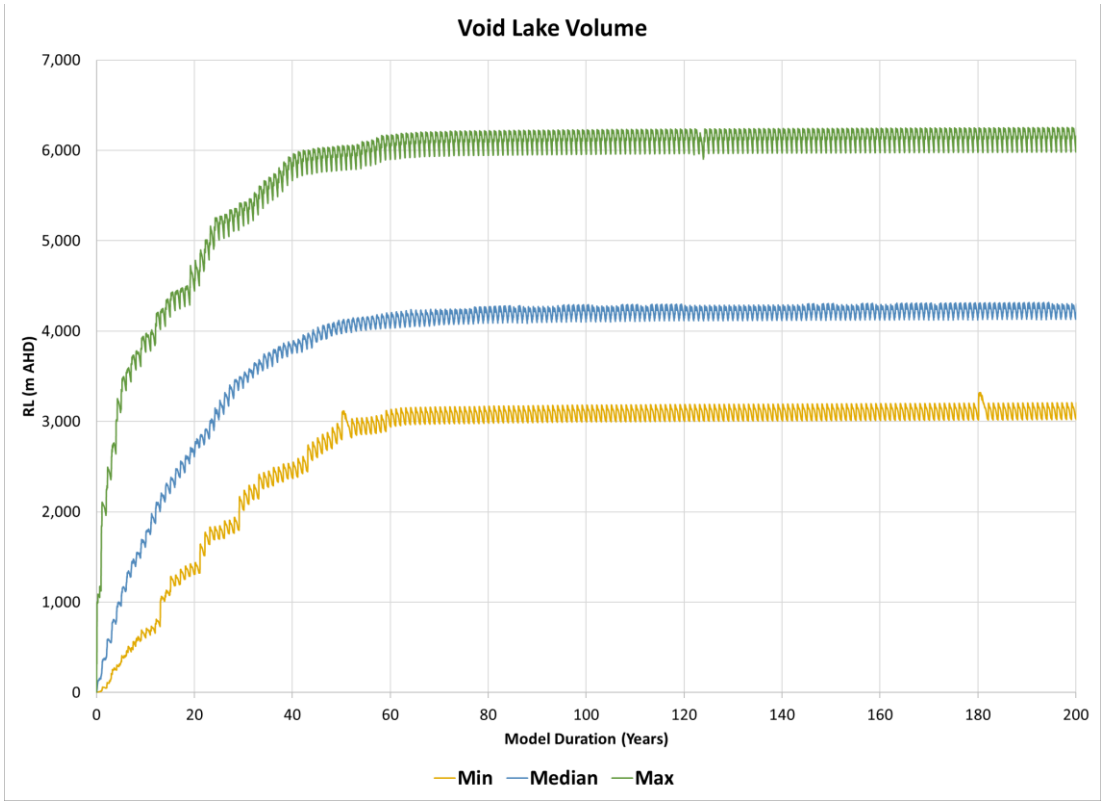


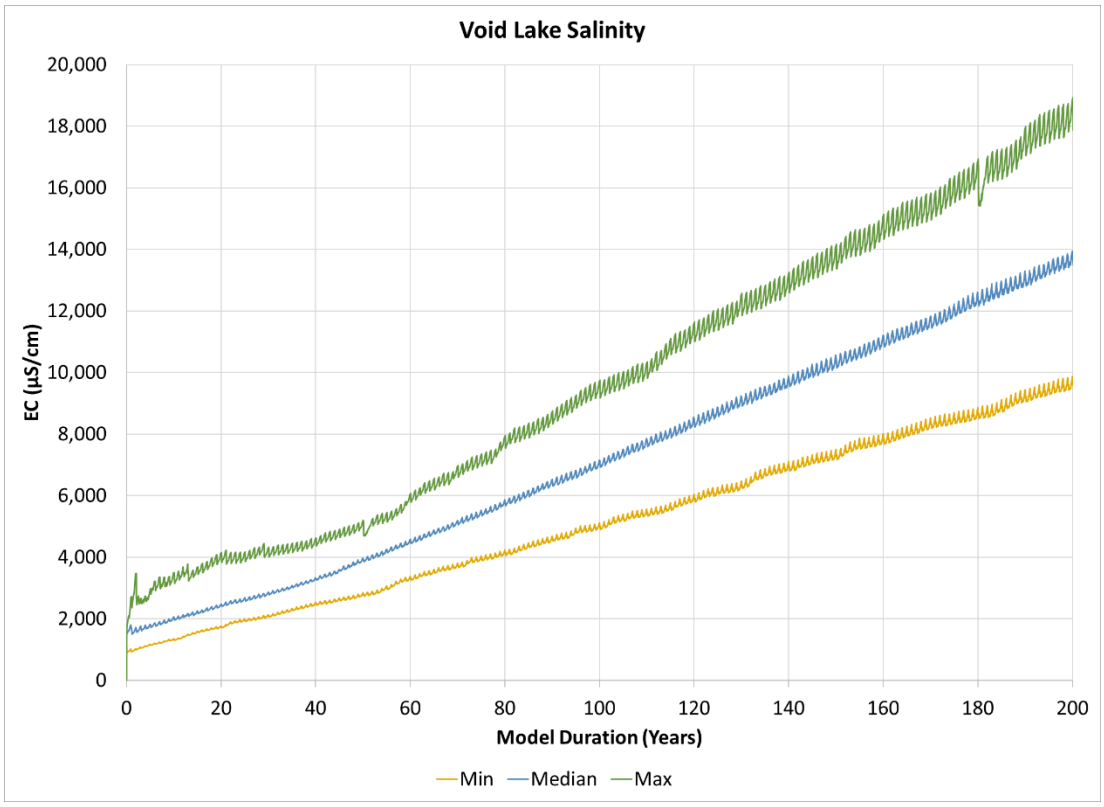



160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

Drake Pit 5


Void Lake Level
RL (m AHD)
160
150
140
130
120
110
100
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max
Bottom of Pit
Pit Crest Level
Base of Weathering
Pre-mining Regional Groundwater Level


Void Lake Volume
RL (m AHD)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

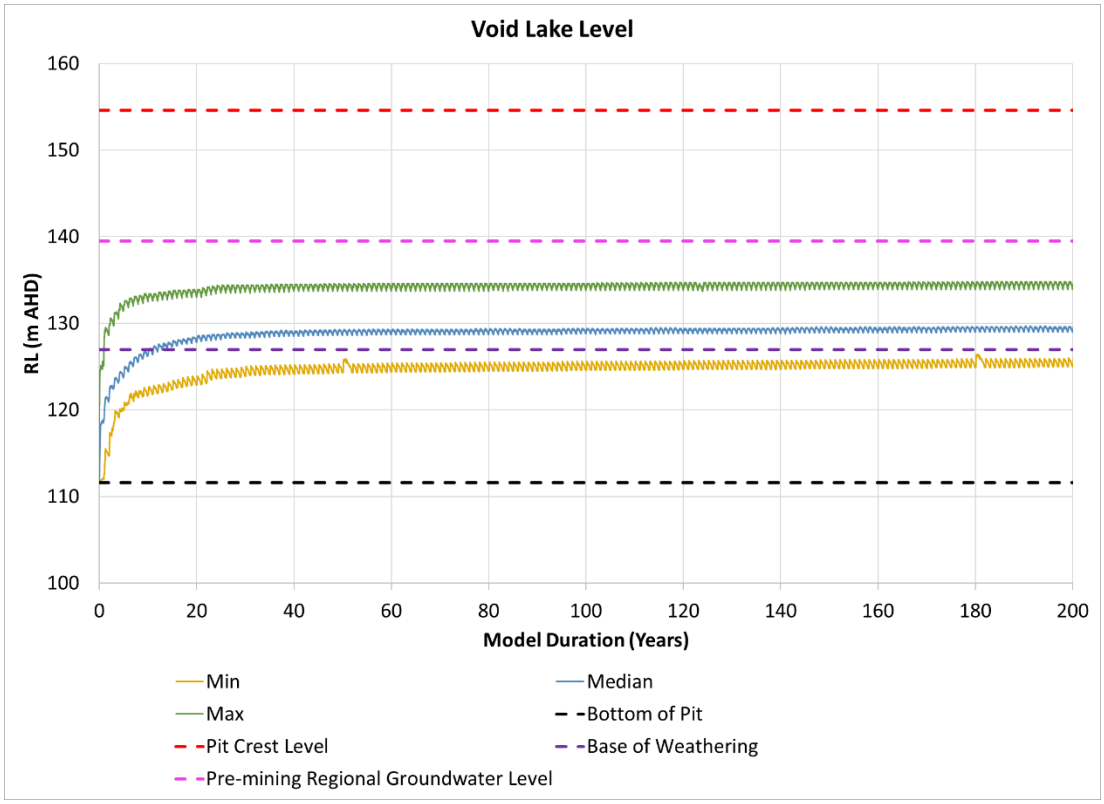

Void Lake Salinity
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

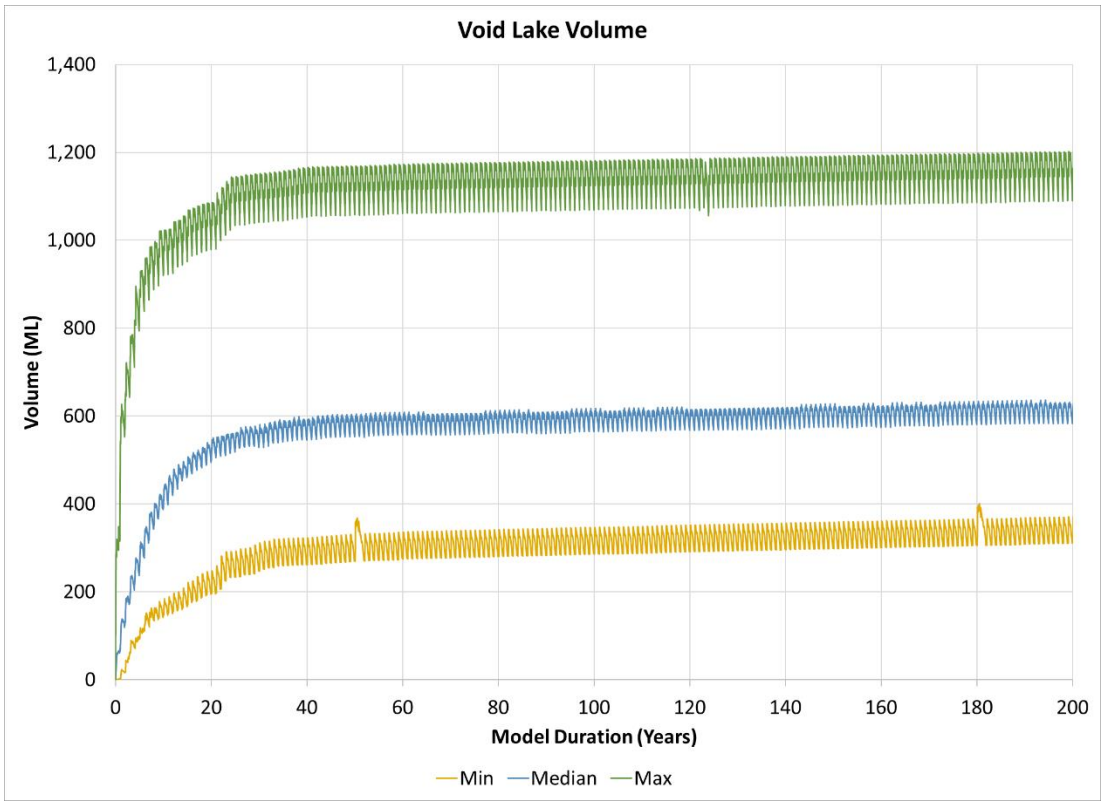
Appendix D

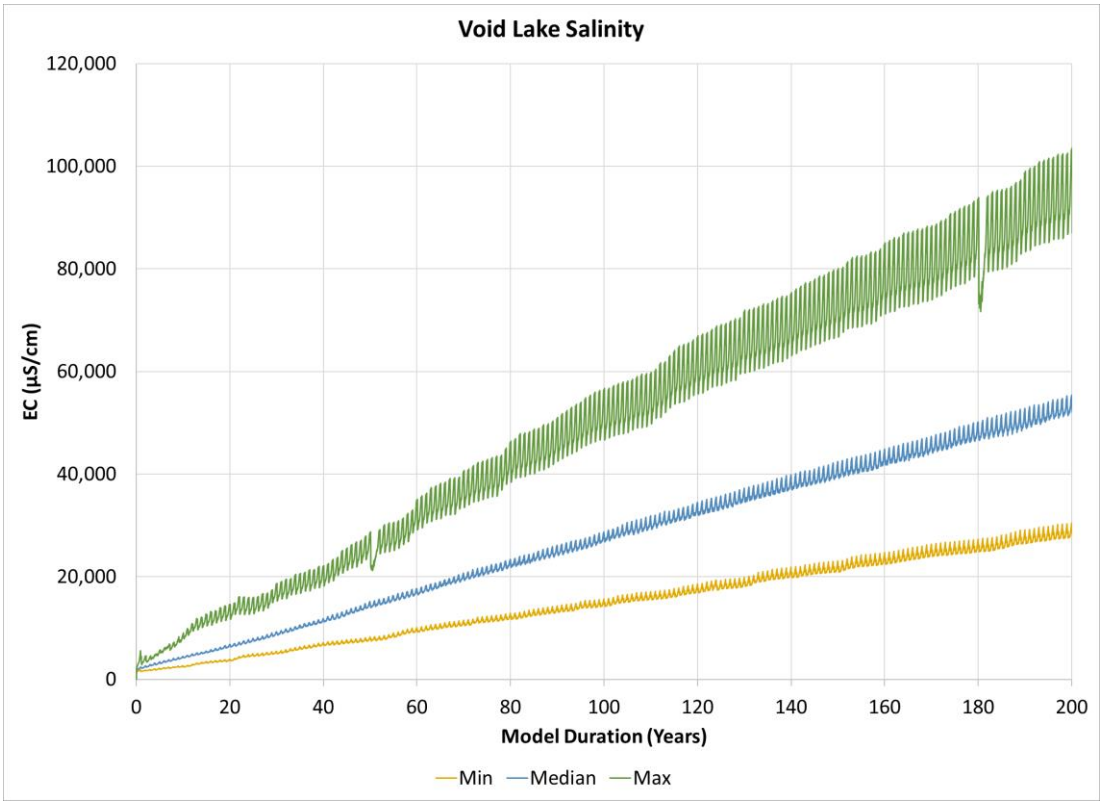
Void Hydrology Model Results

Mitigated Scenario

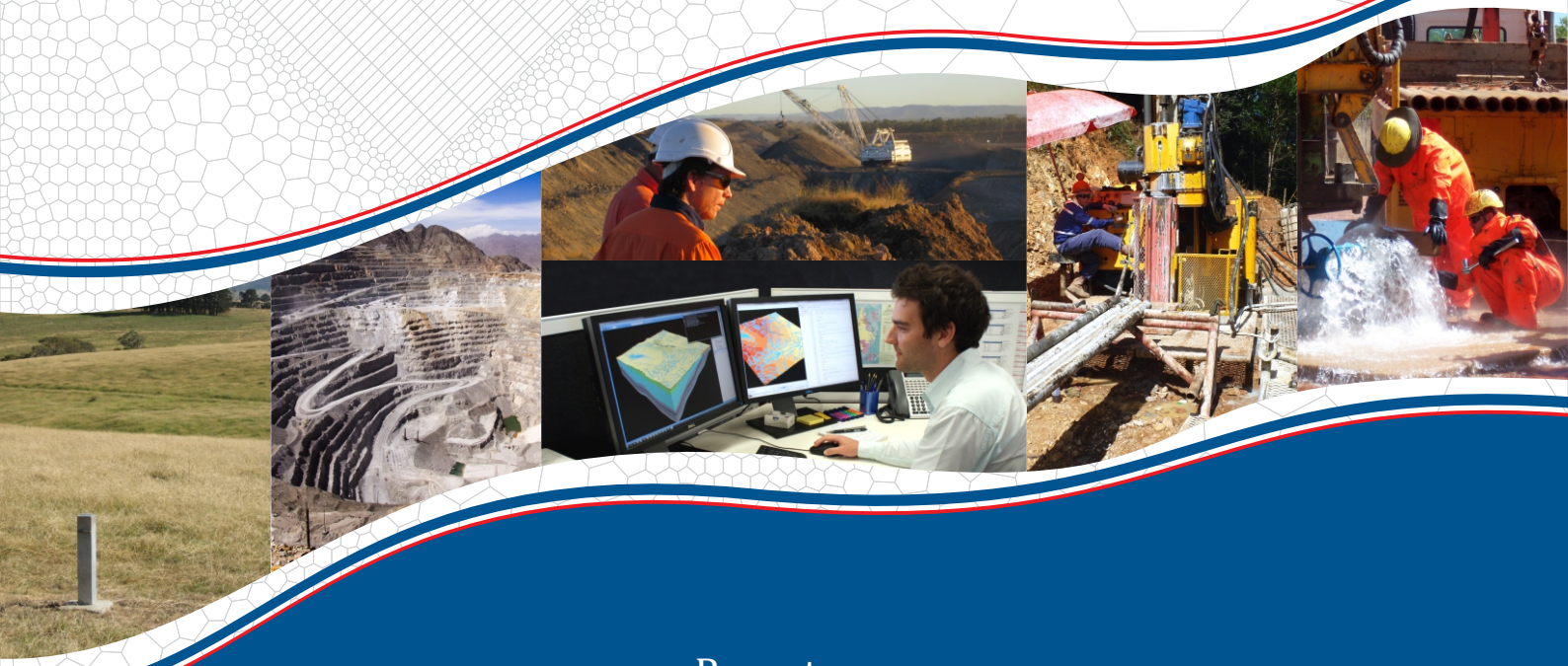
Drake Pit 4 North






Void Lake Salinity
120,000
100,000
80,000
60,000
40,000
20,000
0
EC (µS/cm)
0
20
40
60
80
100
120
140
160
180
200
Model Duration (Years)
Min
Median
Max

Australasian Groundwater and
Environmental Consultants Pty Ltd



Report on

QCoal Northern Hub Groundwater Model Update

Prepared for
QCoal Pty Ltd

Project No. G1779E June 2020
www.ageconsultants.com.au ABN 64 080 238 642

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Report on

QCoal Northern Hub
Groundwater Model Update

1 Introduction

QCoal Pty Ltd (QCoal) owns and operates the Sonoma, Cows, Drake and Jax open cut mines located in an area south of Collinsville, in north Queensland (Figure 2.1). These mines form the 'Northern Hub' (QNH) for QCoal (the Project). The Project comprises mining leases ML 10325, ML 10326, ML 10327, ML 10345, ML 10345, ML 10346, ML 10349, ML 10350, and ML 10351. Figure 2.1 shows the extent of the QNH mining leases and location to the nearest town of Collinsville.

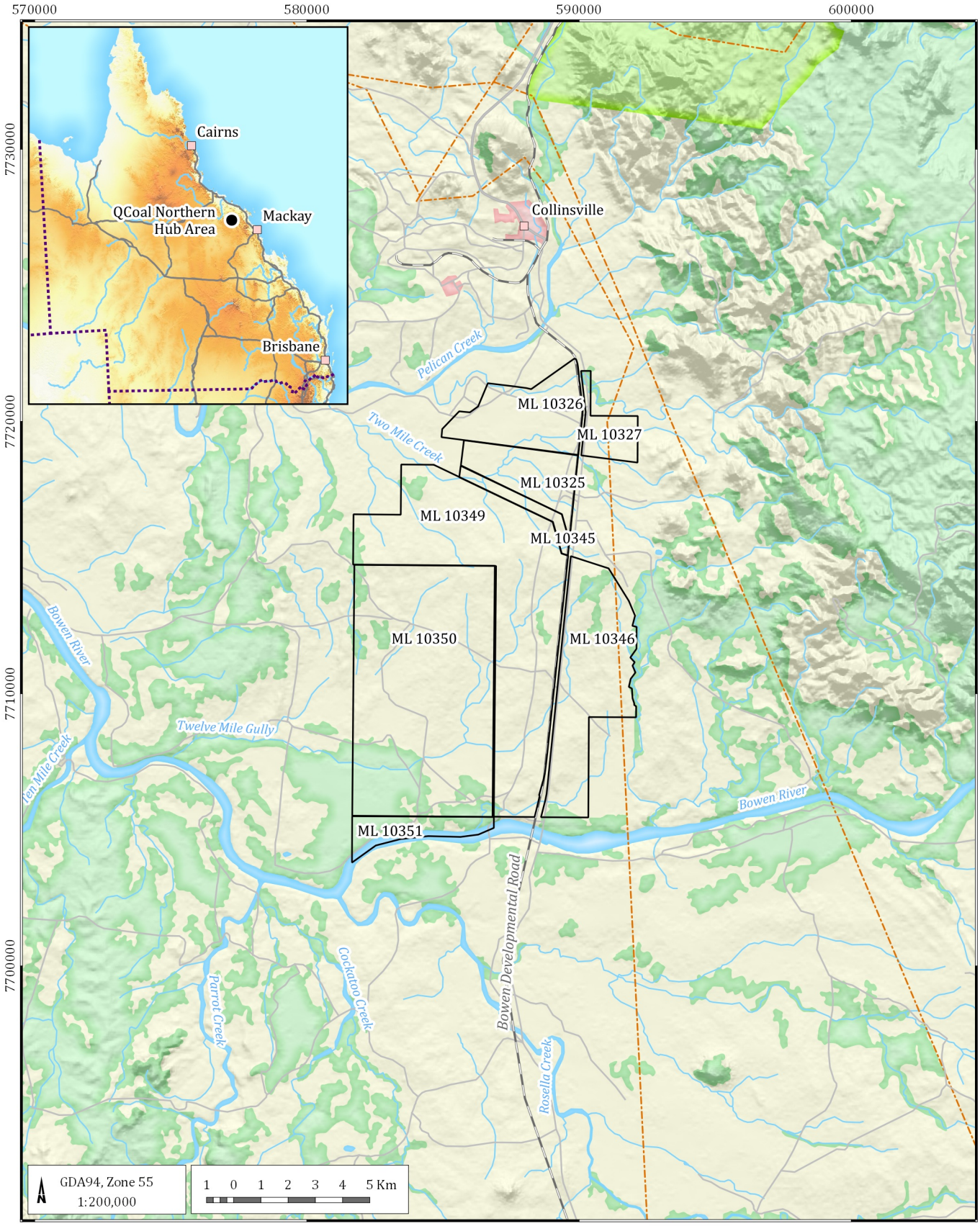
QCoal engaged Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to update the previous groundwater model to capture changes in the historical and future mine plans for the Northern Hub mines. AGE has also recognised the opportunity to contemporise the underlying model software as part of this model update.

2 Objectives and scope of work

The objective of this study was to update the existing groundwater model (AGE, 2015) that was generated to satisfy the Federal condition of approval for the Drake Project. This update to the model implements a change to the mine plan and a change of software from MODFLOW SURFACT to MODFLOW USG. To achieve this objective the scope of work included the following key tasks:

- review of existing data (including any new drilling and monitoring information);
- updating the model to run with MODFLOW USG;
- updating the mine plan to reflect the timing and direction of historical and proposed mining;
- assessing the take of water for each of the mine areas;
- assessing the impacts of the Northern Hub mines using the numerical groundwater flow model; and
- reporting the results of the study.

This report outlines the results of each of these key tasks.



LEGEND

- Populated place
- QNH mining leases
- Built up area
- Reserve
- Vegetation
- Road
- Rail
- Watercourse
- Powerline

Northern Hub Groundwater Assessment (G1779E)

Northern Hub Location

DATE 04/06/2020

FIGURE No: **2.1**

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G:\Projects\G1779E.Northern Hub Groundwater Model Update\3_GIS\Workspaces\001_Deliverable1\02.01_G1779E_Northern Hub Location.qgs

3 Site setting

3.1 Climate

The Collinsville region has a semi-arid to tropical climate with high variability in rainfall, temperature and evaporation. The area experiences a warm humid summer and a relatively dry winter, and can experience drought, floods, heatwaves and frosts. The annual average rainfall recorded at Collinsville Post Office (1939-2014) is 713.2 mm. Lower than average rainfall since 2014 reduce this number a little to around 700 mm. The Collinsville Post Office (Station No. 033013) is located about 10 km to the north of the Project at an elevation of 196 m AHD. Over 65% of the mean annual rainfall occurs in the wet season months between December and March from thunderstorms and tropical lows associated with cyclones.

Table 3.1 presents average evaporation rates recorded at the Collinsville Post Office for the period 1967 to 2013, together with the above-mentioned rainfall data. Evaporation exceeds annual rainfall in all months of the year.

Table 3.1 Mean rainfall and evaporation (mm); Collinsville Post Office – Stn 033013

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall	136	161	96	43	32	27	20	18	11	21	52	95	713
Evaporation	189	162	161	132	105	87	96	127	159	198	207	214	1839

Note: *data rounded to zero decimal places*

Figure 3.1 presents the Cumulative Rainfall Departure (CRD) (also commonly referred to as the rainfall residual mass) for the Collinsville. The CRD graphically presents long-term trends in rainfall, with a rising slope indicting above average rainfall, and a falling slope indicating below average.

Figure 3.1 indicates that the area has experienced a period of consistently below average rainfall from 2000 to 2008, a period now known as the 'Millennium Drought' Rainfall was well above average between 2008 and 2011 and resulted in significant flooding in central Queensland. The recent records suggest the area is experiencing another period of below average rainfall.

Groundwater levels can be commonly related to the CRD, with water levels falling in dry periods and rising in response to above average rainfall. The recent climate records suggest groundwater levels are now falling in response to a below average rainfall.

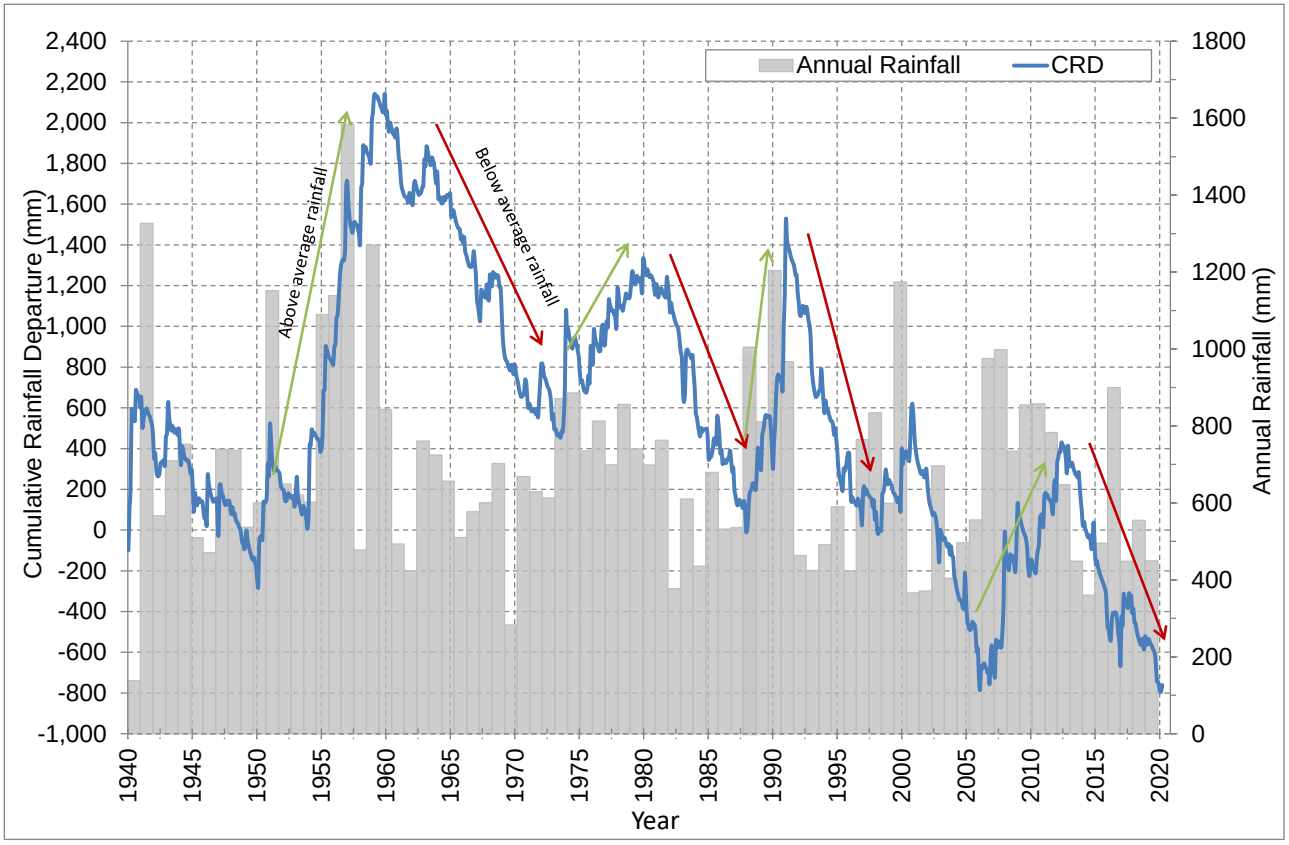


Figure 3.1 Annual Rainfall and Cumulative Rainfall Departure

3.2 Topography and drainage

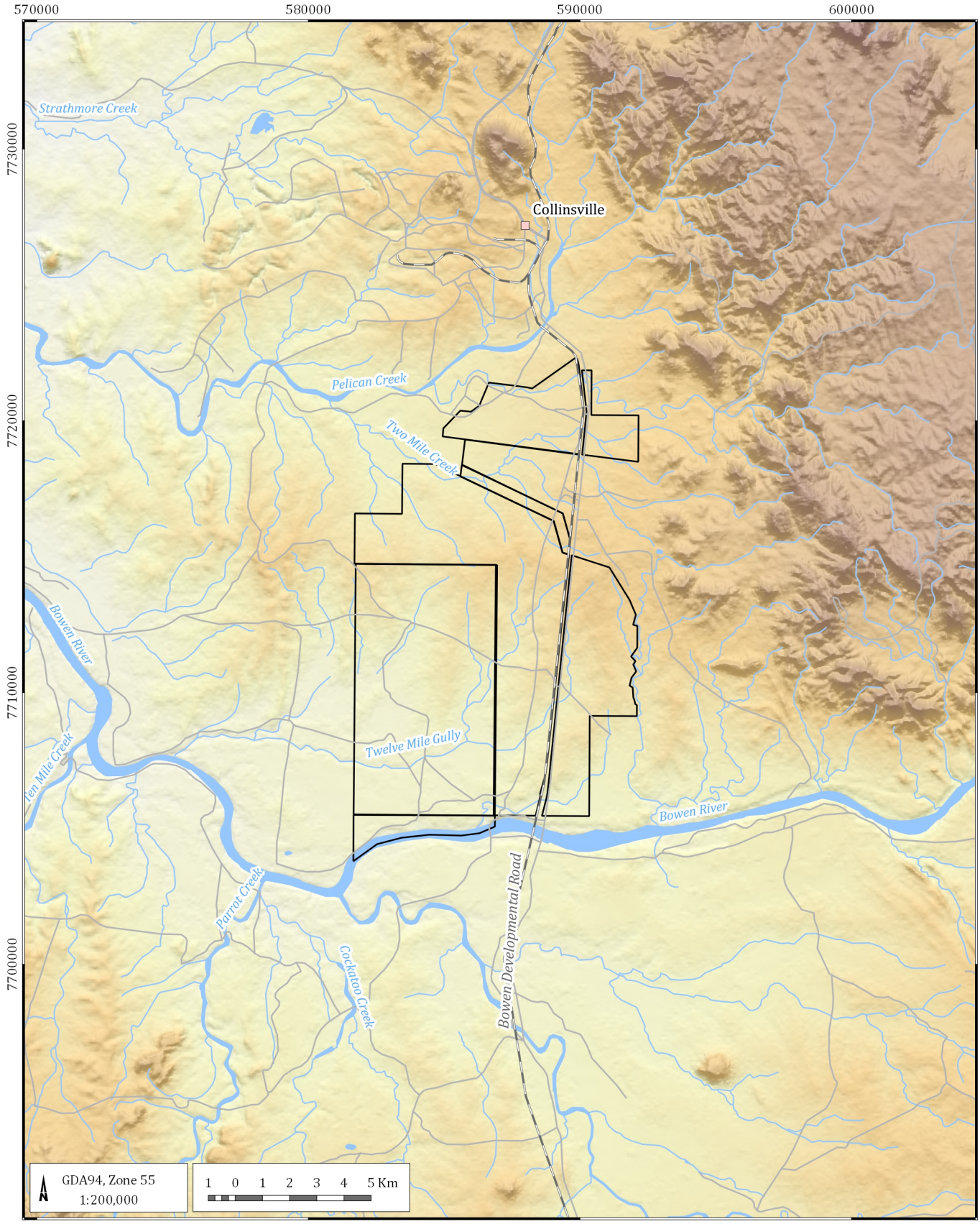
Flat to slightly undulating plains characterise the southern portion of the project site, with minor hills in the north-east and north-west. Elevation of the site varies from 130 m to 200 m Australian Height Datum (AHD). The general slope is ≤3% over much of the project site with steeper slopes of up to 10% associated with hills in the northeast.

The Project site is located within the Bowen River Catchment (a sub-catchment of the Burdekin River catchment), which originates in Eungella National Park and flows in a north-west direction to join the Burdekin River upstream of the Blue Valley Weir. The catchment area of the Bowen River is approximately 9,530 km^2, while the Burdekin River catchment area is approximately 130,000 km^2.

Two minor creeks drain the project site; Twelve Mile Gully (an upper tributary of the Bowen River) and Two Mile Creek, also a tributary of the Bowen River that flows into Pelican Creek (Figure 3.2). The majority of the site (70.5 km^2) drains in a south-west direction into the Twelve Mile Gully catchment, while the northern most portion of the site (18 km^2) drains in a north-west direction into the Two Mile Creek catchment. Twelve Mile Gully and Two Mile Creek are both ephemeral and only flow during, and shortly after, heavy rainfall. In contrast the Bowen River experiences a perennial flow of water due to a combination of catchment runoff and releases from Eungella Dam.

3.3 Land use

The Project area was formally used for beef cattle grazing using the cell grazing technique. The Newlands-Abbot Point railway line and Bowen Development Road corridor cut through the Northern Hub project area. The Collinsville mine is located to the north of the Project area, with cattle grazing land to the east. The Collinsville Township is approximately 5 km north of the Project's northern boundary.



LEGEND

- Populated place
- QNH mining leases
- Road
- Rail
- Watercourse

Elevation (mAHD)

- 0
- 100
- 150
- 200
- 400
- 600
- 800

Northern Hub Groundwater Assessment (G1779E)

Topography and drainage

DATE 04/06/2020

FIGURE No: **3.2**

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G:\Projects\G1779E.Northern Hub Groundwater Model Update\3_GIS\Workspaces\001_Deliverable1\03.02_G1779E_Terrain and drainage.qgs

3.4 Geology

The Project area is located on the northern tip of the north-south trending Bowen Basin. The Bowen Basin is an Early Permian to Middle Triassic geological unit extending over 600 km through central Queensland from Collinsville in the north, to Rolleston in the south.

The underlying geology comprises the basal Lizzie Creek Volcanics, overlying marine (Back Creek Group) and Upper Permian freshwater sediments (Blackwater Group). The marine sedimentary rocks of the Back Creek Group are subdivided into the Collinsville Coal Measures and the laterally equivalent Gebbie Formation, Blenheim Formation and Exmoor Formation. The Blackwater Group comprises the Moranbah and Fort Cooper Coal Measures. A blanket of unconsolidated Quaternary alluvium covers the coal measures along the main drainage lines. Table 3.2 summarises the main stratigraphic units present in the region, with Figure 3.4 showing the surface geology of the area.

Table 3.2 Generalised stratigraphy of the Collinsville area

Age	Group	Formation	Description
Cainozoic		Quaternary alluvium	Unconsolidated clay, silt, sand and gravel
Permian	Black-water group	Fort Cooper Coal Measures	Sandstone, conglomerate, mudstone, carbonaceous shale, coal, cherty tuff
		Moranbah Coal Measures	cross-bedded lithic sandstone and siltstone, mudstone, coal and fossil logs
	Back Creek Group	Exmoor Formation	sandstone, siltstone, mudstone, rare fossils
		Collinsville Coal Measures/ Gebbie Formation	Quartzose sandstone, conglomerate, siltstone, coal (mined at Collinsville mine)
		Blenheim subgroup	Micaceous siltstone, pebbly in places, labile sandstone, quartzose lithic sandstone, coquinite, limestone
Carboniferous/ Permian		Lizzie Creek Volcanics	Basaltic, andesitic rhyolitic to dacitic lavas, volcaniclastic rocks, local siltstone, shale and conglomerate

At the time of the previous model development, no surface geology map was available. The Geological Survey of Queensland within the Department of Natural Resources and Mines (DNRM) indicated in communications in early July 2014 that they were still working on preparing a surface geology map that would be available in the near future. That map is now available, however the this model update has not considered any reassignment of aquifer parameter distribution, nor any calibration, so this updated mapping has not been included in the model development to date. It is recommended that it be included the next time the model is calibrated. The extent of the alluvium across the project site was therefore projected based on topography around the main drainage lines and additional anecdotal information sources such as the Drake Environmental Impact Statement (GHD, 2012).

The Moranbah Coal Measures contain the main economic seams being targeted by the QCoal Northern Hub mining complex that includes Drake, Sonoma, Cows, and Jax mines, however the mining will also intercept the R and S seams of the Fort Cooper Coal Measures which overly the Moranbah Coal Measures. The coal seams are relatively clean and contain only minor tuffaceous and mudstone bands. Figure 3.3 summaries the nomenclature for the coal seams and the various plys that occur in the area. A summary of the coal seam geology is presented in Table 3.3.

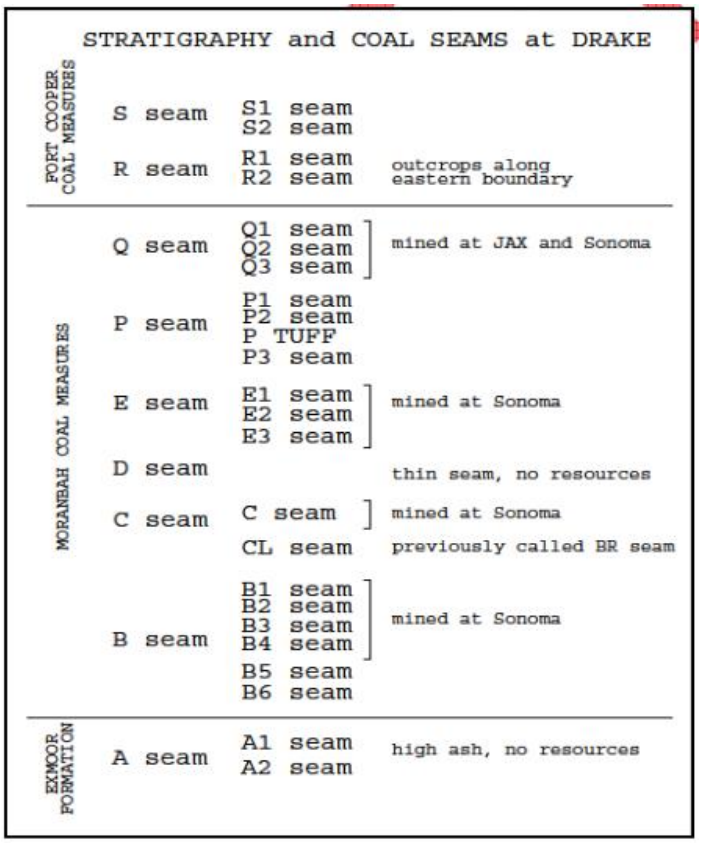
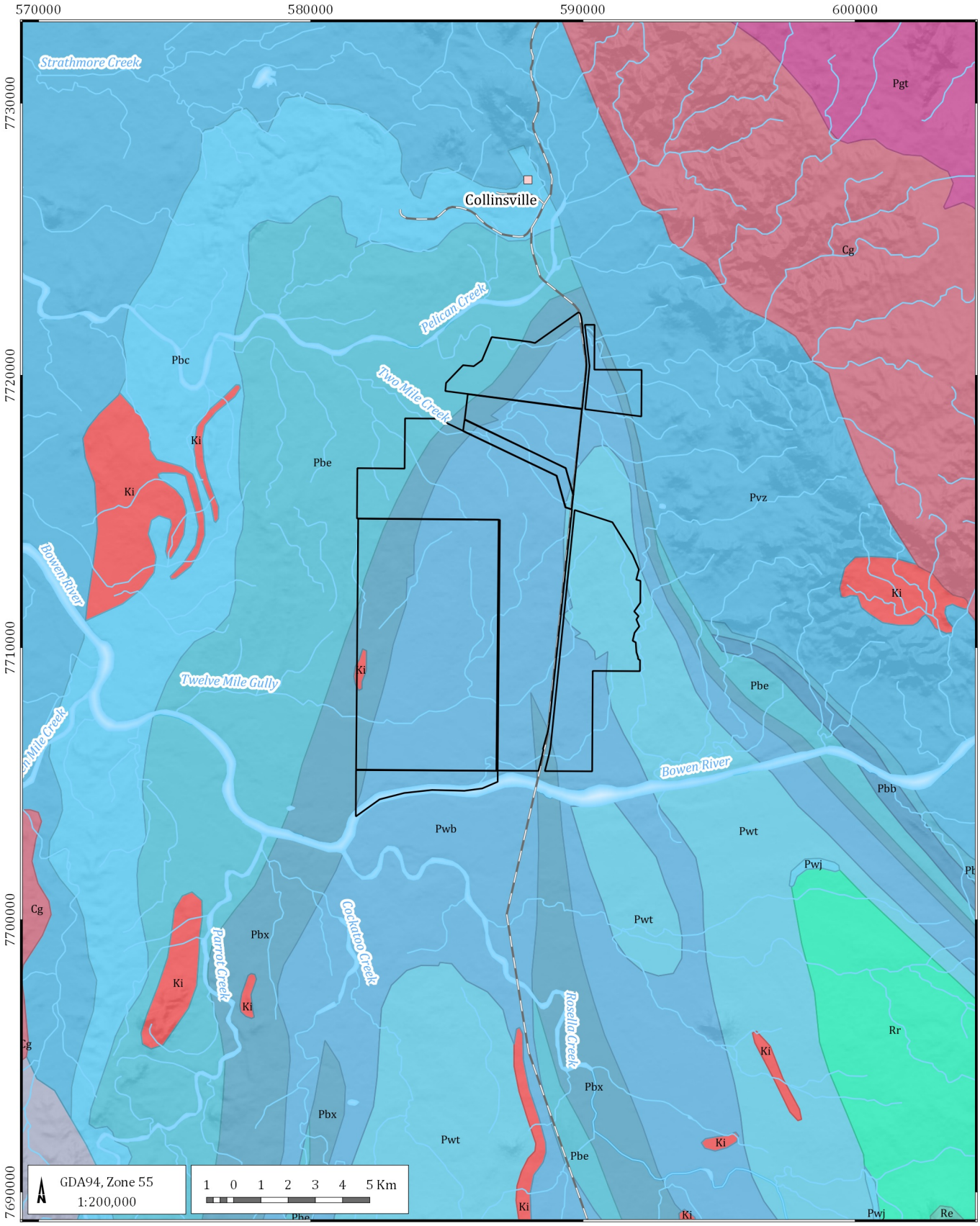


Figure 3.3 Coal seam nomenclature in project area

Table 3.3 Summary coal seam geology

Seam	Summary
Q seam	This is the uppermost coal horizon of the Moranbah Coal Measures and dips toward the south at 4-5°. The seam occurs over a 10-11 m interval and is readily subdivided into an upper, middle and lower section and is separated from the underlying P Rider seam by a ~30 m thick sequence comprising fine to coarse-grained sandstone and minor siltstone.
P Rider seam	The P Rider seam occurs some 5-25 m above the P seam, separated by an interbedded sequence of siltstone and fine-grained sandstone that in places coarsens markedly. The P Rider seam is banded, comprising up to three coal horizons of 0.5 m to 1.5 m individual thickness.
P seam	The seam is comprised of an upper and lower horizon with the upper ply ranging between 0.5 m and 1.0 m thick and the lower ply between 1.0 m and 1.5 m thick. The P seam is separated from the underlying E seam by approximately 30-40 m of siltstone, along with a medium to very coarse-grained volcanolithic sandstone units (to 8 m thick).
E seam	Comprised of three coal horizons. The upper section commonly hosts a 3.5 m thick feldspar porphyry sill. The middle coal section varies in thickness between 2.0-3.2 m with the lower coal ply varying between 1.0-1.5 m. The C to E seam interval comprises fine to coarse-grained volcanolithic sandstone, with minor mudstone and siltstone.
C seam	Seam sub-crops dips to the south at an angle of 4-5° and is comprised of upper and middle sections of coal with numerous thin tuffaceous bands, and a 1.5-2.0 m clean lower section. The C seam is separated from the underlying B seam by approximately 70m of siltstone, mudstone and fine to medium-grained, felspathic sandstone.
B seam	Essentially a single entity, of between 12-16 m thick from the sub-crop zone to a depth of 100 m. Whilst the seam is very thick over a large proportion of the drilled area, igneous intrusions are commonplace. The B seam is separated from the underlying A seam by 15-24 m of fine-grained sandstone, siltstone and carbonaceous mudstone.



LEGEND

- QNH mining leases
- Watercourse

Regional geology

- Pbt - Tiverton Formation
- Pwt - Fair Hill Formation
- Rr - Rewan Formation
- Cvb - Bulgonunna Volcanic Group
- Ki - Ki-CQ
- Pvz - Lizzie Creek Volcanics
- Cg - Cg-BBG
- Pbx - Exmoor Formation
- Pbe - Blenheim Subgroup
- Re - Clematis Group
- Pwb - Moranbah Coal Measures
- Pbc - Collinsville Coal Measures
- Pbb - Gebbie Subgroup
- Pgt - Thunderbolt Granite
- Pwj - Rangal Coal Measures

Northern Hub Groundwater Assessment (G1779E)

Regional geology

DATE 04/06/2020

FIGURE No: **3.4**

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4 Hydrogeology

4.1 Aquifers and aquitards

Two geological units have been identified that have the potential to comprise aquifers within the region:

- Cainozoic alluvial sediments that form a sporadic shallow unconfined aquifer where sufficiently thick; and
- Deeper confined aquifers within the Permian coal seams.

Quaternary alluvium occurs intermittently within the flood plains of Coral Creek and the Bowen River and comprises finer silts and clays overlying coarser sands and gravels at the base of the unit. At Sonoma the alluvium is only sporadically saturated in areas where the alluvial material is thicker and below the water table. In the area between the Coral Creek and the Bowen River there would only be limited alluvium present.

Registered bores within a 20 km radius from the Project boundary recorded alluvial units up to 19.5 m, with one registered bore (RN60362 approximately 18 km south) recording 74.7 m. Overall, the alluvial units present range in thickness from a thin veneer in the south to a maximum of 24 m near Coral Creek in the north.

It is generally accepted that in the Bowen Basin coal seams have a higher permeability than the inter-burden and therefore comprise the main water bearing beds. The review of the resource exploration data for the Sonoma and Drake deposits indicates that the inter-burden is typically comprised of fine-grained sandstone, siltstone and mudstone that are of low primary porosity and would be expected to yield only very limited quantities of poor quality groundwater.

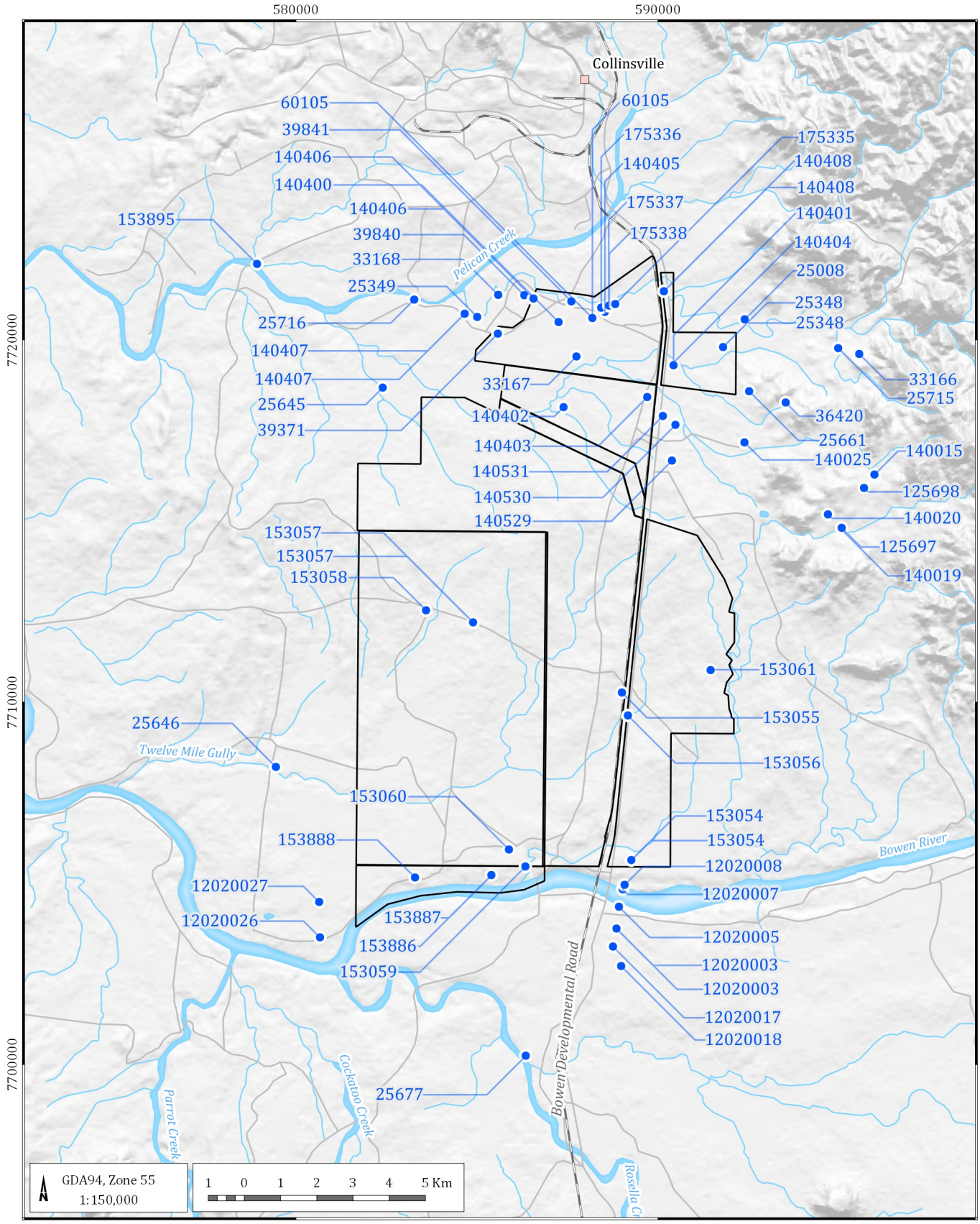
A series of thrust fault displace and offset the coal seams through the project site. The displacements are in the order of 20 m to 40 m greater than the typical thickness of the coal seams interrupting the continuity of the groundwater through the coal seams.

4.2 Water users

A search of the DNRM groundwater database identified 47 registered bores within the immediate Northern Hub area (Figure 4.1).. Of these 47 bores, 2 have been abandoned and destroyed, 5 are abandoned but usable and 40 have been recorded as existing. Of these existing bores, 13 are noted as existing and being equipped.

4.3 Groundwater monitoring bores

Groundwater monitoring bores used to determine groundwater level and quality in the Project area are located throughout the Northern Hub mining areas.



LEGEND

- Populated place
- QNH mining leases
- Road
- Rail
- Watercourse
- Registered bores in model area

Northern Hub Groundwater Assessment (G1779E)

Registered groundwater bores within and around Northern Hub

DATE 04/06/2020

FIGURE No: **4.1**

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Table 4.1 Registered groundwater bore details

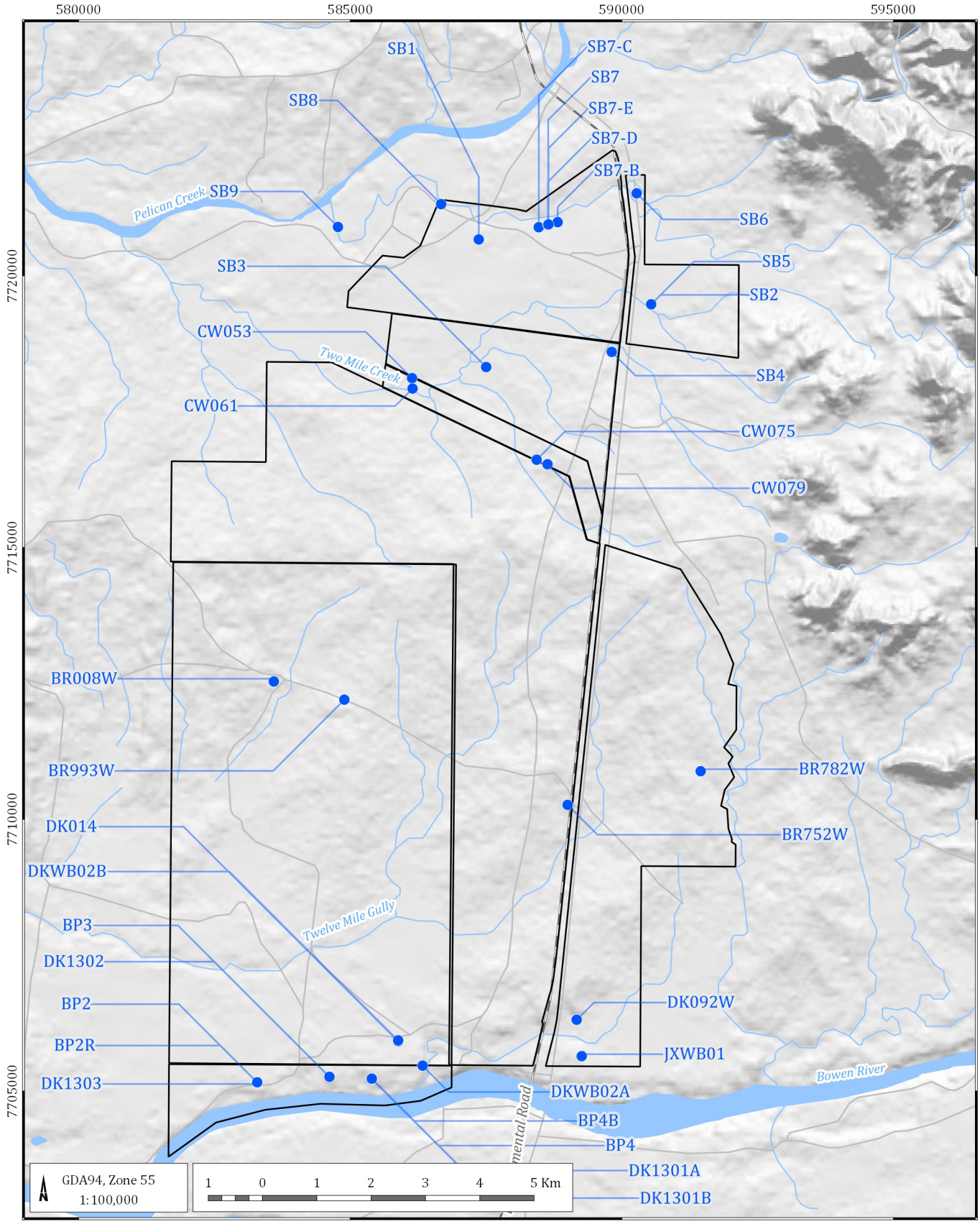
RN[1]	Bore name	Easting[2]	Northing	Bore status	Year drilled	Equipment	Formation	SWL	Discharge (m^3/d)	Screen material	Top of Screen (mbgl)[4]	Base of Screen (mbgl)
25348		591794	7719800	Existing	1966	Windmill_Cylinder Pump		-9.1	40.4			
25349		585005	7720630	Existing	1966	Windmill_Cylinder Pump				Steel	0	18.3
25645		582395	7718680	Existing	1967	Windmill_Cylinder Pump			76.4		0	15.2
25646		579445	7708210	Existing	1967	Windmill_Cylinder Pump			43.6	Steel	0	90.5
25661		592514	7718580	Existing	1967	Windmill_Cylinder Pump						
25677	House	586345	7700240	Existing	1967	Windmill_Cylinder Pump				Steel	0	28.9
25716		583265	7721110	Existing	1968	Centrifugal Pump	Alluvium	-9.7	218.0	Steel	0	14.9
33167		587745	7719540	Existing	1967	Windmill_Cylinder Pump	Basalt	-10.3	109.2	Steel	0	15.2
33168		585585	7721240	Existing	1970	Turbine						
39371	Near Pelican Ck Sth	585575	7720170	Existing	1973	Turbine	Alluvium	10.67	1,310.4	Steel	18.3	19.5
39840	Homestead Bore	586305	7721230	Existing	1975	Turbine	Alluvium	-9.1	1,965.6	Steel	13.4	14.6
39841		587605	7721060	Existing	1975	Windmill_Cylinder Pump	Alluvium	-6.1	43.6	PVC	0	11.2

RN[1]	Bore name	Easting[2]	Northing	Bore status	Year drilled	Equipment	Formation	SWL	Discharge (m^3d)	Screen material	Top of Screen (mbgl)[4]	Base of Screen (mbgl)
60105		588185	7720600	Existing	1980	Windmill_Cylinder Pump	Alluvium			PVC	18.3	19.5
140400	SB1	587252	7720490	Existing	2007	NA				PVC	22.0	25.0
140401	SB2	590426	7719297	Existing	2007	NA				PVC	18.5	21.5
140402	SB3	587389	7718142	Existing	2007	NA				PVC	27.0	30.0
140403	SB4	589700	7718421	Existing	2007	NA				PVC	66.0	72.0
140404	SB5	590426	7719297	Existing	2007	NA				PVC	67.0	73.0
140405	SB7	588530	7720770	Existing	2007	NA				PVC	24.9	27.9
140406	SB8	586560	7721140	Existing	2007	NA				PVC	18.5	21.5
140407	SB9	584660	7720720	Existing	2007	NA				PVC	23.9	26.9
140529		590383	7716667	Existing	2007	No Equipment				PVC	18.0	30.0
140530		590479	7717653	Existing	2007	No Equipment				PVC	9.0	20.0
140531		590132	7717898	Existing	2007	No Equipment				PVC	9.0	24.0
12020017A		588754	7703253	Existing	1996	No Equipment				PVC	19.1	22.1
12020017B				Existing	1996	No Equipment				PVC	6.5	7.5
12020018	Havilah Line	588980	7702715	Existing	1996	No Equipment				PVC	15.2	16.2
12020026		580663	7703507	Existing	1996	No Equipment				PVC	7.0	8.0
12020027		580641	7704484	Existing	1996	No Equipment				PVC	5.0	6.0
12020003		588851	7703750	Abandoned	1975	No Equipment				PVC	15.4	18.4

RN[1]	Bore name	Easting[2]	Northing	Bore status	Year drilled	Equipment	Formation	SWL	Discharge (m^3/d)	Screen material	Top of Screen (mbgl)[4]	Base of Screen (mbgl)
				Usable								
12020004		588856	7038255	Abandoned Usable	1975	No Equipment				PVC	0	12.6
12020005		588919	7704352	Abandoned Usable	1975	NA				PVC	12.2	18.2
12020007		589023	7704833	Abandoned Usable	1975	NA				PVC	0	7.3
12020008		589075	7704956	Abandoned Usable	1975	NA				PVC	0	12.2
140025		592385	7717168	Abandoned Destroyed	2006	NA						
Northern Hub monitoring bores												
153054	JXWB01	589260	7705640	Abandoned Destroyed	2009	Abandoned and Destroyed				PVC	6.0	12.0
153056	DK092W	589167	7709631	Existing	2009	NA				PVC	29.35	41.35
153057	BR993W	584890	7712200	Existing	2009	NA				PVC	36.0	51.0
153058	BR008W	583592	7712534	Existing	2009	NA	Exmoor			PVC	42.0	66.0
153059	DKWB02A	586335	7705463	Existing	2009	NA				PVC	8.0	17.0
153060	DKWB02B	585881	7705931	Existing	2009	NA				PVC	7.0	10.0
153061	BR782W	591450	7710883	Existing	2009	NA				PVC	10.0	16.0
153055	BR752W	589001	7710264	Existing	2009	NA				PVC	41.0	44.0

RN[1]	Bore name	Easting[2]	Northing	Bore status	Year drilled	Equipment	Formation	SWL	Discharge (m^3d)	Screen material	Top of Screen (mbgl)[4]	Base of Screen (mbgl)
	BP2R	583288	7705159	Existing	2014	NA				PVC	5.0	11.0
	BP3	584616	7705260	Existing	2014	NA				PVC	15.0	21.0
	BP4	585395	7705226	Existing	2014	NA				PVC	21.0	27.0
	BP4B	585402	7705226	Existing	2014	NA				PVC	3.0	8.0
	CW053	586137	7718115	Existing	2010	NA						
	CW061	586145	7717924	Existing	2010	NA						
	CW075	588430	7716614	Existing	2010	NA						
	CW079	588631	7716532	Existing	2010	NA						

Notes: *1 RN – Department of Natural Resources and Mines Registered Number*
2 GDA 94 Zone 55
3 NA denotes information not available
4 mbgl – meters below ground level



LEGEND

- QNH mining leases
- Road
- Rail
- Watercourse
- QNH monitoring bores

Northern Hub Groundwater Assessment (G1779E)

Northern Hub monitoring bore locations

DATE 04/06/2020

FIGURE No: **4.2**

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5 Conceptual hydrogeological model

5.1 Geological model

The regional geology is described in Section 3.4 of this report. Exploration drilling at Sonoma, Drake and Havilah has been used by QCoal to create a detailed geological model of the Project area. This model was further simplified at AGE's request to identify the key basal seams and accumulated coal seam thicknesses for the requested groupings. The geological model has captured the faulting and displacement of seams that has taken place.

Since the previous model development, the availability of surface geology information has been increased, with the Geological Survey of Queensland releasing surface geology for the Collinsville 100K map area. The model update for this body of work has focused on the mine plan and has not attempted to change the model setup in terms of geological or hydrogeological extents and parameters. The previous modelling based the extent of alluvium across the project site has been projected based on the location and dimensions of the surface drainages. The new mapping does demonstrate a difference in the alluvium extent, and it is recommended that the mapped alluvial extent be incorporated when the model is next recalibrated.

The weathered cover material is understood to be mostly comprised of fines (silts and clays), although there would be isolated sand and gravel pockets where historical river channels have existed. The base of weathering elevation has been used to define the floor of the cover material.

The geological model used as a basis for the numerical flow model has been simplified to the target coal seams in the Moranbah Coal Measures separated by interburden. Underlying these layers is the Exmoor formation, which is also simulated, but as a single discrete unit. On the eastern margin of the project site, aligned to the deeper central part of the basin, the Fort Copper Coal Measures overly the Moranbah Coal measures, and these are also represented in the model as a single discrete unit. Further to the east of project site the Moranbah Coal Measures and Exmoor Formation subcrop again (forming the other side of the basin) and the underlying Lizzie Creek Volcanics outcrop.

A review of the available data indicates that the hydrogeological regime in and around the project site consists of:

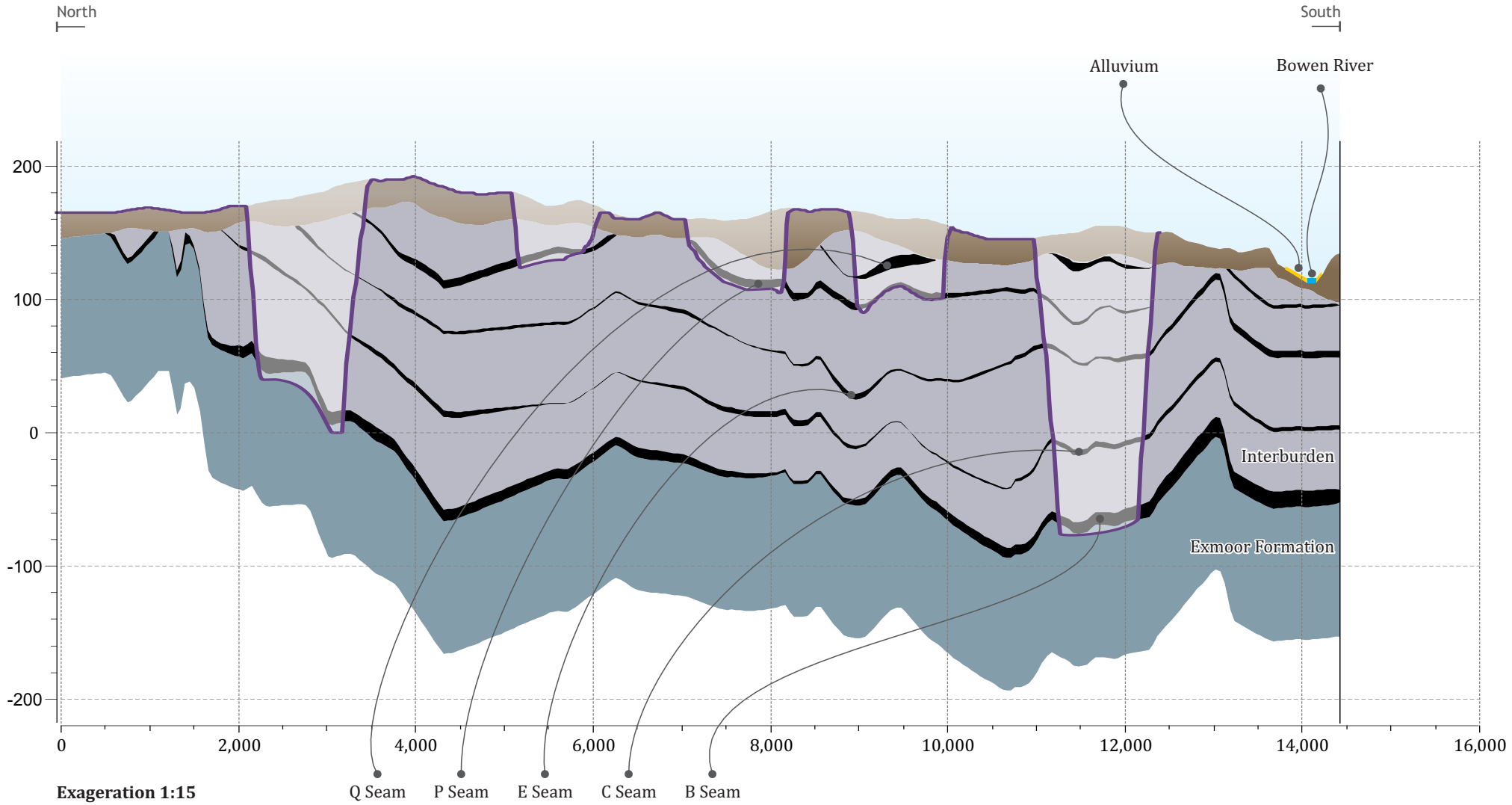
- a shallow unconfined aquifer in the Cainozoic alluvial sediments; and
- deeper confined aquifers within the Permian coal seams.

It is generally accepted that in the Bowen Basin coal strata have a higher permeability than the inter-burden and therefore comprise the main water bearing beds. The review of the resource exploration data indicates that the interburden is typically comprised of fine-grained sandstone, siltstone and mudstone that are of low primary porosity and would be expected to yield only very limited quantities of poor quality groundwater. Although each individual coal seam may be regarded as an aquifer unit separated by low permeability interburden, for the purposes of this assessment it is considered that, as mining will be undertaken through multiple seams, the Permian sequence can be simplified to isolate the key coal seams and the remainder represented as a single interburden unit between the coal seams.

In addition, the thrust fault displacements are in the order of 20-40 m greater than the typical thickness of the coal seams which are only several metres thick which serves to interrupt the lateral extent and continuity of the coal seam aquifers. It is understood there is only limited broken ground associated with the faults and therefore the faults would only be expected to transmit low volumes of groundwater.

A critical aspect of this assessment is the interaction of the mine with the Bowen River. Figure 5.2 presents detail from the cross section presented in Figure 5.1.

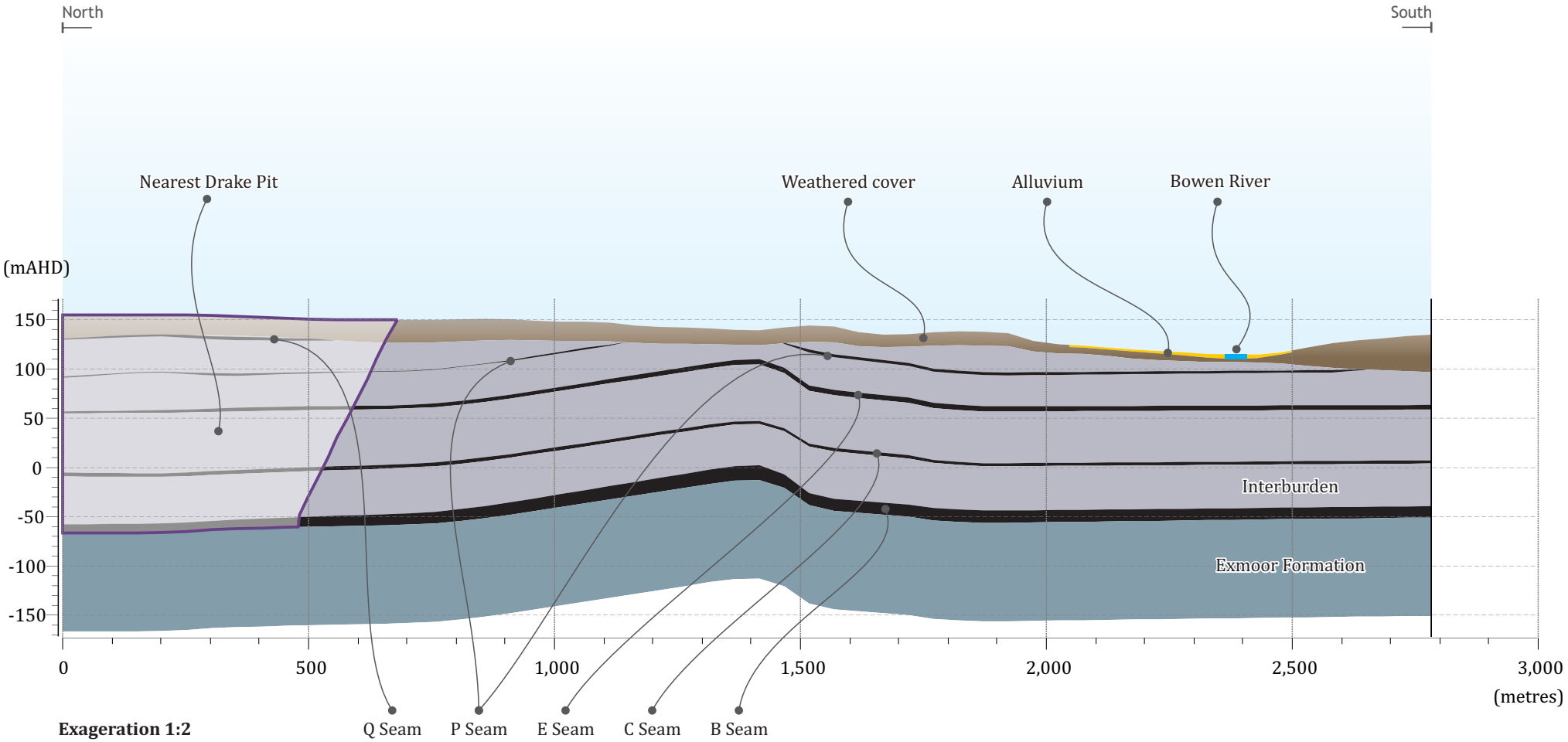
This demonstrates how the coal seams at this location dip below the river and keep getting deeper within the Bowen Basin to the south of the project area.



Cross-section

Figure 5.1

Northern Hub Groundwater Assessment (G1779E)



Cross-section - detail

Figure 5.2

Northern Hub Groundwater Assessment (G1779E)

5.2 Aquifer parameters

Geoaxiom (2010) measured hydraulic conductivity in four bores at the project site using falling head tests. These tested zones were within the upper coal seams and intrusive sills of the Moranbah coal measures for bores DK092W, BR752W, and BR993W, and within sandstone and sandy siltstone for bore BR782W. The estimated hydraulic conductivity ranged from 0.1 m/day to 0.7 m/day. Geoaxiom concluded the tested zones form semi-pervious poor aquifers.

These estimates are considered an upper bound to the Permian due to the shallow depth. Hydraulic conductivity is known to decline with depth in coal as increasing overburden pressure closes up the fractures or cleats in the coal seam reducing permeability.

No data was obtained for the alluvium and the weathered zone; however, the alluvium is expected to have a higher permeability than the measured coal seams due to its unconsolidated nature. The hydraulic conductivity of the weathered zone is expected to be highly variable depending on clay and silt content and fracture networks, but it is not considered to form an aquifer.

The interburden units between the coals seams typically have a lower hydraulic conductivity than the coal seams, and thus act as confining layers for the coal seams. Observations at the Sonoma mine indicate these units are particularly dry and tight, and are indicative of a hydraulic conductivity several orders of magnitude lower than the coal seams.

5.3 Groundwater levels and flow direction

QCoal commenced monitoring groundwater levels at the project site in 2007 as part of the coal exploration program. They have also installed electronic water level loggers in selected bores, which are measuring water levels at three hourly intervals. They also periodically dip the bores where data loggers are to confirm the electronic water level measurements.

Appendix A shows the observation data available from the manual dipped measurements. Of the 35 QNH monitoring bores, a number of bores are showing dry records, those being bores DKWB02A, DKWB02B, JXWB01, DK1301B, DK1302, DK1303, SB7-B, SB7-C, SB7-E, BP3, and BP4. Some of these bores are between proposed Drake mine pits and the Bowen River and are screening an upper zone of the alluvial sequence.

The CRD shown on Figure 3.1indicates that most of the groundwater levels have been monitored over a relatively wet period with well above average rainfall occurring from 2009 to 2012, followed by generally below average rainfall to present. The majority of the monitoring bores have recorded a rise in groundwater levels over the period 2009 to 2012 when the soil profile was frequently saturated, promoting deep drainage and recharge to the groundwater systems. Groundwater levels have generally fallen since 2012 as no significant recharge events have occurred due to the relatively low rainfall and soil moisture levels.

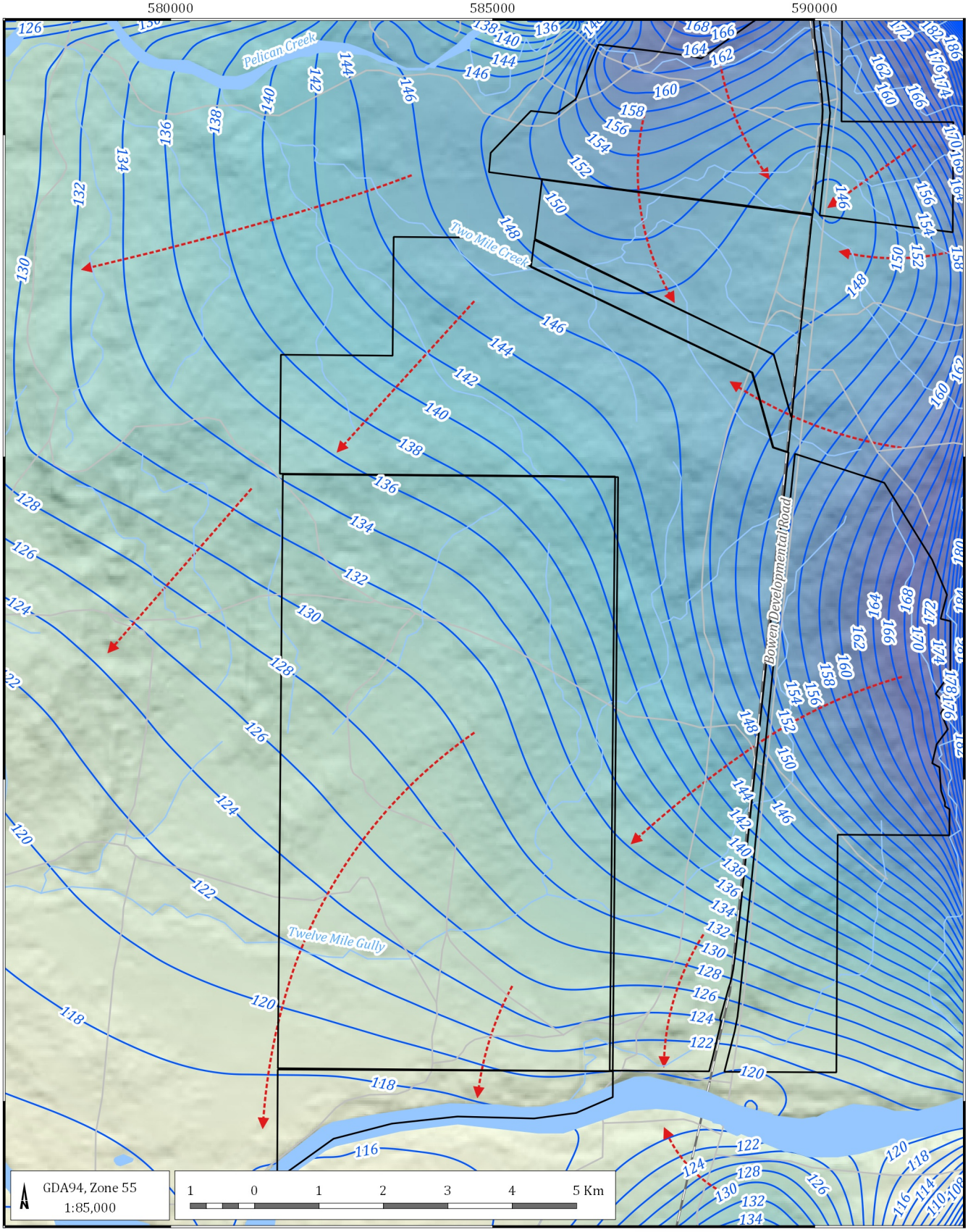
Bore BR752W has recorded a decline in water levels below the static level recorded in 2009, and because this bore is near the Jax pit it may be due to ongoing passive evaporative pit dewatering depressurising the groundwater system. Bore BR782W shows the opposite effect, stabilising at a level higher than recorded at the commencement of monitoring in 2009. This may be due to rewetting of the alluvial sediments in this area.

Water levels recorded in bore BR008W are anomalous, showing a continual rising trend since 2009. This bore monitors the Exmoor formation, and it is considered likely that the very slow recovery of this bore post construction is due to it being within a zone of extremely low permeability.

Mine inflow has been observed at Sonoma Main Pit. Water can be seen seeping through the pit wall. A snapshot measurement undertaken by draining the sump and measuring the subsequent fill rate indicates a current inflow rate of around 1 ML/day. In the mine pit itself, the coal seams are wet; however, the interburden is noted as being dry and dusty when being mined through. Evaporation would account for some of this dryness; however, the observation indicates that the interburden is tight with low storage and low hydraulic conductivity.

Despite the observed inflow and decline in water level within the Sonoma pit, the observation bores located around the pit in various geologies show a general rise in groundwater levels since records started in 2008 until a recent minor decline. This is in line with the climate variation (CRD) which indicates above average rainfall observed throughout most of this period. The proximity of these observation bores to the existing pit extent highlight the tightness of the surrounding material and that the observable extent of drawdown directly from the pit excavation is limited.

Observed groundwater levels indicate groundwater flow directions that follow the topography, with water generally moving towards the south west across the project site as shown in Figure 5.3. The dominant surface drainage feature in the area is the Bowen River to the south of the project site. It is likely that the shallow groundwater system at the site does drain back into the Bowen River after large rainfall/flooding events, providing a component of baseflow, however the extent of this is difficult to ascertain as the flow in the river is dominated by releases from Eungella Dam at the headwaters of the river.



LEGEND

- QNH mining leases
- Road
- Rail
- Watercourse
- Groundwater level contours (mAHD)
- Flow directions

Northern Hub Groundwater Assessment (G1779E)

Groundwater level and flow direction

DATE 04/06/2020

FIGURE No: **5.3**

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5.4 Surface water interaction

The expanded groundwater monitoring program developed to address interactions between the Bowen River and the underlying groundwater systems includes additional monitoring bores on the project site in the alluvium that is connected to the Bowen River, Moranbah coal measures (adjacent to the Bowen River) and adjacent geological formations like the Exmoor formation and the Blenheim subgroup that occur within the maximum zone of influence.

QCoal has installed four monitoring bores (BP2R, BP3, BP4, and BP4B) at the southern end of the Drake mining lease and north of the Bowen River. Two of these four bores are dry (BP3 and BP4), while the other two have initial water levels that are 10 to 15 metres below ground and in the Permian sediments. It is possible in the future that the bores that are currently dry will show water level rise during flood events in the river. As these bores have only been monitoring a short while there have been no flood events during that time to confirm this.

Conceptually the shallow groundwater system towards the southern end of the project area is likely to be in connection with the fully incising Bowen River. This connection provides the logical mechanism for recharge to these adjacent aquifers. Generally the Bowen River is considered a gaining stream (water draining from the aquifer to the river); however during high flow periods and flood events, the gradients are likely to be temporarily reversed with water seeping through the river bank into the adjacent aquifer.

Groundwater discharge is also likely to occur in the surface drainage lines across the site when groundwater levels are high enough, or when interflow occurs.

5.5 Recharge and discharge

Recharge to the aquifers in the study areas occurs through rainfall infiltration and potentially through flooding of the Bowen River. The rate of infiltration recharge is expected to be very low given the clayey nature of the unsaturated zone and the high evaporation rate in the region. There is very limited groundwater extraction occurring within the study area, and the primary discharge of groundwater to surface drainages being baseflow. Discharge would also occur through evapotranspiration when water tables are within reach of vegetation root zones.

There is only sparse groundwater abstraction from private bores for stock from the area surrounding the Project; which is further evidenced by the EIS (GHD 2012) identifying the targeted Moranbah Coal Measures as generally having low yields of less than 0.1 Litres per second (L/s), with a maximum yield recorded of 5 L/s.

6 Existing and proposed mining

The focus for this model update has been the update of the mine plans for QNH, which includes updates to all 4 mine areas (Sonoma, Cows, Drake and Jax) over what was previously simulated. The changes to the mine plans are described in the following sections and the proposed pit extents are shown on Figure 6.1. Figure 6.1 also shows the proposed mine progression over time.

6.1 Sonoma and Cows Mines

Sonoma and Cows Mine complex comprises three pits (Main, Q, and B pits). The Main pit and B pit at Sonoma mine down to the B seam, while the Q pit is shallower and has only mined to the Q seam. Mining at Q Pit has been completed and a residual void remains. Main pit has been extended to the south of the previously modelled area and has also been extended to the north into the Coral Creek area, with the creek being diverted around the pit. B pit has been expanded and become amalgamated into the Drake 1 pit.

The updated mine plan also includes two satellite pits located to the east of Sonoma on ML 10327, with one pit mining down to the C Seam and the other mining to the P Seam.

Observations from within the Main pit indicate that groundwater inflow is occurring, with seeps mostly associated with coarser lenses in the Quaternary alluvium associated with more permeable an old river bed deposits or basal units.

The interburden within the Sonoma pit is very dry. When mining through these units the amount of moisture in the rock is removed by evaporation as evidenced by the amount of dust produced.

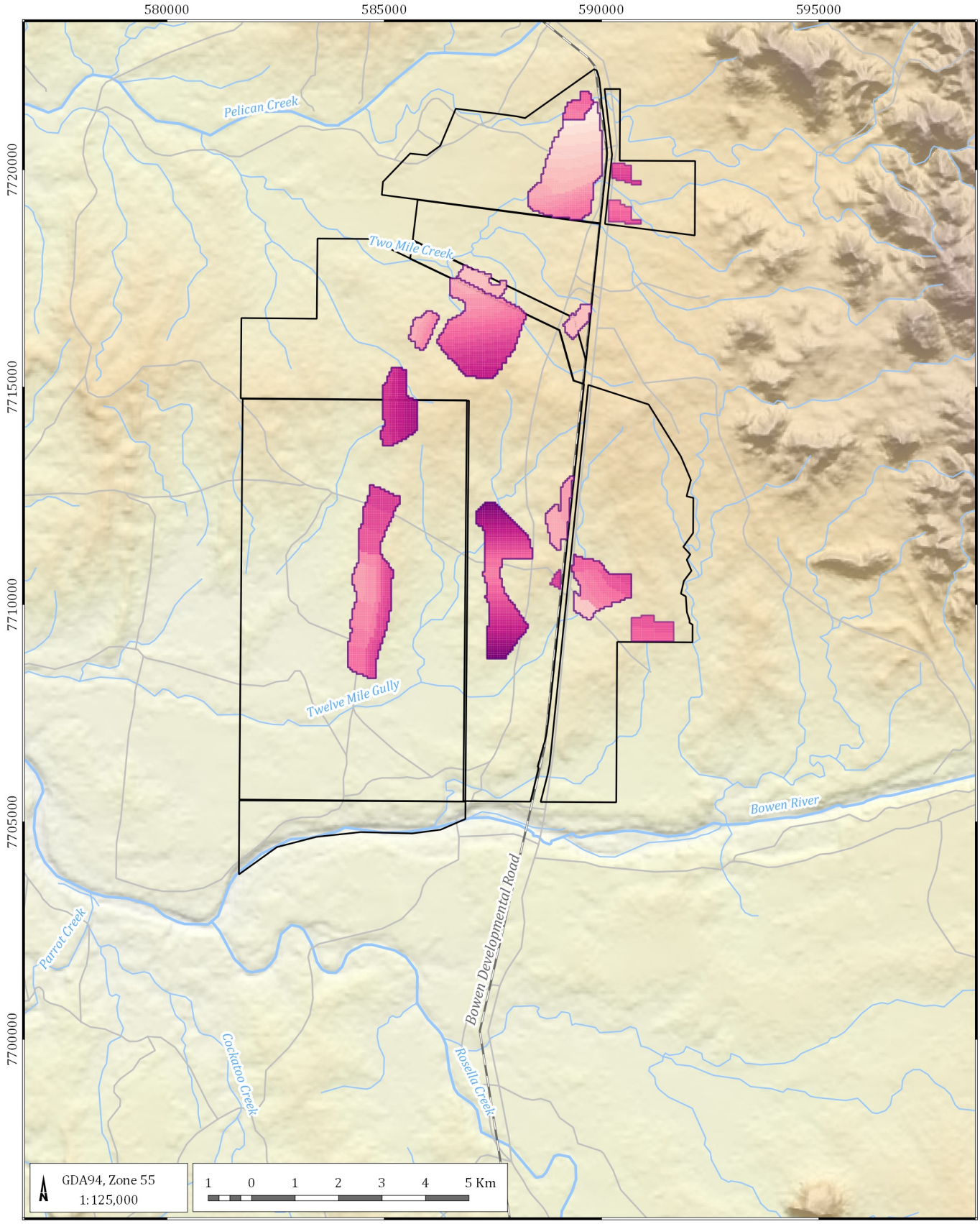
6.2 Drake Project

Drake Coal is located on Mining Leases 10349, 10350 and 10351 which are located within Lot 18 on PH2106 (land lease) and Lot 9 on DK239, covering a total area of 9196 hectares (ha).

The previously proposed mine plans indicate that the Drake Mine was going to consist of nine open cut pits of varying areas ranging from 6.7 ha (South Pit) to 878 ha (West Pit 1) and depths from 45 m (Mid Pit) to 225 m. (Central Pit 2). The layout of the updated mine plan (as shown in Figure 6.1) has varied slightly from the previously proposed based on further data collection. Figure 6.1 shows the planned pits. It is worth noting that the proposed pits do not extend as far south as the previously proposed mine plan, with the old Central 2 Pit no longer planned and the southern extent of WestPit 1 (now Drake 5 Pit) some 800 m further north. This provides a total seperation between mining at QNH and the Bowen River of around 3.3 km, although the previous model predicted only negligable changes to baseflow to the Bowen River from mining in the Drake pits.

6.3 Jax Mine

The Jax mine has been in care and maintenance after the initial development of the Jax 1 Pit. The mine plan going forward sees this pit extending to the north east, followed by a separate pit (Jax 2 Pit) to the south east, with mining progressing in a similar direction to Jax 1 Pit.



LEGEND

- QNH mining leases
- Pit outline
- Road
- Rail
- Watercourse

Mine progression - QNH proposed pit locations (Year)

2008	2015	2022	2029
2009	2016	2023	2030
2010	2017	2024	2031
2011	2018	2025	2032
2012	2019	2026	2033
2013	2020	2027	
2014	2021	2028	

Northern Hub Groundwater Assessment (G1779E)

QNH proposed mine pit locations

DATE 04/06/2020

FIGURE No: **6.1**

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7 Numerical model development

7.1 Code selection

As part of the model updates a decision was made to contemporise the modelling software being used. The previous model utilised the MODFLOW SURFACT (SURFACT) software, which has been somewhat superseded by the MODFLOW Unstructured Grid (USG) software as an industry standard (Panday et. al., 2013). USG has the ability to simulate the same features as SURFACT (unsaturated flow processes, boundary conditions), but also has flexibility in the way the model domain can be discretised. The unstructured nature of the mesh means it is no longer constrained by the orthogonal rows and columns to define the model cells, but can be defined by various sized and shaped polygons. For this update however, there is no change to the model structure, in that the model grid and layers remain the same as the SURFACT model.

The numerical representation of the groundwater flow equations in USG is slightly different to SURFACT in that it is based on the 'control volume finite difference' method. This seems to provide a more stable solution in terms of mass balance, and also provides some computational advantages in being much quicker to run. For instance, the previous SURFACT model took around 30 hours to simulate the updated mine plan, while running the USG code only takes 2 hours for the same model setup with a better overall mass balance.

While there has been an underlying code changed, there was no need to change the model grid from the previous model at this stage. Figure 7.1 shows the position and extent of the model grid. The north-west corner of the grid is located at 575987.2 mE and 7722266.5 mN (MGA 94, Zone 55). The model grid was 18 km wide (E-W) and 25 km long (N-S). It was aligned in a direct north-south alignment to align the model grid to the general east to west movement of groundwater. The boundaries were set at 5 km to 10 km from the proposed mining areas, to minimise the effect of boundaries on the predictions.

The model adopted a cell size of 500 m x 500 m, which was refined to 50 m x 50 m within the proposed mining areas, comprising a total of 60,140 cells per layer. All the cells were set to "active" in the model domain.

When the model is revisited in the future, it is suggested that the model domain be discretised using Voronoi polygons to take advantage of USG's flexibility. This will allow for greater variation in cell size where detail can be placed around key features like mine pits and rivers, and then coarsened up away from those areas. The other feature that USG offers is that model layers do not have to be continuous over the model domain. Because the coal measures are in a basin structure, they could be discretely contained in their true extent where they subcrop. In the existing orthogonal grid, the layers continue on and the aquifer parameters provide the delineation of the coal seams.

7.2 Boundary conditions

7.2.1 External model domain

The external model domain was assigned as no flow boundaries. While it is likely the alluvial systems continue beyond the model domain, this assumption was considered to be the most conservative as it prevents the alluvium acting as an infinite source or sink of water. Apart from the southern boundary, the Moranbah Coal Measures were completely contained within the model domain. The southern boundary was located far enough away that the coal seams are deep and not impacted directly by mining at Drake.

7.2.2 Recharge

Recharge to the aquifer system was distributed across the model domain according to the inferred surface geology. The model domain was zoned into areas where alluvium was likely to occur, with the remaining area set as regolith. The recharge rates were estimated as a proportion of the average annual rainfall for each geology zone. The model assumed the recharge to the alluvium was significantly higher than through the regolith due to greater permeability of the alluvial soils. The adopted recharge rate is a deep drainage value, and therefore it accounts for all other losses of incident rainfall including water intercepted by vegetation and evaporated, transpiration and runoff. The recharge varied in the transient calibration on a monthly basis, with the predictive model using an annual average recharge rate.

7.2.3 Rivers

The SURFACT river package simulated the river and creek drainages in the region. The bed of the major river and creek cells were set at one metre below the LIDAR digital elevation data along the river alignment. The model represented all creeks and drainage lines, other than the Bowen River, as drains where only flow of water from the aquifer to the stream could occur.

A catchment divide occurs through the centre of the project area that splits the site into a north or the south catchment. Surface drainage in the northern catchment flows towards Pelican Creek, while runoff to the south flows to the Bowen River.

The water level in the Bowen River varied uniformly along the cells representing the river. The Bowen River water level for the transient simulation was varied on a monthly basis based on average daily water level records from the gauging station for the corresponding month.

7.2.4 Horizontal flow barrier

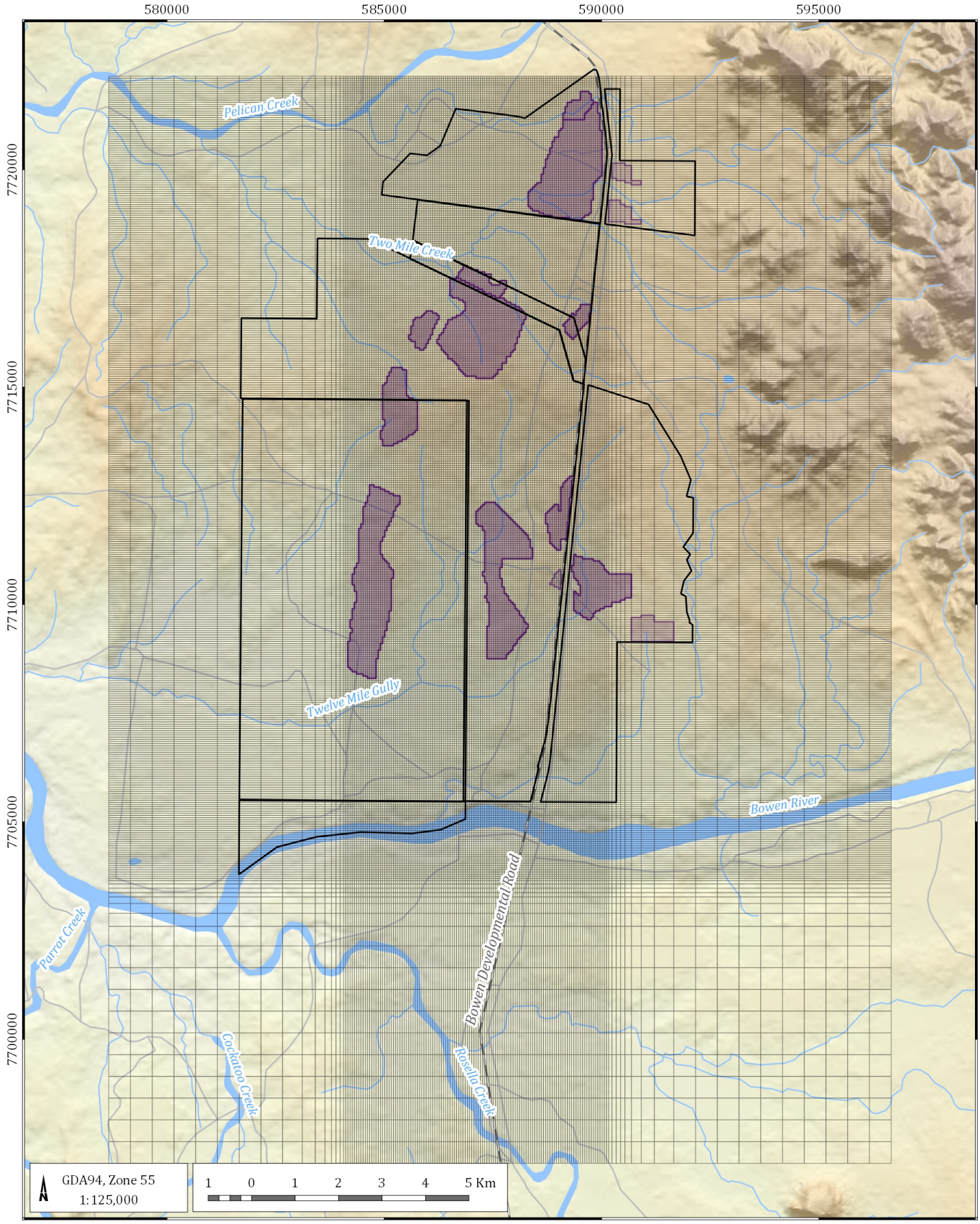
The model represented mapped faulting in the project area with the horizontal flow barrier package. A low conductance value was assigned to limit connection between the coal seams along the faults, with a conductance comparable to the interburden hydraulic conductivity.

7.3 Model layers

QCoal have created a detailed geological model of the region using exploration drilling data from Sonoma, Drake and Havilah. It contains the numerous coal seams and plys that occur at the project site. Numerical groundwater flow models cannot practically represent this level of geological detail as separate layers. QCoal therefore simplified the geological model at AGE's request by amalgamating key seams and numerous plys into larger layers. This allowed the groundwater model to represent the true thickness of the coal seams with less individual layers to ensure the computation time was manageable.

The model grouped geological units with similar hydraulic properties into single layers. Where the geological unit was not present across the entire model domain, the layer thickness was reduced and 'wrapped' under the above layer, adopting the properties of the overlying layer. The model represented the main hydrostratigraphic units as fourteen layers, as follows:

1. Alluvium and weathered zone;
2. Weathered zone (down to base of weathering);
3. Fort Cooper Coal Measures;
4. Interburden;
5. Coal seam (Q seam);
6. Interburden;
7. Coal seam (P seam);
8. Interburden;
9. Coal seam (E seam);
10. Interburden;
11. Coal seam (C seam);
12. Interburden;
13. Coal seam (B seam); and
14. Exmoor Formation.



LEGEND

- QNH mining leases
- Road
- Rail
- Watercourse
- Model grid
- Pit outline

Northern Hub Groundwater Assessment (G1779E)

Model mesh

DATE 04/06/2020

FIGURE No: **7.1**

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G:\Projects\G1779E.Northern Hub Groundwater Model Update\3_GIS\Workspaces\001_Deliverable1\07.01_G1779E_Model mesh.qgs

7.4 Numerical model calibration

No calibration has been undertaken for this model update; however, the calibration statistics are reported for the change in software and for the additional data points available since the previous model development.

7.4.1 Observation data (observation targets)

Observation data used for the calibration statistics were updated to include the new observations form both existing and new observation bores constructed since the last modelling exercise (AGE 2015). The steady state observation dataset remained unchanged and consisted of water levels measured in both monitoring and exploration bores at the project site and surrounding region.

Pre-mining water levels represented by data *circa* September 2007 when Sonoma started mining, were sourced from baseline measurements at Sonoma and from the Queensland Government groundwater database. The groundwater database generally only contained a standing water level at the time of drilling the bore for the private bores, which usually significantly predated the relevant period of 2007. This was considered a valid approach as exiting bore measurements indicate limited variability with time; therefore, any observations prior to mining at Sonoma could be considered representative.

Bore measurement data across the Drake mining area were also used, as it was considered unaffected by the existing neighbouring mines. Some of the Drake bores are dry. These bores were flagged and the model output checked to confirm the predicted water level was below the base of the bore.

7.4.2 Calibration hydraulic parameters

Table 7.1 presents the calibrated hydraulic parameters derived from the previous modelling and adopted for the model development associated with this report.

Table 7.1 Hydraulic parameters

Layer	Parameter	Value
Layer 1 and 2 Alluvium & Weathered Zone (Regolith)	Horizontal hydraulic conductivity [kh]	Alluvium 1 m/day Regolith 0.001 m/day
	Vertical hydraulic conductivity [kv]	Alluvium 0.1 m/day Regolith 6 x 10^{-4}
	Specific yield [S_y]	Alluvium 0.05 Regolith 0.01
	Specific storage [S_s]	Alluvium 1.3 x 10^{-5} Regolith 1,3 x 10^{-5}
Layers 3, 4, 6, 8, 10, 12 and 14 Interburden	Horizontal hydraulic conductivity [kh]	1 x 10^{-4} m/day
	Vertical hydraulic conductivity [kv]	1 x 10^{-5} m/day
	Specific yield [S_y]	5 x 10^{-4}
	Specific storage [S_s]	1 x 10^{-6}

Layer	Parameter	Value
Layer 5, 7, 9, 11, and 13 **Coal Seams**	**Horizontal hydraulic conductivity [kh]**	**1 x 10^{-2} m/day**
	Vertical hydraulic conductivity [kv]	1 x 10^{-3} m/day
	Specific yield [S_y]	5 x 10^{-3}
	Specific storage [S_s]	5 x 10^{-6}
All Layers Lizzie Creek Volcanics	Horizontal hydraulic conductivity [kh]	9 x 10^{-7} m/day
	Vertical hydraulic conductivity [kv]	1 x 10^{-6} m/day
	Specific yield [S_y]	1 x 10^{-4}
	Specific storage [S_s]	1 x 10^{-6}

Along with the aquifer properties, the recharge rate to the alluvium and weathered zone was also adopted from those previously calibrated. The model calibrated best with recharge set at a very low proportion of annual average rainfall as shown below in Table 7.2.

Table 7.2 Calibrated recharge

Geology	Rainfall recharge	
	% of annual rainfall	mm/year
Alluvium	0.057	0.39
Weathered zone(Regolith)	0.0002	0.001

The recharge rates of 0.39 and 0.001 mm/year is significantly lower than GHD previously estimated at 7 to 35 mm/year. The previous estimate was based on field measurements in the Great Artesian Basin intake beds, where coarse porous sandstone outcrops. This does not necessarily translate to the QNH area. The clay bound weathered zone at QNH and the clay soils significantly reduce the ability of rainfall to penetrate and enhance evaporation and transpiration.

The measured water levels at the site used in the steady state model indicate that recharge needs to be this low to maintain an appropriate calibration of hydraulic parameters. Recharge was initially constrained to values higher than the calibrated values, which resulted in the model consistently over predicting water levels.

7.4.3 Steady state calibration measures

Figure 7.2 below shows the simulated and measured groundwater levels graphically as a scatter diagram generated by the MODFLOW USG model:

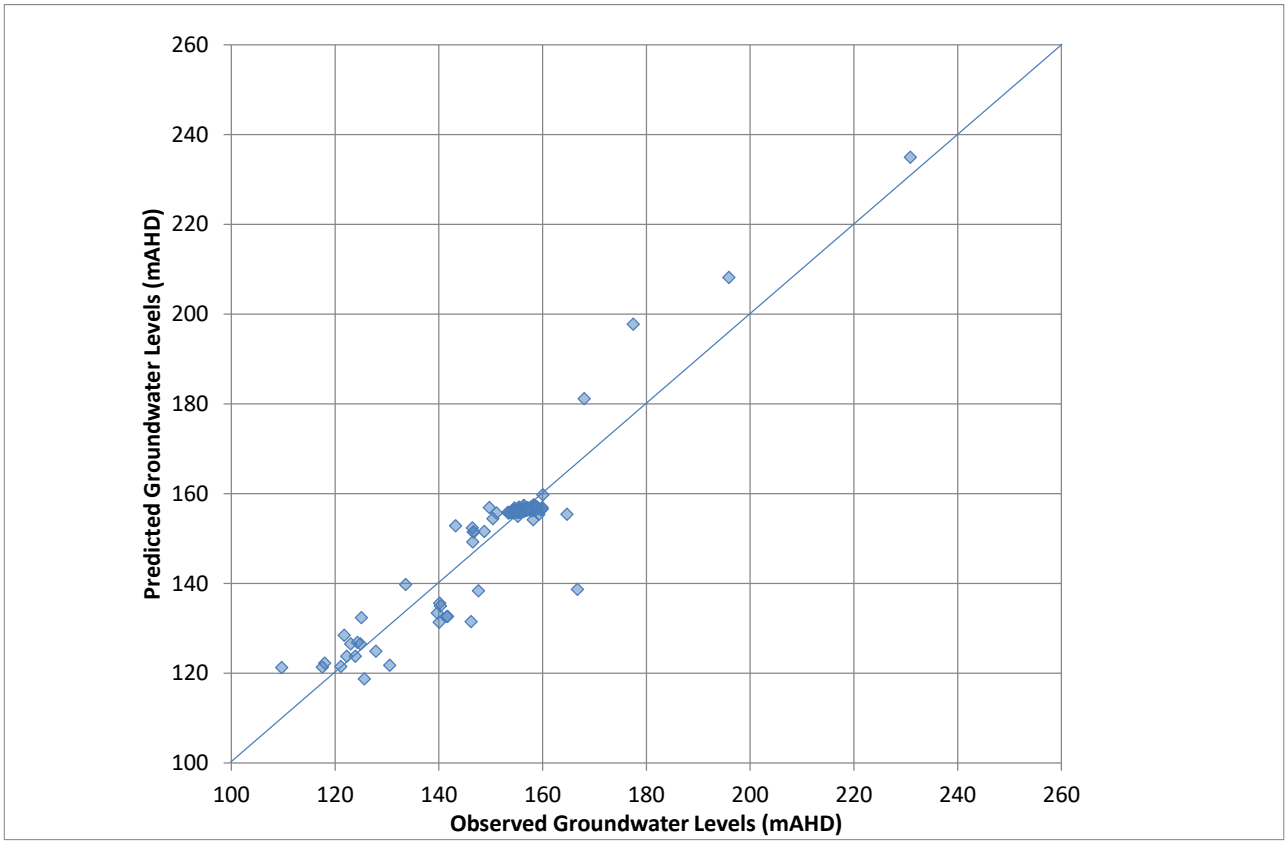


Figure 7.2 Steady state scatter diagram

The measured water levels and the model predicted water levels are generally well correlated. Areas of mismatch in the scatter diagram above are points away from the 1:1 diagonal line and are due to:

- the heterogeneity of the in-situ material that cannot be represented with uniform model parameters; and
- the variability in the baseline observation data that has been compiled from various time periods, and may not truly reflect the long term pre mining water levels.

An objective method to evaluate the calibration of the model is to examine the statistical parameters. One such method measures the error between the modelled and observed water levels. The root mean square (RMS) below is considered the best measure of error, if errors are normally distributed.

$$RMS = \left[1/n \sum (h_o - h_m)_i^2\right]^{0.5}$$

Where n is number of measurements, h_o is observed water level and h_m is simulated water level. The RMS error calculated for the calibrated model was 5.43 m. The maximum acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head loss in the system is small, the errors are only a small part of the overall model response (Anderson and Woessner, 1992). The error based on the population of observations is estimated as follows:

$$Scaled\ RMS = [\frac{RMS}{range}\ x\ 100]\ \%$$

The RMS error, which is a statistic similar to standard deviation, is a measure of the variability in the observed versus simulated water level records. The model reported an RMS error calculated for the calibrated steady state model of 5.3 m.

The ratio of RMS to the total head change across the calibration points (121.2 m) indicated a Scaled RMS of 4.48%, indicating a close and satisfactory match between observed and predicted water levels, and also the close match to the previous modelling which had a SRMS value of 4.37%.

7.4.3.1 Calibrated steady state heads

Figure 7.3 and Figure 7.4 show the predicted pre-mining steady state water levels for the water table and the B seam (Layer 13) respectively. The heads reflect the groundwater flow regime prior to commencement of any mining within the model domain, and indicate a general flow of groundwater towards the south with the water table largely following the surface topography. The major rivers act as groundwater discharge areas in the model. The groundwater regime in Layer 13, which in essence represents the lowest coal seam (B seam) records a similar flow pattern to that of Layer 1, but with less pronounced changes around the rivers due to reduced recharge and attenuation through the overlying geologies.

7.4.3.2 Calibrated steady state water budget

The steady state model water budget is shown below:

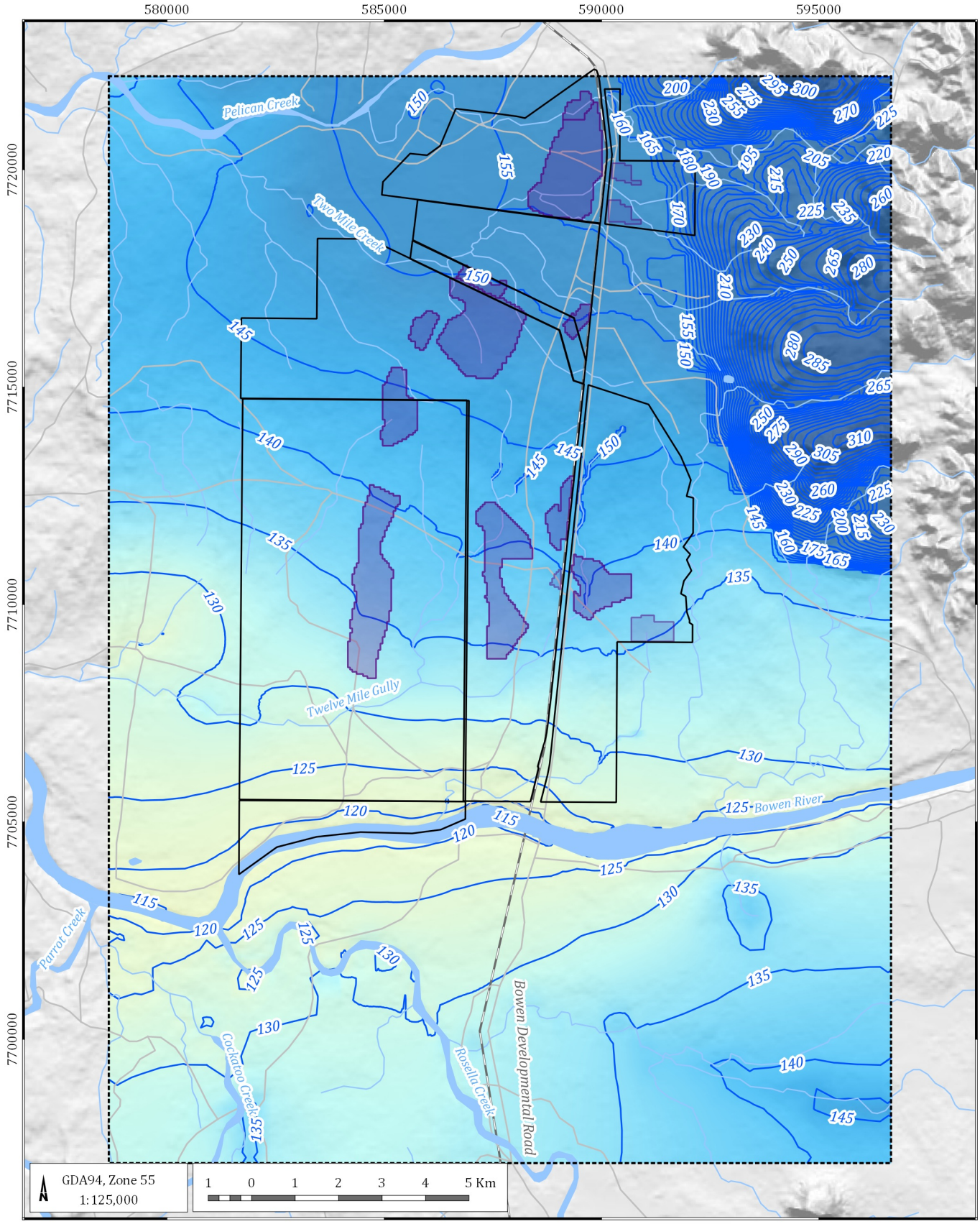
Table 7.3 Water budget – steady state model water budgets (ML/day)

Parameter	Input	Output
Rainfall recharge	0.036	-
River leakage	0.274	-
River baseflow	-	0.310
TOTALS	**0.310**	**0.310**

The net discharge from the model is calculated by subtracting river leakage from river baseflow (0.274 ML/day - 0.310 ML/day = -0.036 ML/day). This net value shows the difference between the volume of water going into the groundwater system from the river cells (leakage) and water leaving the groundwater system through the river cells (baseflow) across the whole model domain (net positive value = net leakage, net negative value = net baseflow).

Under steady state conditions, the model predicts the Bowen River has a baseflow of 0.310 ML/day, with a leakage of 0.274 ML/day; indicating a net baseflow of 0.036 ML/day. The average daily flow in the Bowen River measured at the Jacks Creek Weir is 1,797 ML/day; therefore the model estimates that under steady state conditions baseflow represents a very small portion of the average daily flow (about 0.001%), in the Bowen River. This suggests that in the absence of the releases from the Eungella Dam the Bowen River at the project site would likely be dry.

It should be noted the model has 'no flow' boundaries at its extents, and is therefore set up conservatively as a 'bucket'. This approach is considered appropriate based on the limited recharge occurring and the influence the basin shape and faulting on the target coal measures. It is possible that there is flow of groundwater beyond the boundaries of the model, however it is likely to be limited in volume, and therefore has been assumed zero.



LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Predicted groundwater level elevation contour (mAHD)

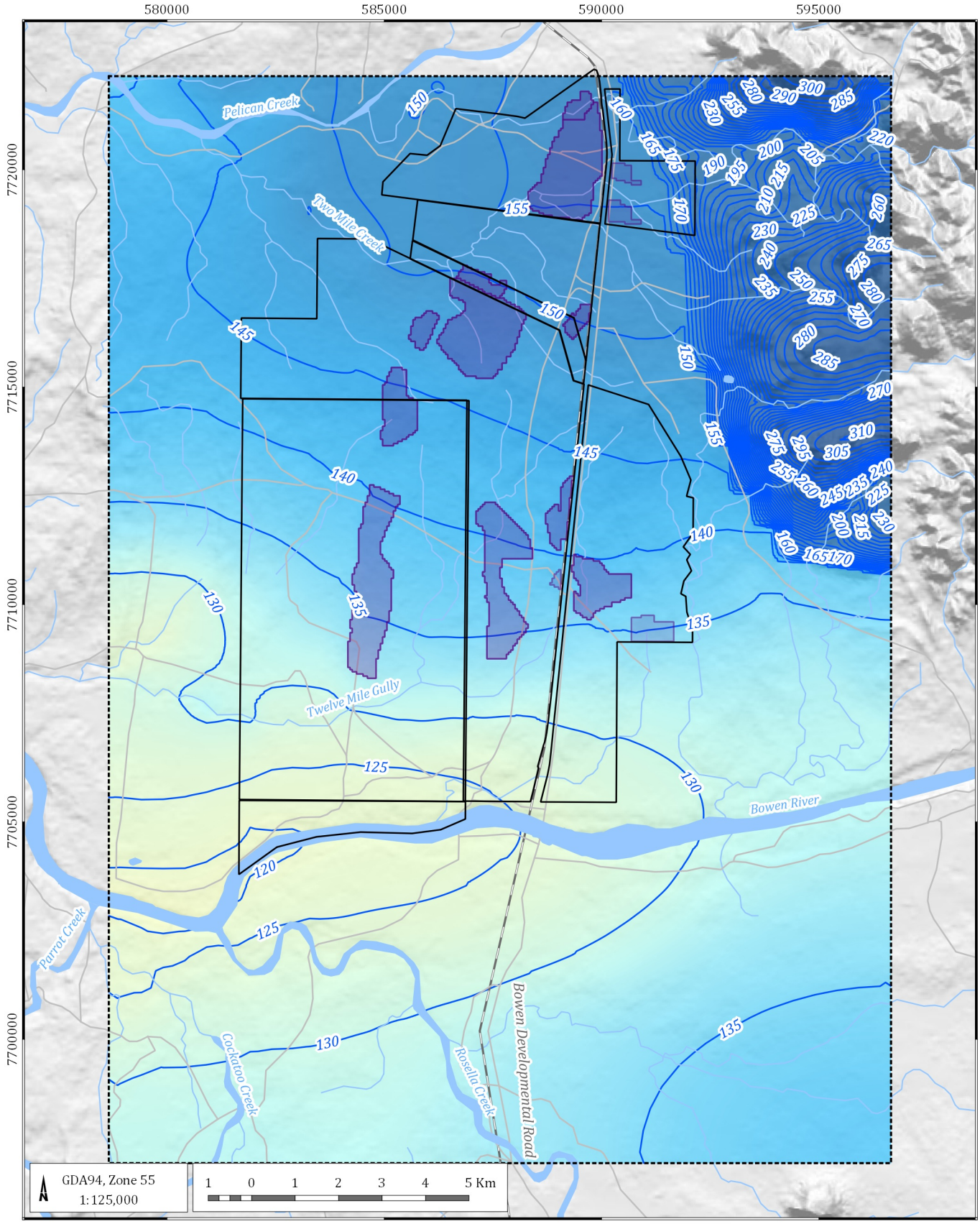
Northern Hub Groundwater Assessmentl (G1779E)

Steady state groundwater levels – water table

DATE 04/06/2020

FIGURE No: **7.3**

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LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Predicted groundwater level elevation contour (mAHD)

Northern Hub Groundwater Assessmentl (G1779E)

Steady state groundwater levels – layer 13

DATE 04/06/2020

FIGURE No: **7.4**

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7.4.4 Transient calibration

Transient model calibration was also checked against the updated code and against the updated water level observations. The scatter diagram below compares the predicated and measured groundwater levels.

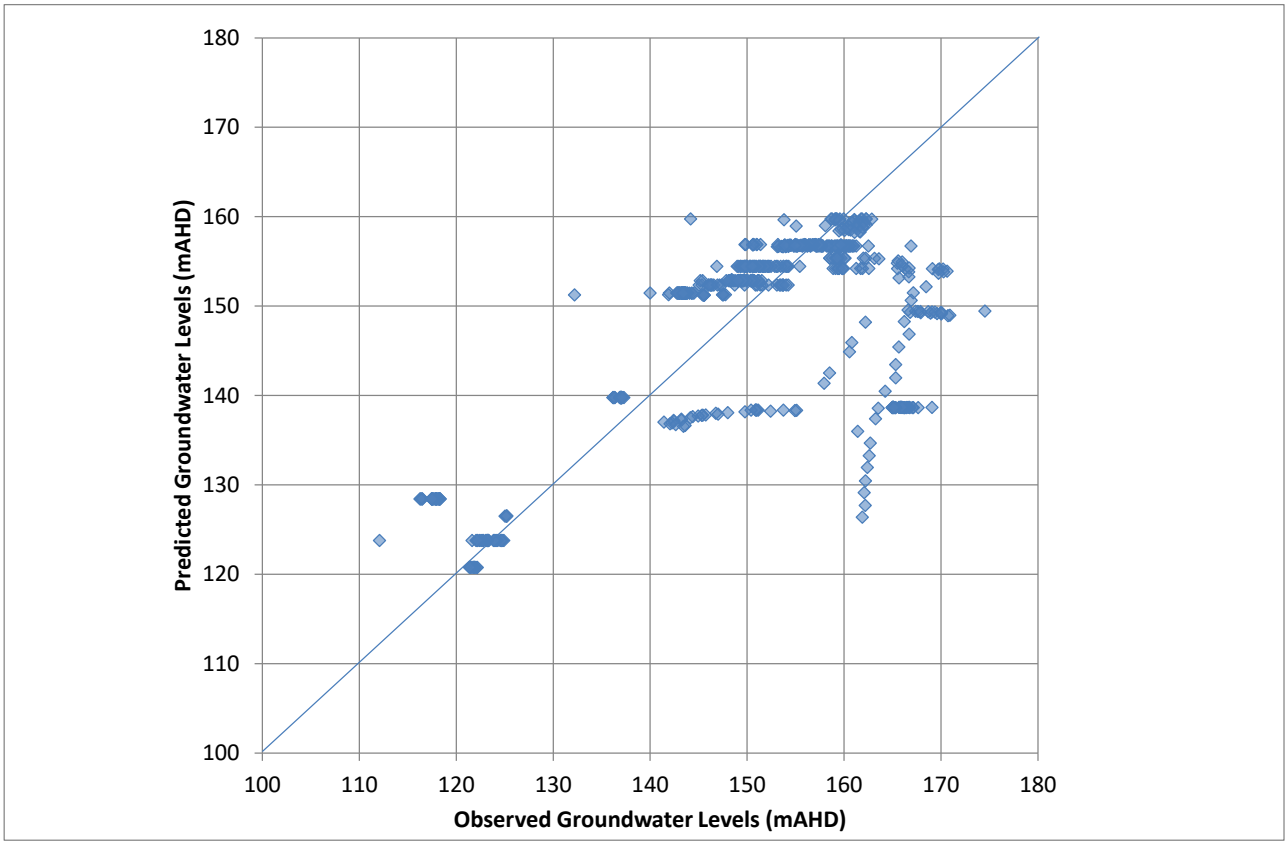


Figure 7.5 Transient scatter diagram

Statistically the transient model is not as well calibrated as the steady state. The RMS error, calculated for the calibrated transient model is 10.26 m. The ratio of RMS to the total head change across the calibration points (62.4 m) indicated a Scaled RMS of 16.4%.

The scattergram shows the transient calibration's limited ability to match transient water level behaviour as a series of straight lines not aligned with the 1:1 diagonal line. Because of the low recharge rates coming from the steady state calibration, the predicted water levels do generally not respond to recharge events. The transient calibration resulted in the storage values calibrating towards the lower bounds assigned in order to maximise water level fluctuations.

Conceptually the recharge seen in observed hydrographs could be in response to higher water levels in the Bowen River and raised groundwater levels propagating outwards. After the river drops, the water levels decline and return to the surface drainage. Another alternate conceptualisation is that during high rainfall events, there is localised flooding across the plain which provides a wetted up soil profile and sufficient residence time to allow for deep drainage to occur. At present the only mechanism simulated in the groundwater model is the higher water level in the Bowen River (based on stream gauge data). By way of example, this mechanism is demonstrated by examining an early component of the transient predicted water balance on the Bowen River (see Figure 7.6) with large volumes of water entering the aquifer during high flow events, followed by a delayed and gradually declining rate of flow back to the river boundary condition.

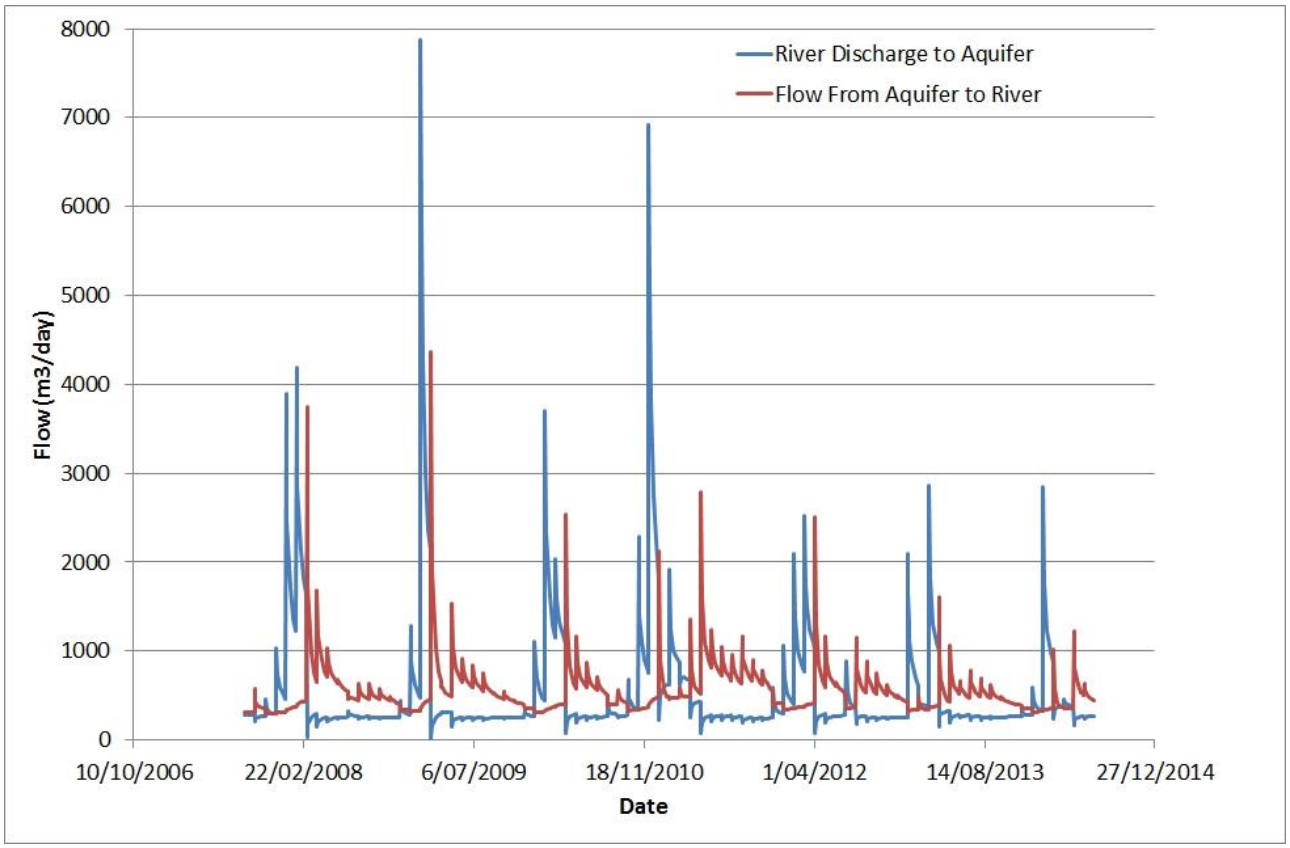


Figure 7.6 Transient river budget

7.4.4.1 Transient calibration hydrographs

Appendix A contains the measured and the model predicted water levels for the monitoring bores used in the transient calibration. Some of the transient water level data contains anomalies, such as the continually rising BR008W, and this data whist included within Appendix A for completeness, was not utilised in the calibration.

Many hydrographs show an initial mismatch from the start of the simulation. This is generally because the water level information for most transient bores was not available in the steady state simulation.

The predicted water levels show almost no response to the climate variability. This is not the case for all the field observations where some bores have risen following high rainfall and floods. The limited response in the model is caused by the very low calibrated recharge rate and the fact the model does not account for antecedent conditions such as the wetting of the soil profile in prior events.

Most importantly though is the matching of trends where mine impacts are apparent. The predicted decline in SB4, SB5 and SB6 show this match, particularly with the more recent observation data. No many of the observation bores are showing mine related impacts at present time, despite their locations. The fact that impacts have remained close to the open cut pits is most likely indicative of the tightness of the geological strata across the QNH area.

7.4.5 Model confidence classification

Barnett *et al* (2012) developed a system to classify the confidence-level for groundwater models. Models are classified as either Class 1, Class 2 or Class 3 in order of increasing confidence (i.e. Class 3 has the highest level of confidence). Several factors are considered in determining the model confidence level:

- available data;
- calibration procedures;
- consistency between calibration and predictive analysis; and
- level of stresses.

The model is currently considered a Class 2 due to the following criteria:

Data

- the majority of all groundwater monitoring data points over the calibration period has been used in the calibration process; and
- high resolution digital elevation data used across the entire model domain.

Calibration

- Scaled Root Mean Squared error (SRMS) is below prescribed limits in the steady state model; and
- recent transient calibration data used.

Prediction

- temporal discretisation and stresses are within the range of those used in the calibration model.

Key indicators

- calibration statistics meet agreed targets for the steady state model;
- mass balance error is close to zero;
- model parameters are consistent with conceptualisation; and
- appropriate computational methods and spatial discretisation used.

The Class 2 confidence level is suitable for predicting groundwater responses to arbitrary changes in applied stress or hydrological conditions and the evaluation and management of potentially high-risk impacts.

8 Predictive mining model

8.1.1 Mine plan and progression, staged timing and stress periods

Mining at QNH has been assumed to commence in 2007 with the Main Pit of Sonoma Mine. Mining progression is shown back in Figure 6.1. For the purposes of predictive modelling mining has been assumed to occur over a 27.3-year period from late 2007 through to the end of 2034.

The mining process, or more specifically the dewatering due to mining, was simulated using the USG drain package. Drains were assigned to dewater model cells that were within the extent of the mining pit shell. A nominally high conductance term was applied to ensure the model cell was completely desaturated within the pit shell.

The previous model had simulated the placement of in pit spoil, however, to be conservative in the estimation of potential inflows, the pits remained open and draining throughout the model simulation once active.

The time discretisation for the predictive period was based on stress periods of one year. This means that all boundary conditions remain constant for the period of a year, such as the locations and elevations of drain cells representing the mining. Within these stress periods the model simulation time was divided into time steps where the groundwater flow equations are solved. The number of time steps within each stress period varied based on how difficult the numerical solution was, but generally varied from 1 to 50 days.

8.1.2 Model objectives

The purpose of the modelling was to update the model with the latest mine plan and then estimate the:

- extent of the zone of depressurisation due to mining activities;
- groundwater seepage rates to the open cut mining areas; and
- potential changes in base flow to the Bowen River.

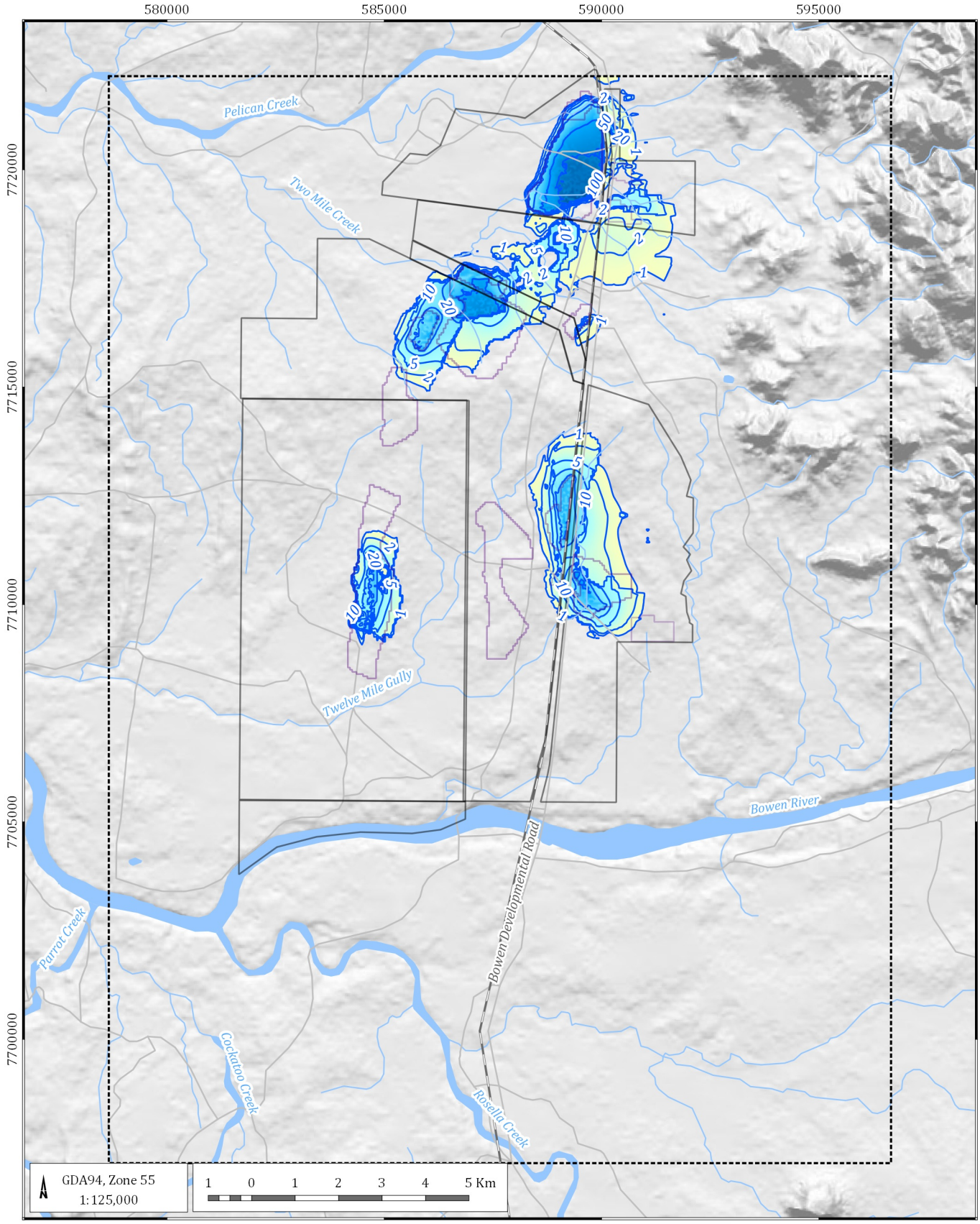
8.1.3 Drawdown extent

The drawdown predicted by the model was calculated by running two paired simulations. The first simulated all the dewatering from mining occurring, and the second assumed no mining occurs at any of the QNH mines. The drawdown is then the difference at any particular time step between these two simulations.

The drawdown produced and presented here is cumulative across the four QNH mining areas.

Predicted drawdown is presented for a number of specific times from present day (end of 2017) through to the end of mining (2034). These specific times are present day (end of 2019), 5 years (end of 2024), 10 years (end of 2029), and then finally the end of mining (2034).

The drawdown can be seen in Figure 8.1 to Figure 8.8 representing predicted drawdown in the water table and Layer 13 of the model. The water table can appear in the weathered zone, shallow alluvium, and the upper sections of the Permian strata depending on location in the model, while Layer 13 is predominantly the B seam which is the lowest of the target seams for mining. Not all pits mine the B seam, and given the tightness of the interburden, there is little indication of dewatering in these shallower pits. The figures show the predicted 1 m drawdown contour as the outer contour.



LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Drawdown contour (m)

Drawdown (m)

- 0
- 1
- 5
- 50
- 100
- 200

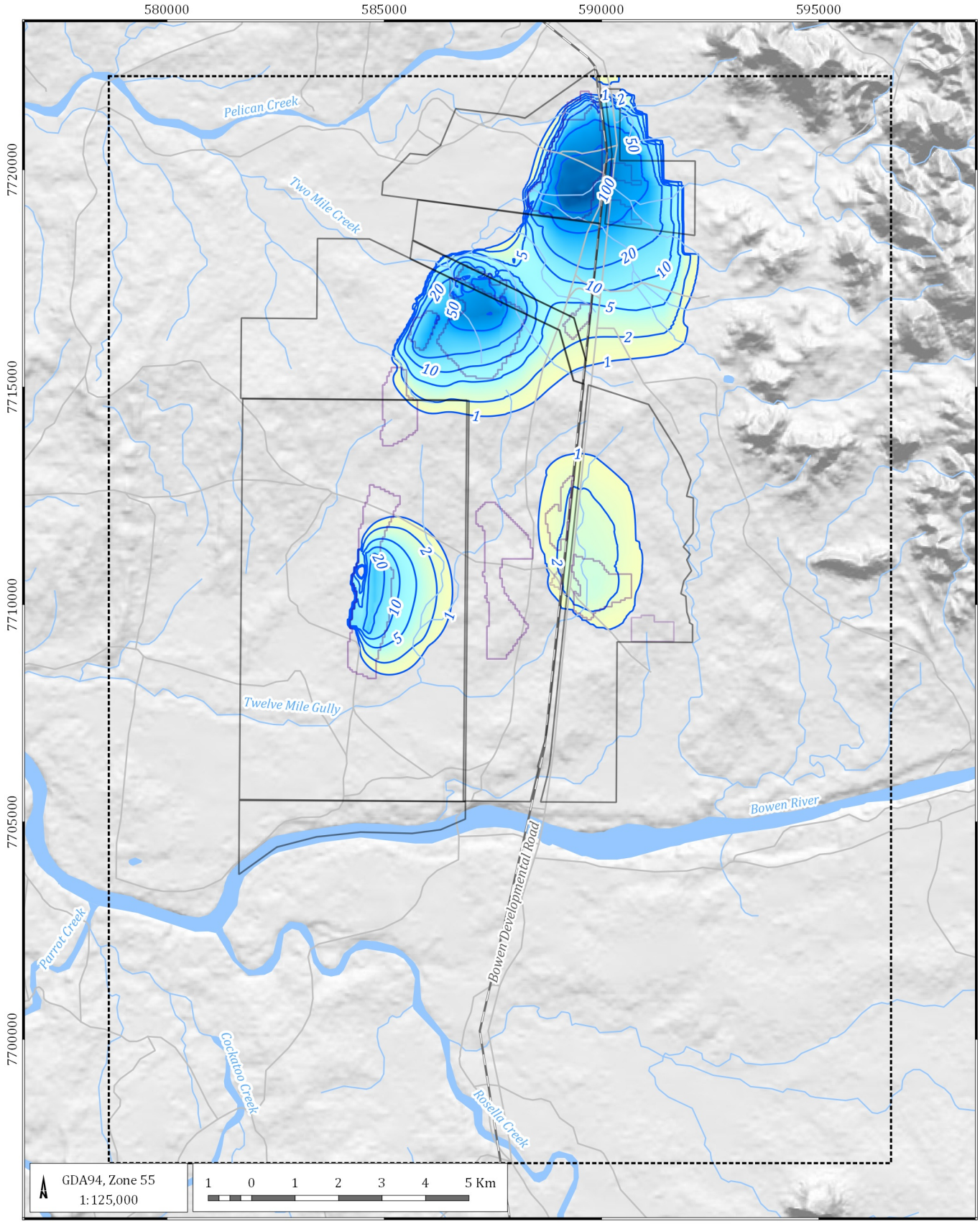
Northern Hub Groundwater Assessment (G1779E)

Predicted drawdowns, present day (2019), water table

DATE 04/06/2020

FIGURE No: **8.1**

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LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Drawdown contour (m)

Drawdown (m)

- 0
- 1
- 5
- 50
- 100
- 200

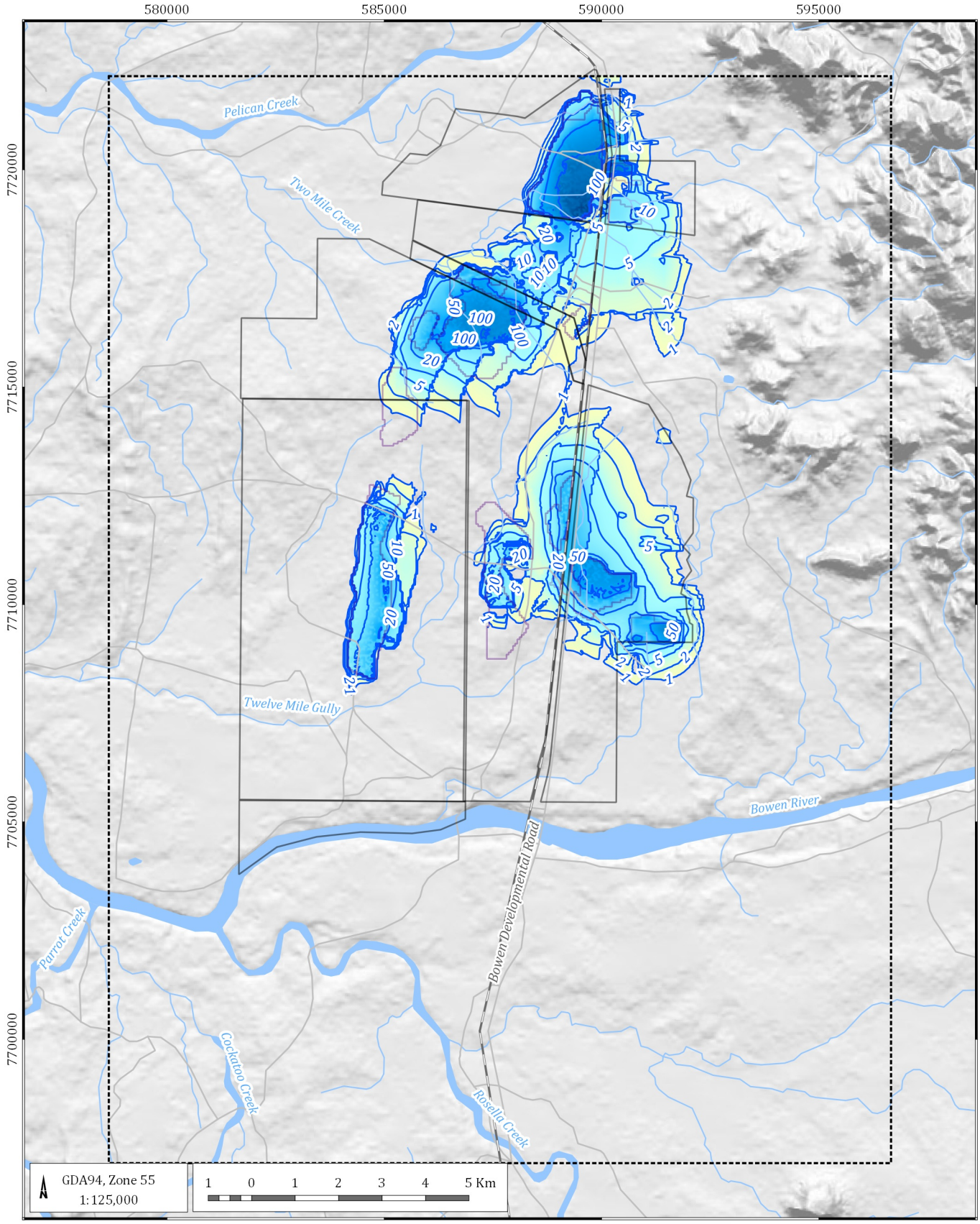
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Predicted drawdowns, present day (2019), Layer 13

DATE 04/06/2020

FIGURE No: **8.2**

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LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Drawdown contour (m)

Drawdown (m)

- 0
- 1
- 5
- 50
- 100
- 200

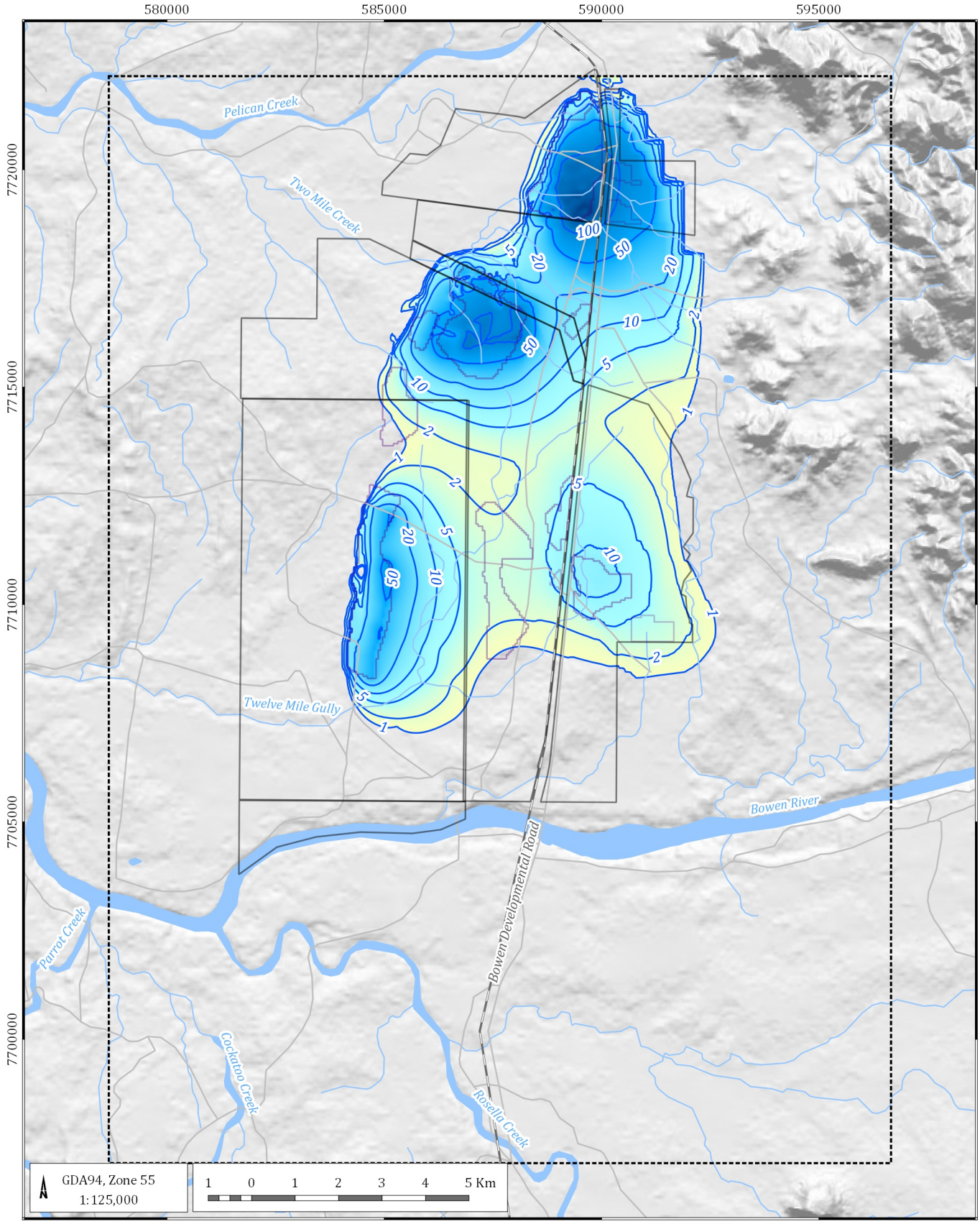
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Predicted drawdowns, 5 years (2024), water table

DATE 04/06/2020

FIGURE No: **8.3**

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LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Drawdown contour (m)

Drawdown (m)

- 0
- 1
- 5
- 50
- 100
- 200

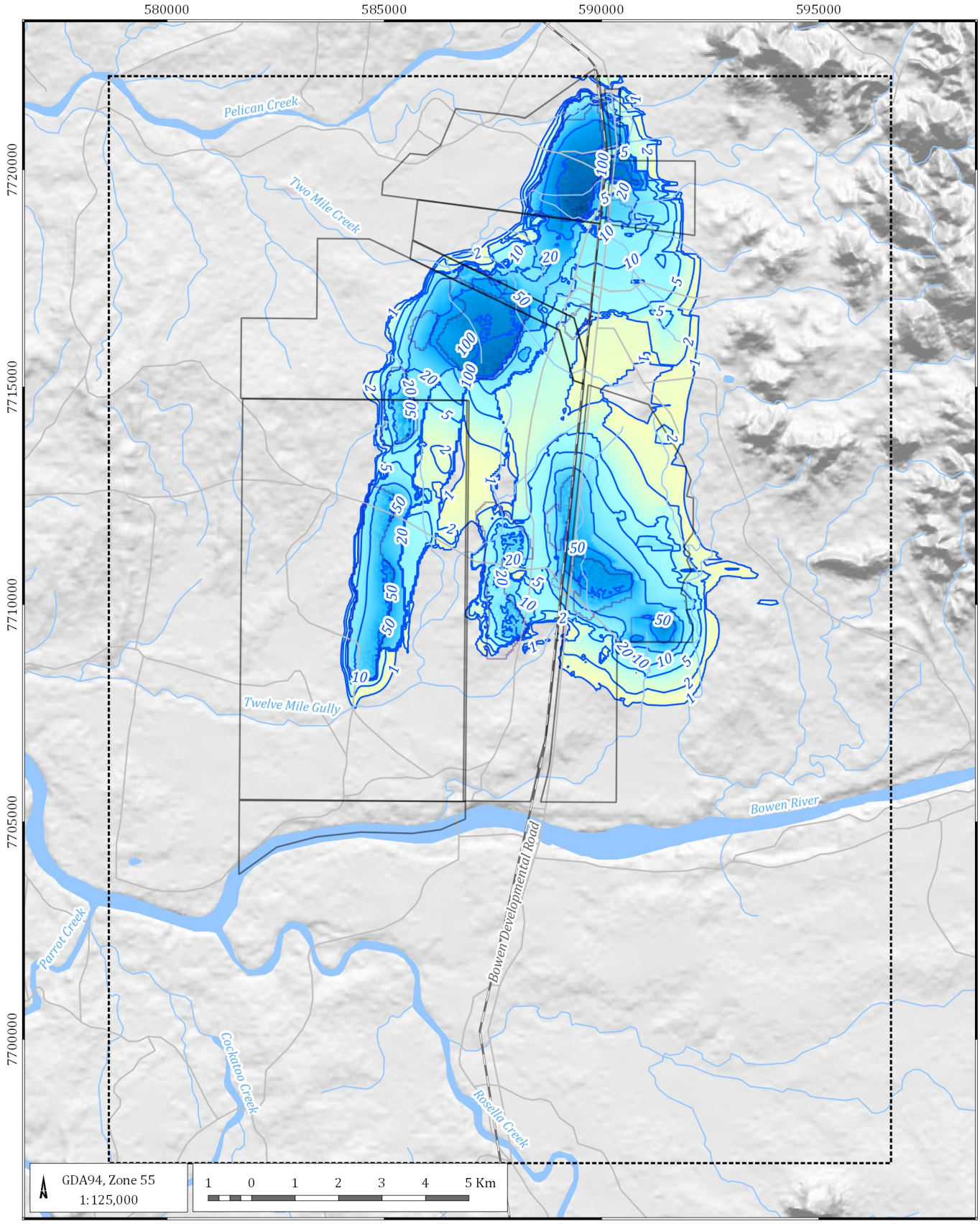
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Predicted drawdowns, 5 years (2024), Layer 13

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FIGURE No: **8.4**

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LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Drawdown contour (m)

Drawdown (m)

- 0
- 1
- 5
- 50
- 100
- 200

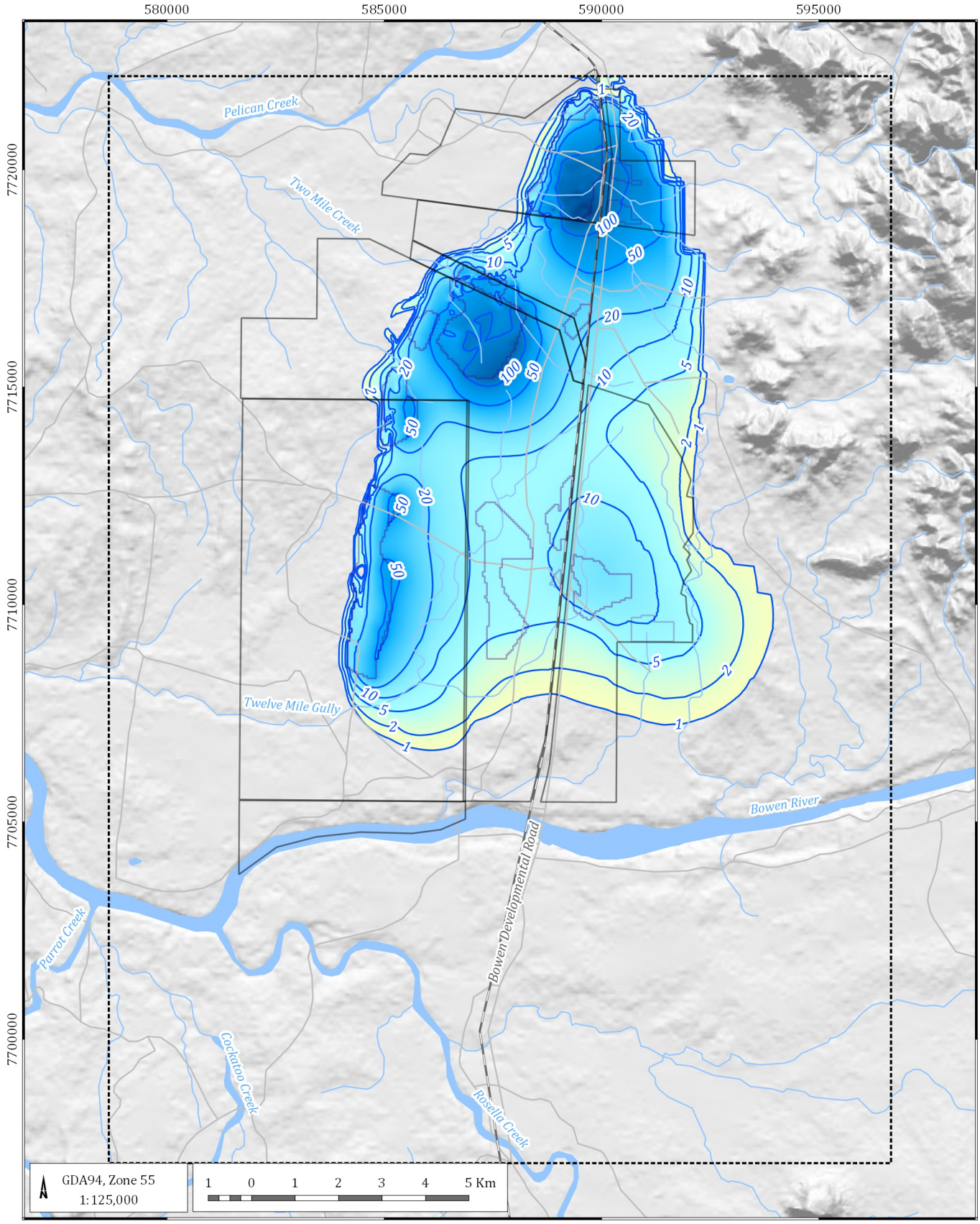
Northern Hub Groundwater Assessment (G1779E)

Predicted drawdowns, 10 years (2029), water table

DATE 04/06/2020

FIGURE No: **8.5**

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LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Drawdown contour (m)

Drawdown (m)

- 0
- 1
- 5
- 50
- 100
- 200

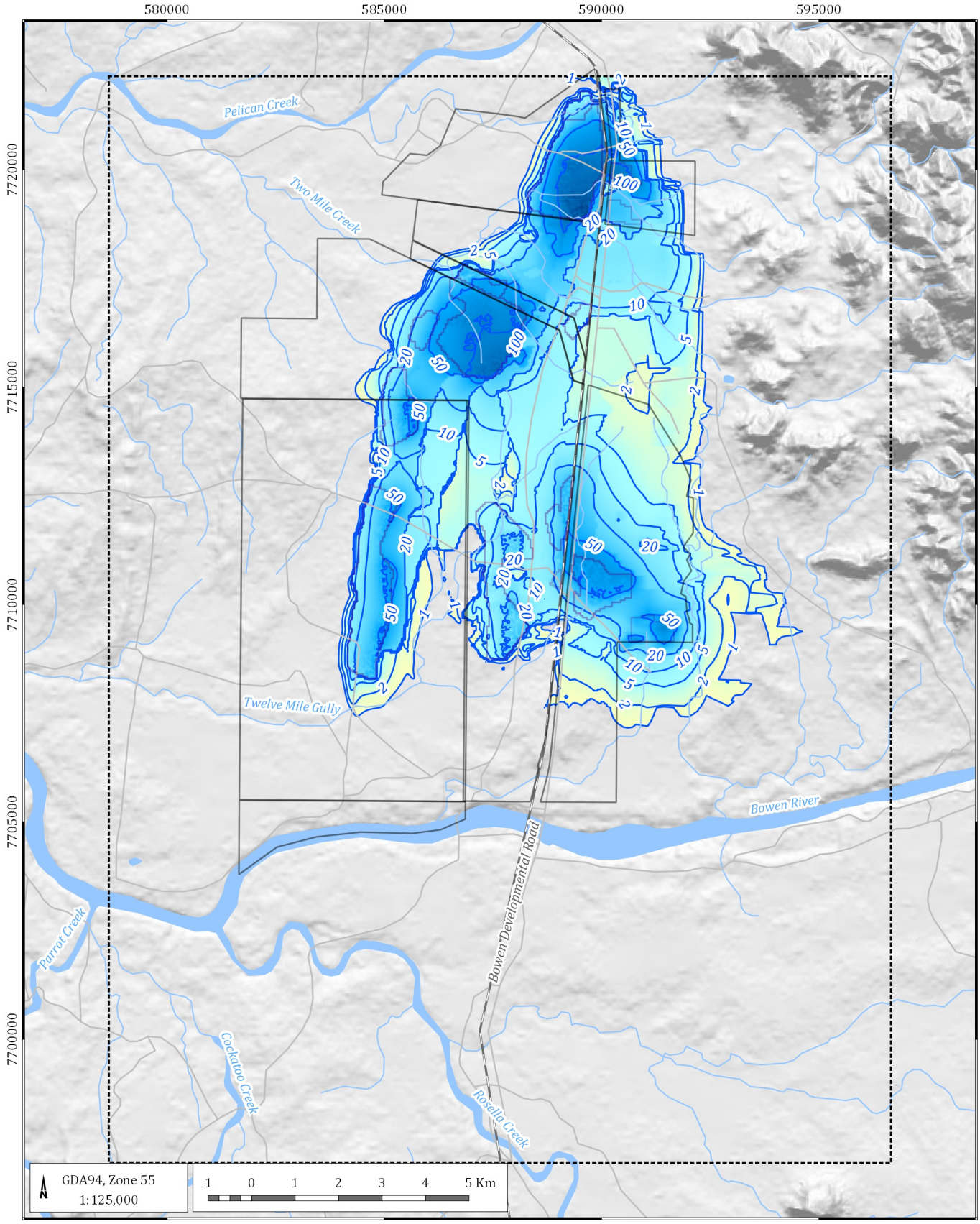
Northern Hub Groundwater Assessment (G1779E)

Predicted drawdowns, 10 years (2029), Layer 13

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FIGURE No: **8.6**

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LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Drawdown contour (m)

Drawdown (m)

- 0
- 1
- 5
- 50
- 100
- 200

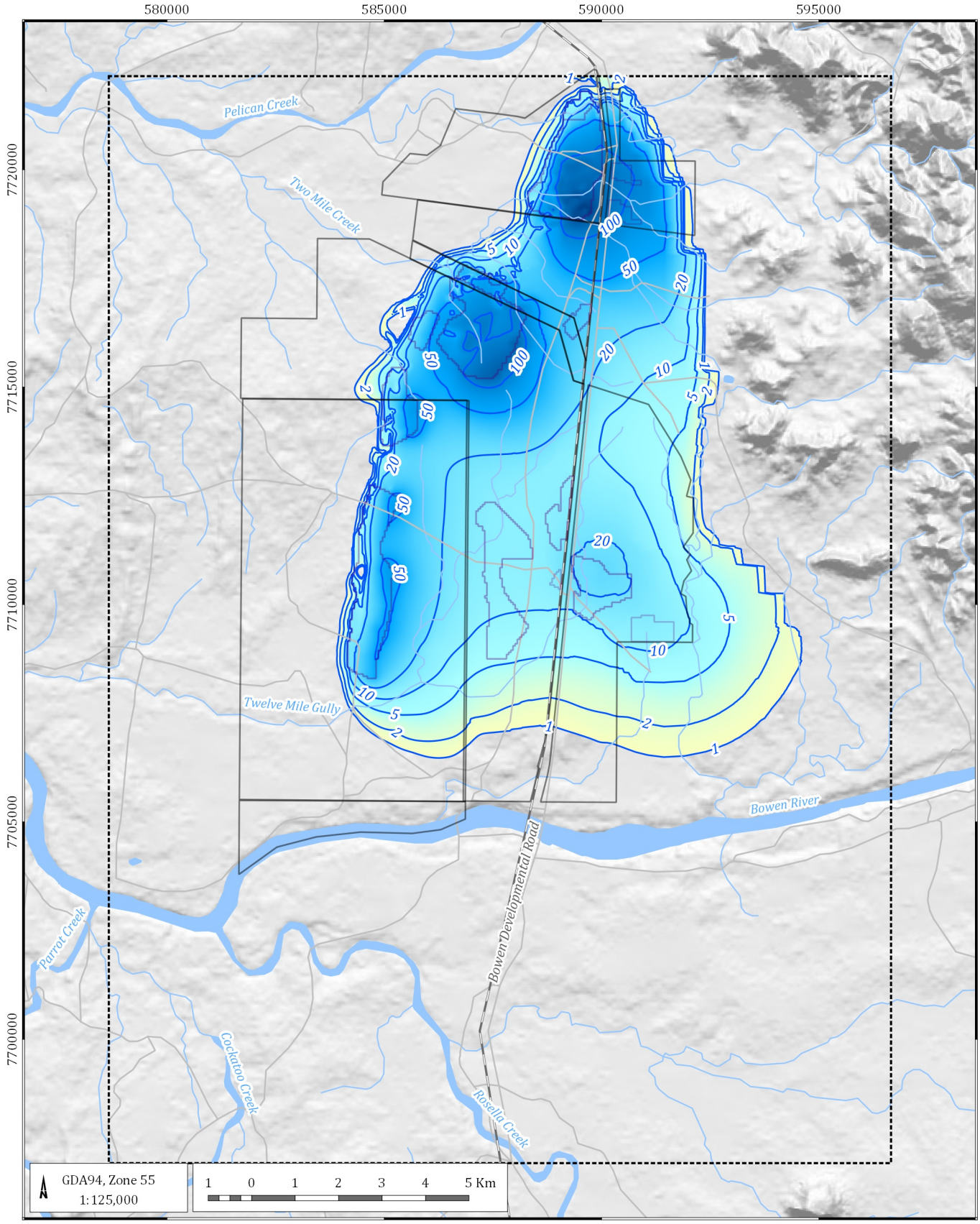
Northern Hub Groundwater Assessment (G1779E)

Predicted drawdowns, end of mining (2034), water table

DATE 05/06/2020

FIGURE No: **8.7**

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LEGEND

- QNH mining leases
- Model domain
- Pit outline
- Road
- Rail
- Watercourse
- Drawdown contour (m)

Drawdown (m)

- 0
- 1
- 5
- 50
- 100
- 200

Northern Hub Groundwater Assessment (G1779E)

Predicted drawdowns, end of mining (2034), Layer 13

DATE 05/06/2020

FIGURE No: **8.8**

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At present day the drawdown extent is limited around the active and recently active mining areas. The water table drawdown shows drawdown predicted for the shallow mining that has occurred in Jax pit and the Drake 3Q and 3R pits. This drawdown has not propagated through to the lower model layers as can be seen in a comparison between Figure 8.1 and Figure 8.2.

One of the key differences between the previous modelling and the updated modelling is that the drawdown in the deeper seams is no longer predicted to go beneath the Bowen River. This is largely because the mine plan does not go as far south as it used to and Drake 4 pit is only mining down to the P Seam, meaning the drawdown is reduced.

At the end of mining there are 14 bores that are predicted to have a drawdown of 1 m or more. These bores are listed below in Table 8.1

Table 8.1 Predicted drawdown of more than 1 m at DNRM registered bores

RN	Other ID	Predicted drawdown (m)	Purpose
153057	BR993W	38.72	Drake Monitoring Bore
140404	SB5	26.84	Sonoma Monitoring Bore
140403	SB4	22.84	Sonoma Monitoring Bore
140408	SB6	15.97	Sonoma Monitoring Bore
140401	SB2	14.04	Sonoma Monitoring Bore
140531		8.89	Sub-artesian Monitoring
140530		8.19	Sub-artesian Monitoring
140402	SB3	4.79	Sonoma Monitoring Bore
153061	BR782W	2.52	Drake Monitoring Bore
153055	BR752W	2.46	Drake Monitoring Bore
153056	DK092W	2.38	Drake Monitoring Bore
140405	SB7	1.27	Sonoma Monitoring Bore
153059	DKWB02A	1.11	Drake Monitoring Bore
153060	DKWB02B	1.09	Drake Monitoring Bore

As can be noted from the table above, all the bores predicted to be impacted by 1 m or more drawdown at the end of mining are monitoring bores. This is because of the limited permeability in the coal measures and proximity of the monitoring bores to the existing and proposed mining. It should also be noted that the above table represents cumulative impacts, where both Sonoma and Drake mines were active; hence the predicted Sonoma monitoring bore impacts as well.

8.1.4 Pit inflows

The model also provides estimates of groundwater seepage to the open cut pits. The pit seepage rates for the proposed QNH pits are presented below in Table 8.2. These values are generally below those estimated by the analytical methods, however this is expected given the extent of predicted impact from the numerical model is smaller than those from the analytical model.

Sonoma Main pit provides the largest predicted daily inflow, peaking at 0.114 ML/day. This is the largest pit inflow predicted as it has the largest operating footprint.

The predicted pit inflows presented below have not been adjusted for evaporation losses. The low predicted rates would in most cases experience some evaporative loss at the pit face before arriving at a pit sump; however, event based pit inflows (from large rainfall events) would require storage and subsequent pumping from an in pit sump.

Table 8.2 Predicted pit inflows

	Main Pit	Coral Ck	Sonoma E C	Sonoma E P	Q Pit	B Pit	Drake 1	Drake 2	Drake 2S	Drake 5	Drake 4	Drake 3Q&3R	Drake 3Q Sth	Jax Pit 1	Jax Pit 2	TOTAL
Year	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML
2008	14.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.88
2009	19.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.76
2010	21.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.82
2011	24.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.58
2012	23.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	25.56
2013	26.37	0.00	0.00	0.00	0.51	2.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.60	0.00	32.49
2014	36.06	0.00	0.00	0.00	0.19	5.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.53	0.00	44.32
2015	29.87	0.00	0.00	0.00	0.00	0.00	4.49	3.03	0.00	0.00	0.00	5.05	0.00	2.17	0.00	44.60
2016	29.89	0.00	0.00	0.00	0.00	0.00	8.20	3.75	0.00	0.96	0.00	10.95	0.00	2.05	0.00	55.80
2017	31.31	0.00	0.00	0.00	0.00	0.00	12.25	3.92	0.00	5.56	0.00	9.10	0.00	1.94	0.00	64.08
2018	30.57	0.00	0.00	0.00	0.00	0.00	15.57	4.63	0.00	8.71	0.00	7.89	0.00	8.04	0.00	75.40
2019	32.38	0.18	0.00	0.00	0.00	0.00	21.25	3.40	0.00	12.10	1.56	7.04	0.00	9.92	0.00	87.82
2020	36.36	0.22	0.00	0.01	0.00	0.00	18.81	2.76	0.00	12.65	2.05	6.42	0.00	11.13	0.00	90.41
2021	32.78	0.26	0.00	0.28	0.00	0.00	20.73	1.72	0.00	11.13	5.30	5.51	0.00	13.69	8.66	100.05
2022	29.79	0.23	4.61	0.31	0.00	0.00	21.17	1.19	0.00	15.49	5.24	5.09	0.00	12.54	10.30	105.95
2023	27.70	0.21	5.35	0.35	0.00	0.00	22.02	0.88	0.00	20.15	5.80	4.76	0.00	11.81	9.20	108.22
2024	25.88	0.19	8.95	0.19	0.00	0.00	22.72	0.68	0.00	23.46	6.30	4.50	0.00	10.66	8.53	112.07
2025	24.55	0.18	7.34	0.10	0.00	0.00	24.70	0.55	3.17	20.54	6.51	4.29	0.00	9.88	8.05	109.85

	Main Pit	Coral Ck	Sonoma E C	Sonoma E P	Q Pit	B Pit	Drake 1	Drake 2	Drake 2S	Drake 5	Drake 4	Drake 3Q&3R	Drake 3Q Sth	Jax Pit 1	Jax Pit 2	TOTAL
2026	23.50	0.17	6.45	0.05	0.00	0.00	26.07	0.44	3.61	18.86	6.53	4.10	0.00	9.28	7.65	106.70
2027	22.57	0.16	5.78	0.03	0.00	0.00	25.72	0.35	4.83	17.68	6.74	3.93	0.00	8.80	7.29	103.88
2028	21.78	0.15	5.30	0.02	0.00	0.00	23.18	0.27	5.74	16.78	6.47	3.77	0.00	8.40	6.99	98.85
2029	21.07	0.14	4.84	0.01	0.00	0.00	21.53	0.21	5.83	16.06	6.19	3.64	0.00	8.04	6.73	94.28
2030	20.41	0.13	4.46	0.00	0.00	0.00	20.32	0.16	4.89	15.45	6.02	3.52	0.00	7.74	6.50	89.61
2031	19.80	0.13	4.17	0.00	0.00	0.00	19.39	0.12	4.32	14.92	5.86	3.40	0.00	7.48	6.31	85.91
2032	19.25	0.12	3.92	0.00	0.00	0.00	18.59	0.09	3.93	14.46	5.64	3.29	0.00	7.26	6.14	82.69
2033	18.77	0.11	3.69	0.00	0.00	0.00	17.95	0.07	3.62	14.05	5.43	3.19	0.00	7.06	5.99	79.93

8.1.5 Impacts on the Bowen River

As mining progresses the drawdown extent propagates to the south. Unlike the previous model, the drawdown is not predicted to reach the alluvium/river, nor propagate under it at depth. The previous model predicted the average net baseflow in the rivers will be by around 0.02 ML/day at the end of mining. The new predictions with the updated mine plan predicts a peak reduction of 0.005 ML/day baseflow during the mining period. This would be indiscernible in a river that has a daily average flow measured at the Jacks Creek Weir of 1797 ML/day.

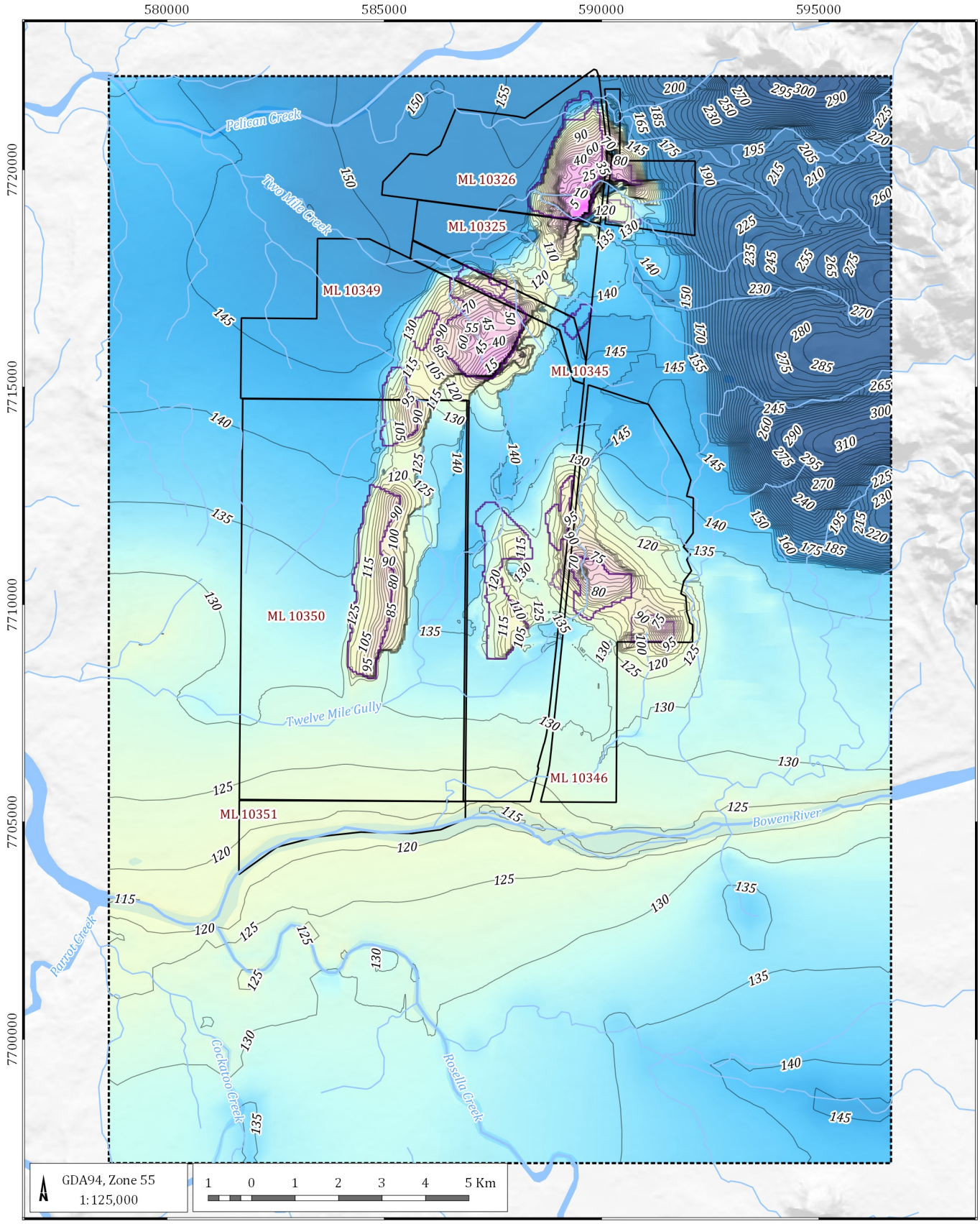
9 Predictive model - post-mining

Figure 9.1 shows the predicted water level in layer 1 for the end of mining. This has all pits dewatered. This water level is representative of the water table and in some areas across the model domain layer 1 is unsaturated and that the predicted level resides in lower model layers. Predicted water levels in lower layers echo these contours though any sharp changes become gradually muted with depth. Due to the low permeability of the geology, predicted (and observed) impacts to the surrounding groundwater system remain local to the pits, as can be seen in Figure 9.1. The water levels in this figure become the starting point for the recovery simulation.

The recovery is simulated in the pits by assuming recharge to the spoil and voids, and by applying evaporative losses to the void lakes. The level of recovery is controlled by the balance of water coming in from rainfall derived recharge and groundwater inflow as inputs and the loss due to evaporation from the void lake. Recharge to the void and spoil are much higher than the undisturbed recharge rate calibrated for the model.

Figure 9.2 and Figure 9.3 show different stages of the recovery process, with Figure 9.2 representing the recovery after 10 years, while Figure 9.3 shows the recovered groundwater level at equilibrium. Equilibrium in the recovery is predicted to occur 350 to 400 years post mining, however this is a prediction made where only long-term average recharge is applied to the void. This tends to extend the recovery period because the evaporation has more influence on the water level at these average rates. In reality, it will be the large rainfall events that will create the water level rises for the filling of the voids, so it is expected that this timing is an overestimate.

The extent of groundwater change is largest at equilibrium due to the continued dewatering offered by evaporation from void lakes that equilibrate below the pre mining water levels. Some of the pits have been predicted to become sources of groundwater across the site, particularly where they have been completely backfilled or where the void footprint is small. The concern with this occurrence is that water may migrate away from site. With this in mind, the predicted equilibrium water levels have been forensically interrogated to identify that all these potential sources are predicted to be intercepted by the larger and deeper voids (such as Drake 1, Drake 5, Sonoma East 1, and Jax 1) and will not migrate away from the site. To demonstrate this, groundwater flow directions have been added to Figure 9.3.



LEGEND

- Road
- Rail
- Watercourse
- Predicted groundwater level elevation contour (mAHD)
- QNH mining leases
- Model domain
- Pit outline

Water level (mAHD)

- -50
- 0
- 100
- 200
- 300

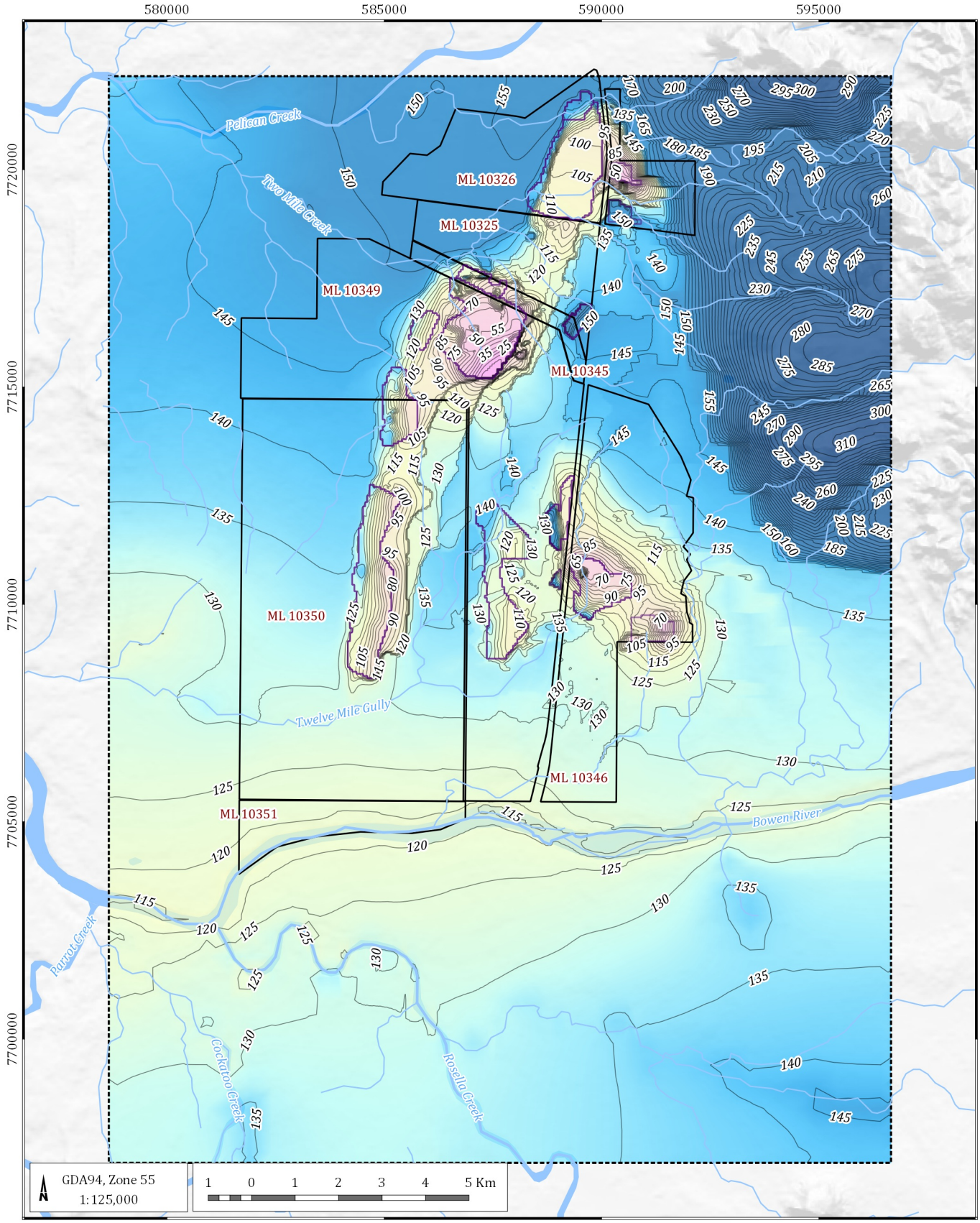
Northern Hub Groundwater Assessmentl (G1779E)

Predicted water levels – end of mining – layer 1

DATE 04/06/2020

FIGURE No: **9.1**

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LEGEND

- Road
- Rail
- Watercourse
- Predicted groundwater level elevation contour (mAHD)
- QNH mining leases
- Model domain
- Pit outline

Water level (mAHD)

- -50
- 0
- 100
- 200
- 300

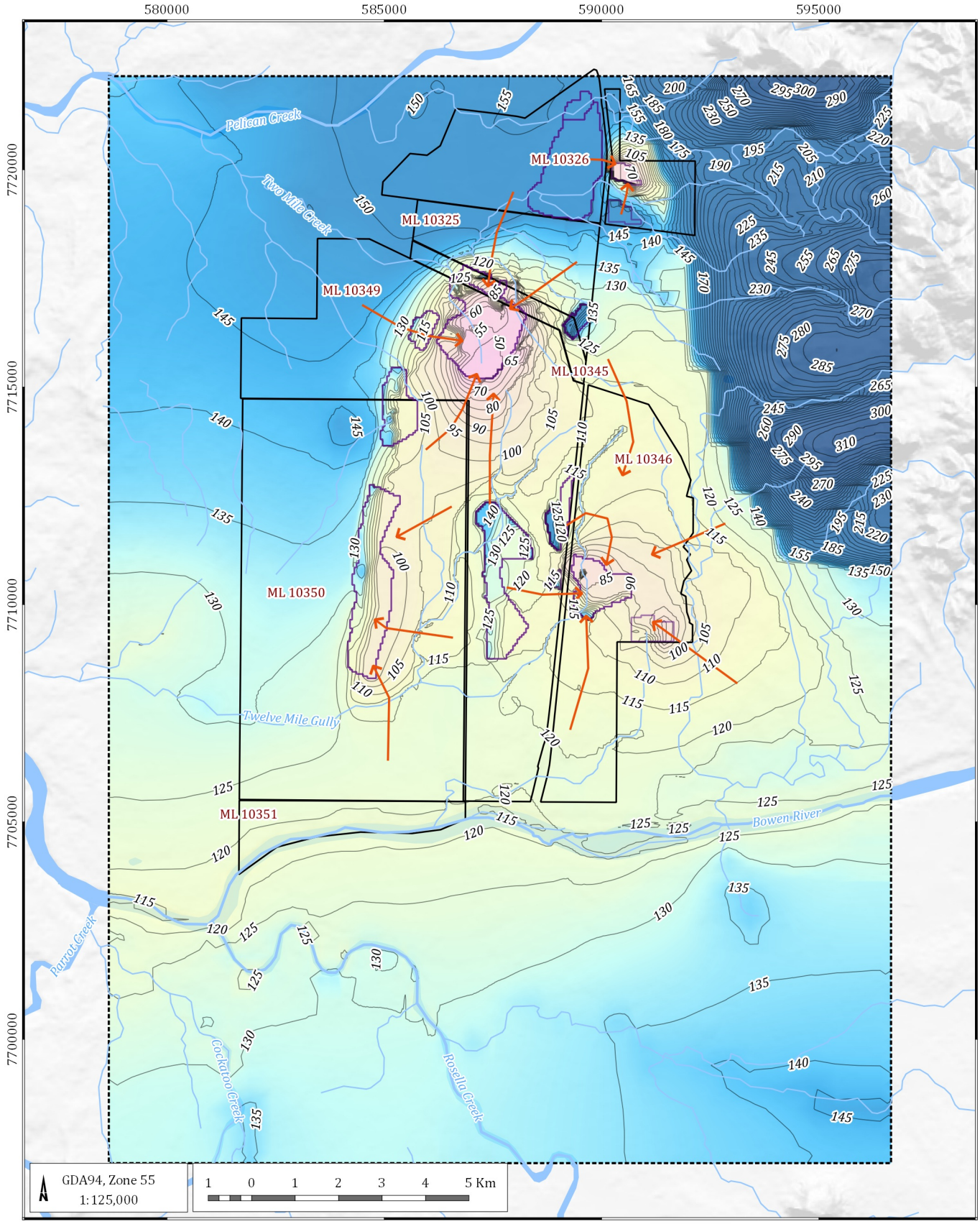
Northern Hub Groundwater Assessmentl (G1779E)

Predicted water levels after 10 years of recovery – layer 1

DATE 04/06/2020

FIGURE No: **9.2**

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LEGEND

- Road
- Rail
- Watercourse
- Predicted groundwater level elevation contour (mAHD)
- Flow direction
- QNH mining leases
- Model domain
- Pit outline

Water level (mAHD)

- -50
- 0
- 100
- 200
- 300

Northern Hub Groundwater Assessmentl (G1779E)

Predicted water levels when recovery reaches equilibrium – layer 1

DATE 04/06/2020

FIGURE No: **9.3**

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10 Conclusions and recommendations

The modelling presented in this report has been undertaken to provide QCoal with a management tool to make informed decisions relating to potential groundwater impacts associated with their current and proposed QNH operations. The original model development was undertaken to satisfy conditions for the Commonwealth approval of the Drake Project. The groundwater model has been given a broader focus of the QNH area (including the Sonoma, Cows, Drake and Jax mines). The groundwater model has been updated with a new mine plan that looks towards mining within the QNH to 2034. The changes to the groundwater model have not modified the previous assessment that the model satisfies a confidence classification of Class 2 as assessed against the criteria in Barnett et. al. (2012).

The model was previously calibrated well against pre mining water levels, but not as well against transient water levels. The updated water level observations for the model fits in to the conceptualisation that the groundwater occurrence across the site is limited.

The following recommendations are made to ensure the model development continues and is able to confirm the future predictions, and be enhanced with any conceptual changes that may arise from continued field observations:

- Updating the alluvial extent with new mapping from the Geological Survey of Queensland – this will require recalibration of the model.
- Redefine the mesh with the use of Voronoi polygons with MODFLOW USG.
- Truncation of model layers where geological units (such as coal seams) subcrop within the model domain.
- Re-calibrate the model once the updates to the model structure and mesh are made, as those changes may significantly improve the transient calibration.
- Uncertainty analysis should be undertaken the next time the model is revisited to contemporise the work and bring it in line with guideline amendments for large coal seam gas and coal mine assessments, which will stipulate the use of these techniques for any assessments in the future.
- Continued monitoring of the bores beside the river including the dry bores to capture any occurrences where they do rewet during periods of high rainfall.
- Installing soil moisture data loggers next to a key monitoring bore to improve recharge estimates.

11 References

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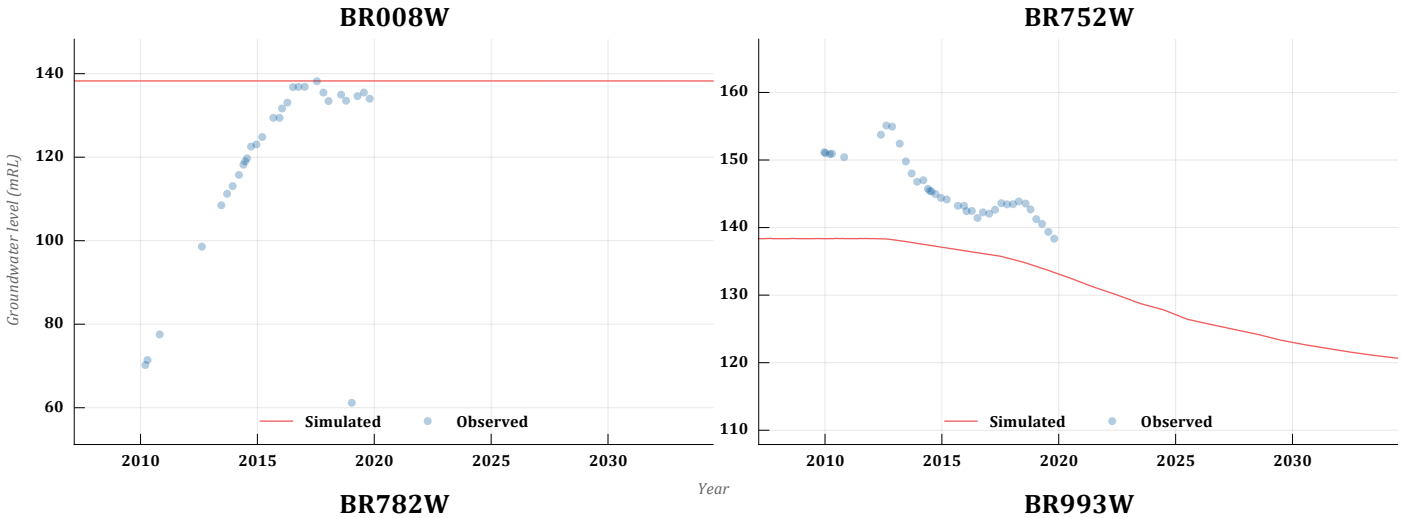
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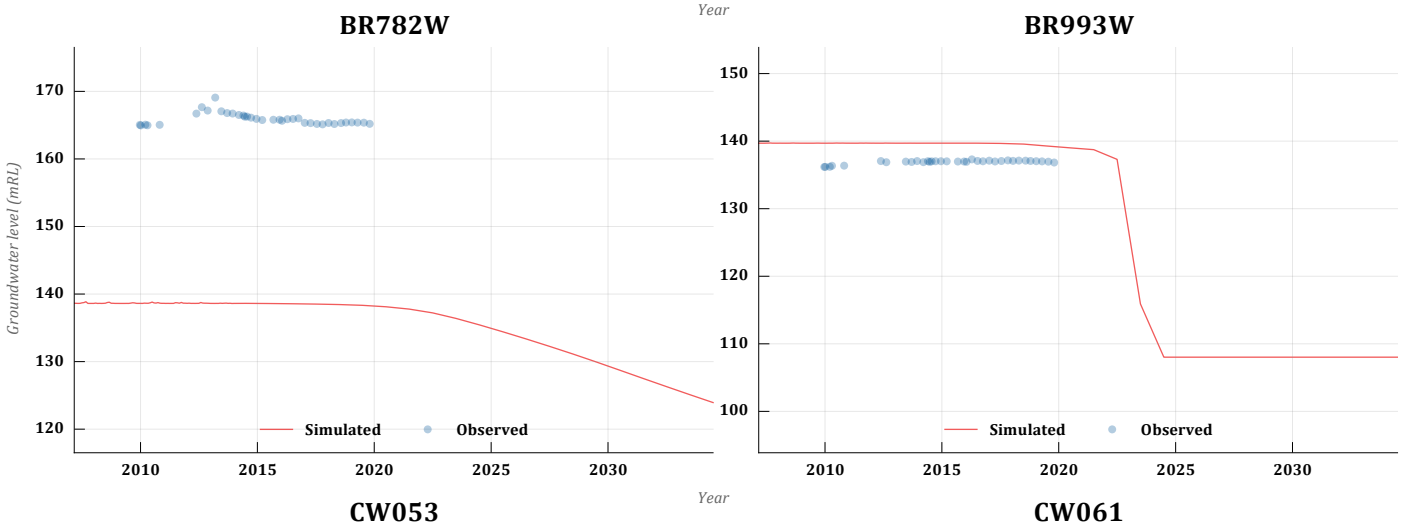
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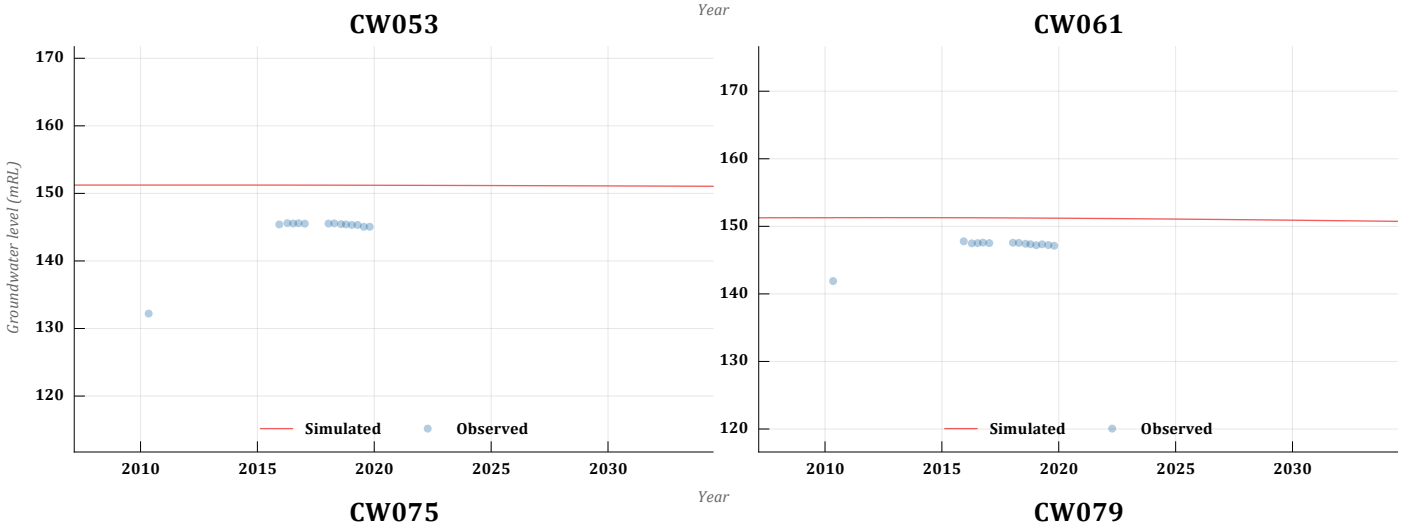
Appendix A Calibration hydrographs


BR008W
Groundwater level (mRL)
140
120
100
80
60
Simulated
Observed
2010
2015
2020
2025
2030
Year

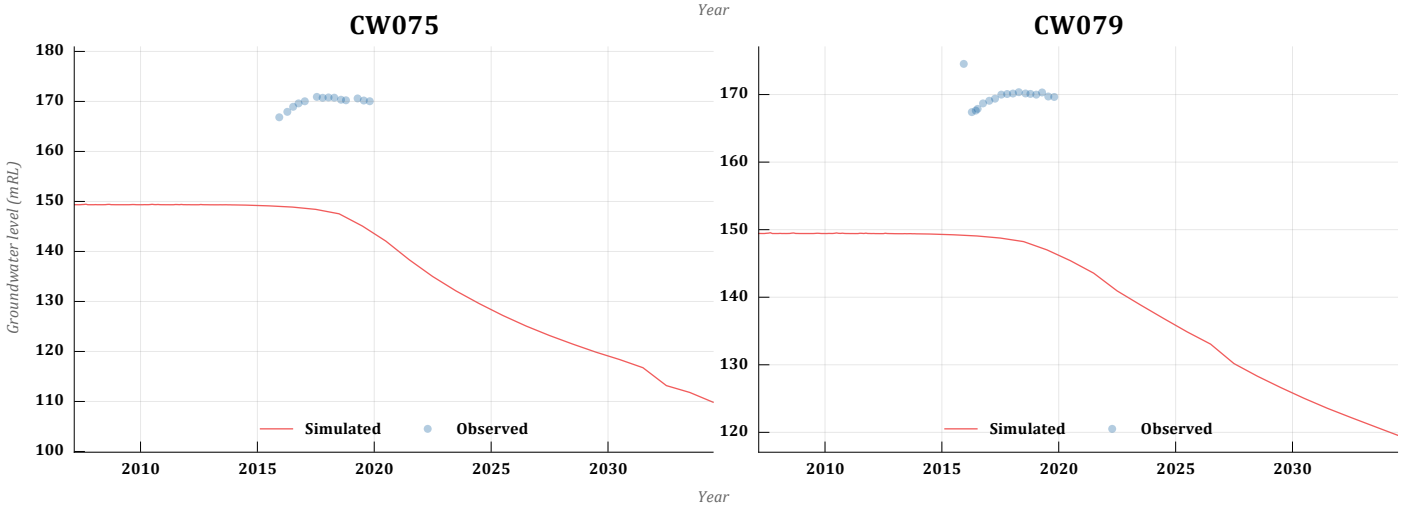
BR752W
160
150
140
130
120
110
Simulated
Observed
2010
2015
2020
2025
2030


BR782W
Groundwater level (mRL)
170
160
150
140
130
120
Simulated
Observed
2010
2015
2020
2025
2030
Year

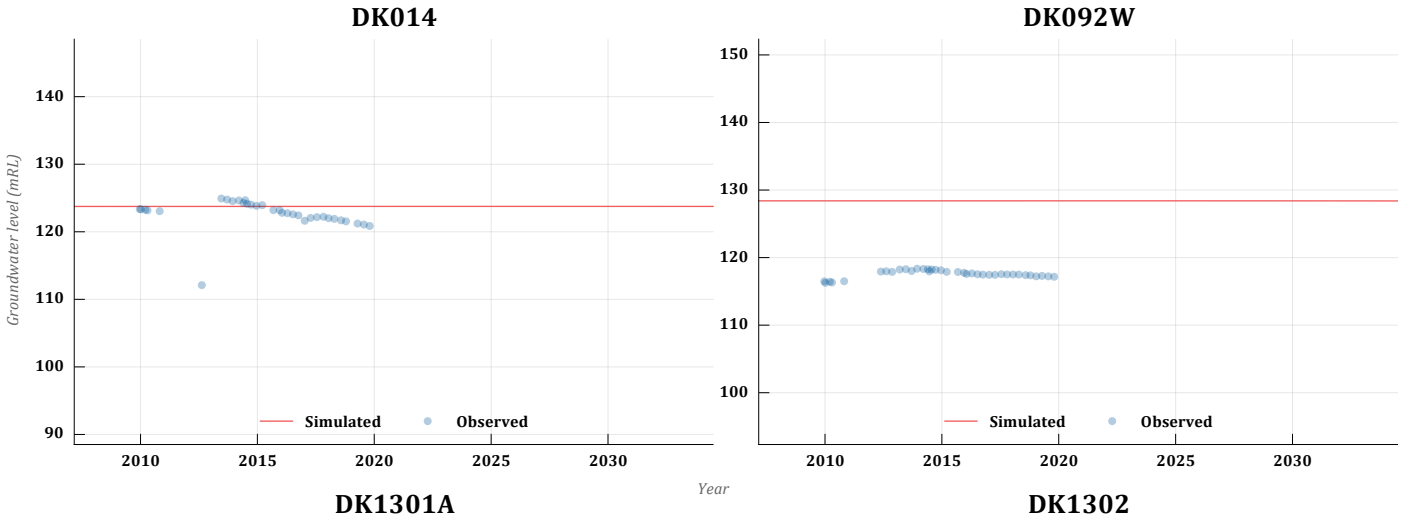
BR993W
150
140
130
120
110
100
Simulated
Observed
2010
2015
2020
2025
2030


CW053
Groundwater level (mRL)
170
160
150
140
130
120
Simulated
Observed
2010
2015
2020
2025
2030
Year

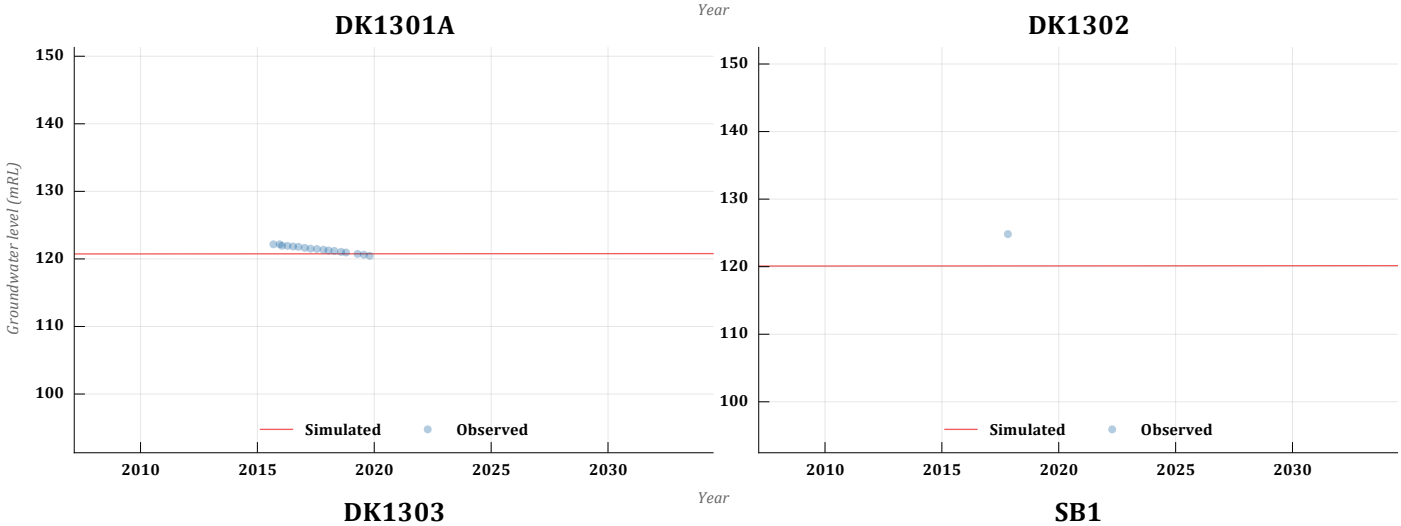
CW061
170
160
150
140
130
120
Simulated
Observed
2010
2015
2020
2025
2030


CW075
Groundwater level (mRL)
180
170
160
150
140
130
120
110
100
Simulated
Observed
2010
2015
2020
2025
2030
Year

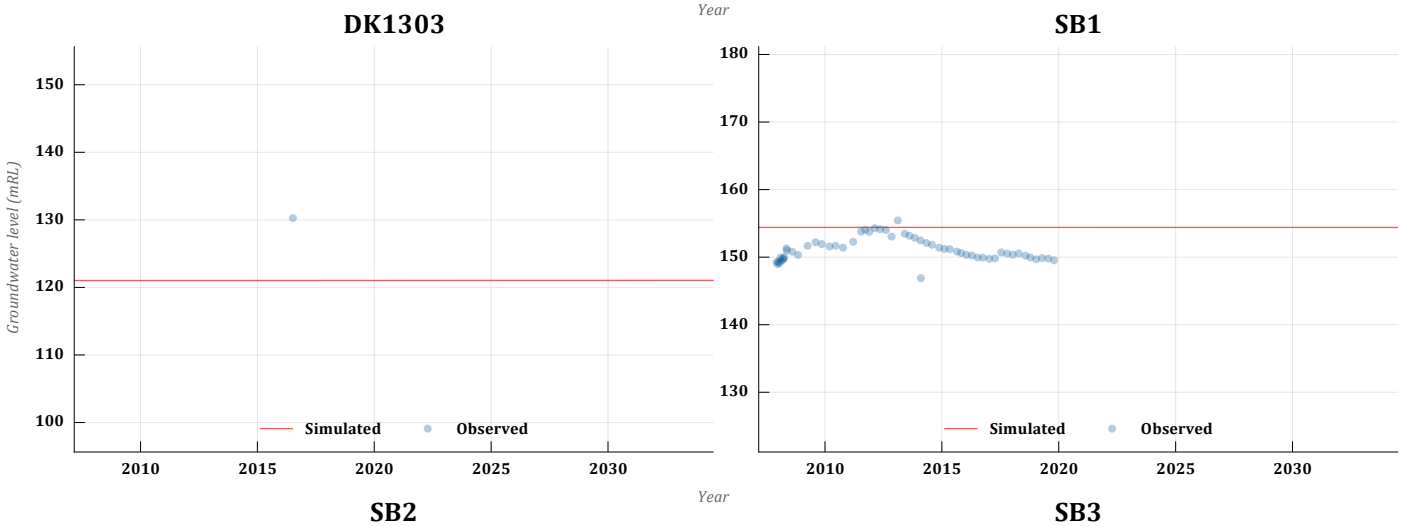
CW079
170
160
150
140
130
120
Simulated
Observed
2010
2015
2020
2025
2030


DK014
Groundwater level (mRL)
140
130
120
110
100
90
Simulated
Observed
2010
2015
2020
2025
2030
Year

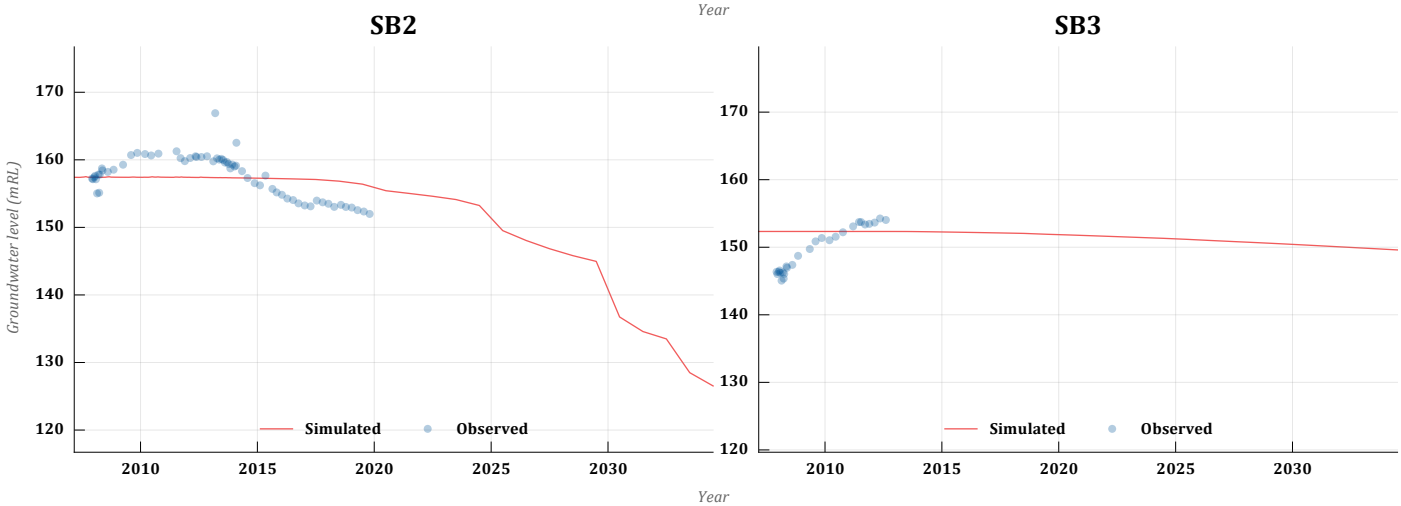
DK092W
150
140
130
120
110
100
Simulated
Observed
2010
2015
2020
2025
2030


DK1301A
Groundwater level (mRL)
150
140
130
120
110
100
Simulated
Observed
2010
2015
2020
2025
2030
Year

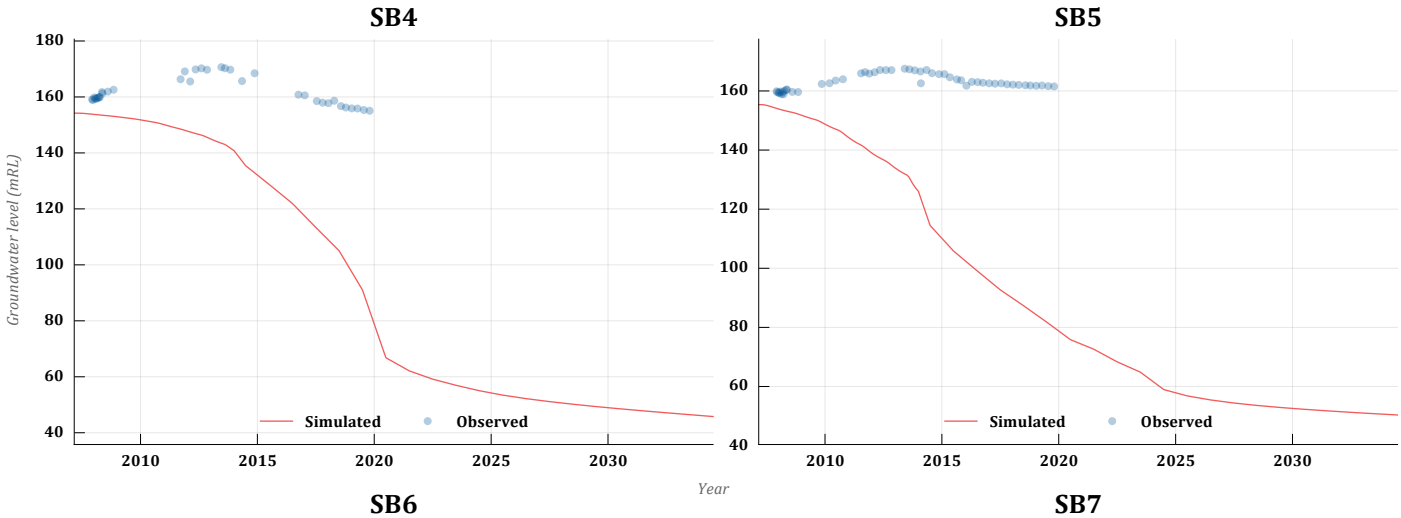
DK1302
150
140
130
120
110
100
Simulated
Observed
2010
2015
2020
2025
2030


DK1303
Groundwater level (mRL)
150
140
130
120
110
100
Simulated
Observed
2010
2015
2020
2025
2030
Year

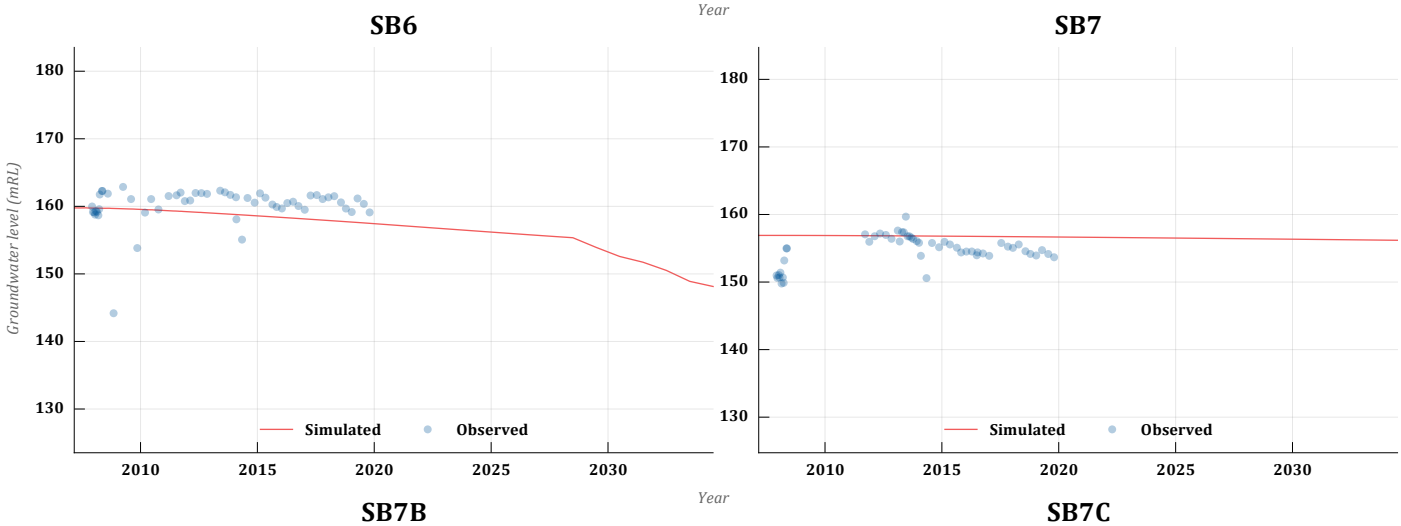
SB1
180
170
160
150
140
130
Simulated
Observed
2010
2015
2020
2025
2030


SB2
Groundwater level (mRL)
170
160
150
140
130
120
Simulated
Observed
2010
2015
2020
2025
2030
Year

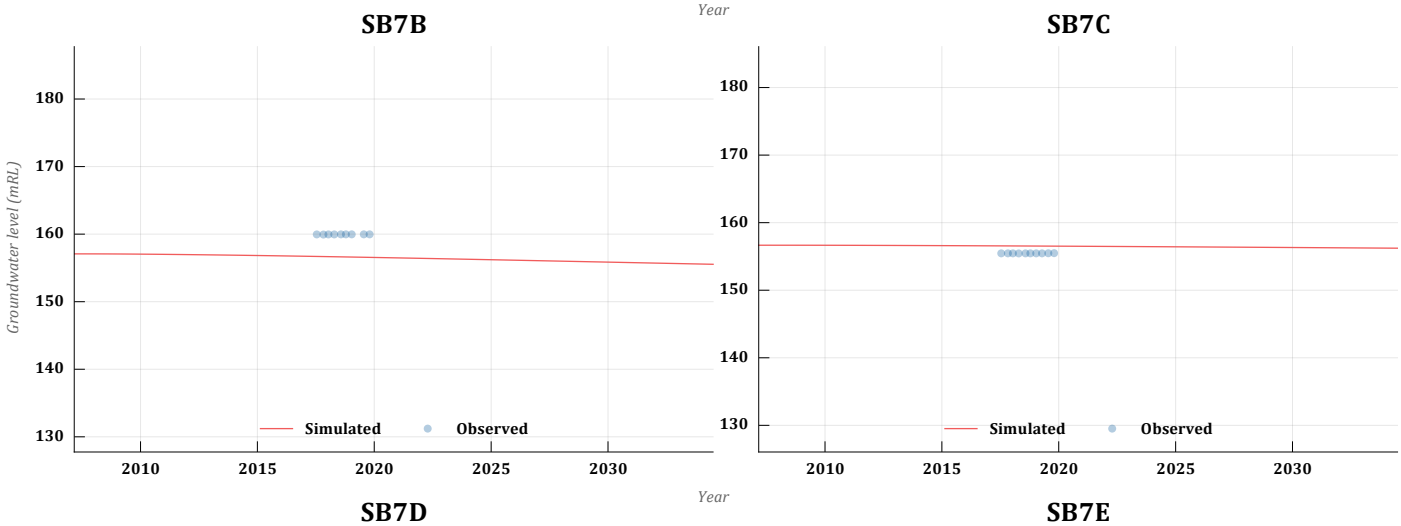
SB3
170
160
150
140
130
120
Simulated
Observed
2010
2015
2020
2025
2030


SB4
Groundwater level (mRL)
180
160
140
120
100
80
60
40
2010
2015
2020
2025
2030
Simulated
Observed
Year

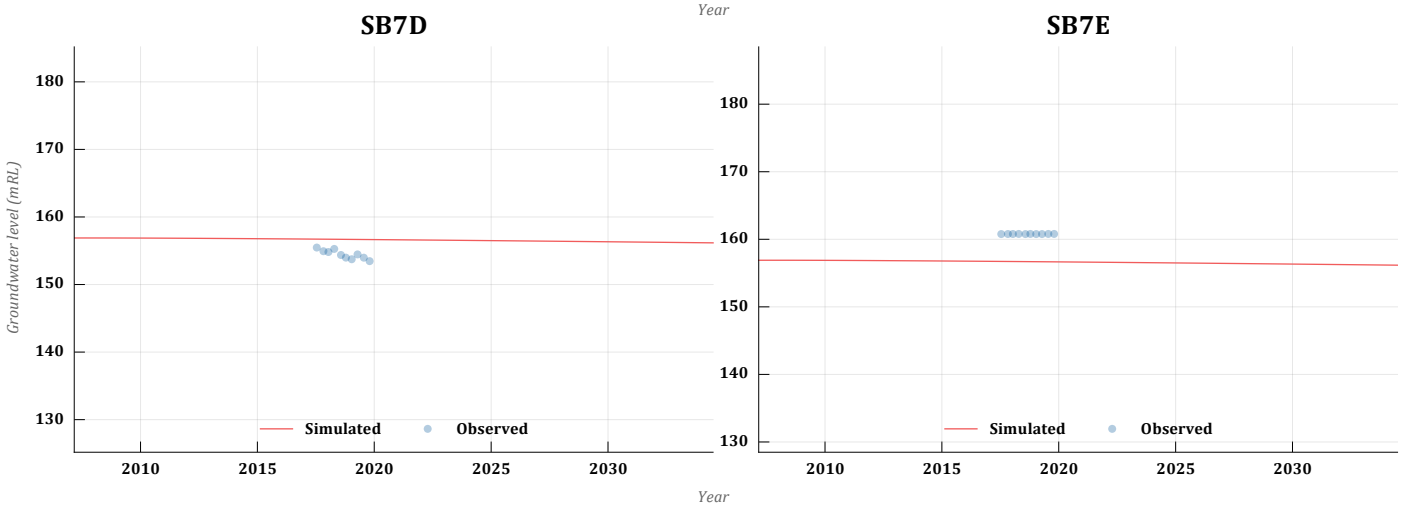
SB5
160
140
120
100
80
60
40
2010
2015
2020
2025
2030
Simulated
Observed


SB6
Groundwater level (mRL)
180
170
160
150
140
130
2010
2015
2020
2025
2030
Simulated
Observed
Year

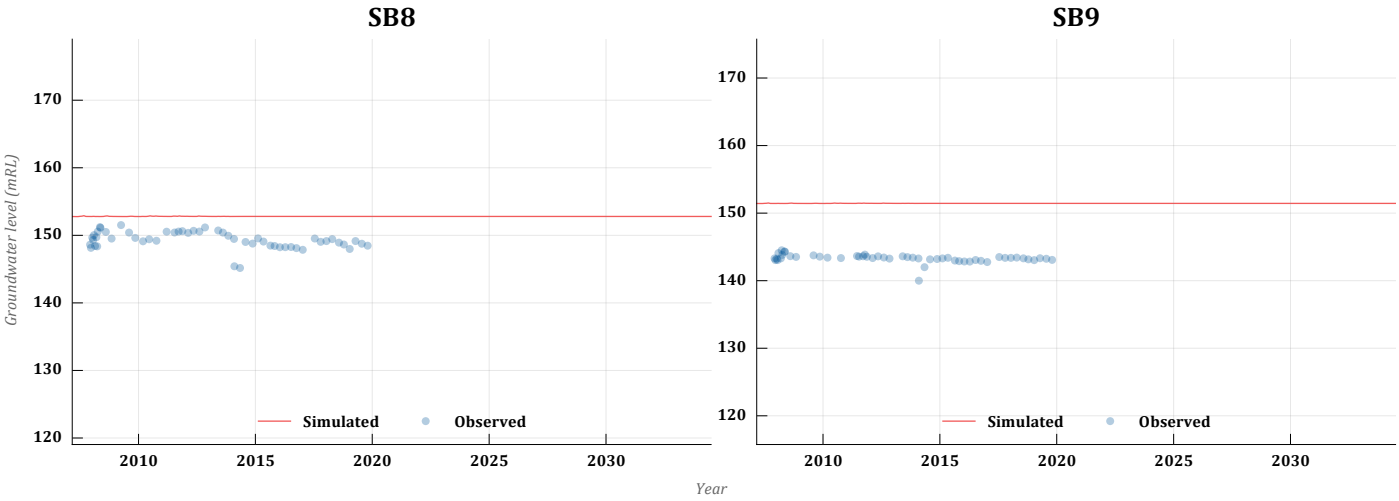
SB7
180
170
160
150
140
130
2010
2015
2020
2025
2030
Simulated
Observed


SB7B
Groundwater level (mRL)
180
170
160
150
140
130
2010
2015
2020
2025
2030
Simulated
Observed
Year

SB7C
180
170
160
150
140
130
2010
2015
2020
2025
2030
Simulated
Observed


SB7D
Groundwater level (mRL)
180
170
160
150
140
130
2010
2015
2020
2025
2030
Simulated
Observed
Year

SB7E
180
170
160
150
140
130
2010
2015
2020
2025
2030
Simulated
Observed


SB8
SB9
Groundwater level (mRL)
170
160
150
140
130
120
Simulated
Observed
2010
2015
2020
2025
2030
Year

Cows Coal Project
Groundwater Impact Assessment

Geoaxiom Pty Ltd

May 2011

Report No.

110504_Cows-GW_CH-RP01

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Abbreviations

AHD	**Australian Height Datum**
ANZECC	**Australian & New Zealand Environment and Conservation Council**
AWBM	**Australian Water Balance Model**
BGL	**Below Ground Level**
BOM	**Bureau of Meteorology**
DNRW	**Department of Natural Resources and Water**
EC	**Electrical Conductivity**
EIS	**Environmental Impact Study**
EMOS	**Environmental Management Overview Strategy**
EMP	**Environmental Management Plan**
MGA	**Map Grid of Australia**
Q	**Discharge m^3/s**
ROP	**Resource Operations Plan**
RL	**Reduced level**
Sy	**Specific Yield**
T	**Transmissivity**
TDS	**Total Dissolved Solids**
VFD	**Variable Frequency Drive**
WL	**Water Level**
WRP	**Water Resource Plan**

1.0 Introduction

The Cows Coal Project (Cows) is being developed by Bowen River Coal Pty Ltd (BRC), a subsidiary of QCoal Pty Ltd. This project will involve the development of two open-cut coal mining pits just south of the Sonoma Coal Mine.

Geoaxiom Pty Ltd (GPL) was commissioned to assess the impacts of the proposed development on the groundwater regime.

1.1 Scope of Work

The objective of this report is to provide an assessment of the existing hydrogeological regime and to identify potential impacts of the mine development with recommendations for monitoring and/or mitigation of impacts.

To achieve this objective the scope of work included:

- Review of geological data existing in the public domain and published geological maps
- Review of data provided by the proponent including information relating to the Sonoma Coal Mine
- Review of hydrogeological data held in the Department of Environment and Resource Management (DERM) Groundwater Database for existing registered bores in the area
- Assessment and analysis of available data and preparation of this report

1.2 Location and Access

The Cows Coal Project is located approximately 13km south of Collinsville in northern portion of Queensland's Bowen Basin. The lease is bounded to the east by the Bowen Development road and to the north by the Sonoma Coal Mine. The lease boundary and proposed site layout are shown in Figure 1.

Access the Cows lease is gained from the north from Collinsville along the sealed Collinsville Development Road or from the south via the Peak Downs Highway from Nebo. Access within the lease is limited to generally well maintained property tracks, however, many of the tracks traverse black soil plains and are unsuitable for use immediately after heavy rain.

1.3 Climate

Rainfall is highly variable between seasons, within years and across the project area. The region receives dominant summer rainfall (Table 1). Bureau of Meteorology (BoM) data from 1913 shows the average annual rainfall is 681 mm. Evaporation rates are substantially higher than precipitation and are seasonal ranging from 198 mm for January to 94 mm in June (Table 1). Temperatures are typically sub-tropical; however, frost can occur in some winter years.

Table 1 – Composite Rainfall Summaries in Collinsville

Month	Average Rainfall (mm)	Average Evaporation (mm)
January	137	198
February	134	197
March	89	172
April	34	143
May	28	111
June	30	94
July	22	103
August	15	131
September	11	164
October	22	207
November	53	217
December	97	215
TOTAL	681	1952

586000 587000 588000 589000

7718000 7717000 7716000 7715000

10 DK7

1 SP190745

618 PH2106

B-SEAM PIT

HAUL ROAD

POND 2

ROM/MIA

POND 1

Q-SEAM PIT

QCOAL PTY LTD

COWS COAL PROJECT (ML 10345)

FIGURE 1: CONCEPT LAYOUT DRAWING

0 250 500 750 1,000

Metres @ A3

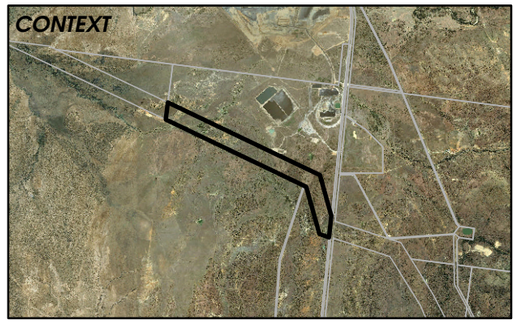
Scale: 1:15,000
Projection: UTM Zone 55
Datum: GDA 1994

N W E S

Legend

- Internal Access Road (2.5 km)
- Pit (34 ha & 7 ha)
- Out of Pit Waste Dump (9.2 ha)
- Run Of Mine/Mine Infrastructure Area (2.5 ha)
- Pond
- Topsoil Locations (2.3 ha)
- Haul Road Corridor (50 m wide; 19 ha)
- Cows ML 10345
- Digital Cadastral Database

CONTEXT



Date: 10 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DEEDI, DERM & Google

1.4 Landforms and Surface Water

At a regional level, Collinsville and its surrounds form part of the southern catchment area of the Burdekin River Basin. Collinsville is situated in the Bowen sub-catchment of the Burdekin River Basin. The sub-catchment is separated from the remainder of the Burdekin catchment by the Leichardt Range to the west. The sub catchment is also bound by the Clarke and Connors Ranges to the east and the Denham Range to the south. The main artery of the stream network is the Bowen River located some 10km to the south of the Cows lease.

The proposed mining lease area is located on a relatively flat alluvial plain drained by the west flowing Two Mile creek in the western portion and an unnamed tributary of this creek running northerly through the centre of the lease. The creeks draining the Cows lease are ephemeral and drain into Coral Creek which flows westerly around the northern side of the Sonoma Mine and ultimately joins the Bowen River some 25km to the north west of the project.

A 1-2m layer of black clay soil is typically present across the area with a heavy texture and uniform profile. When dry these soils develop closely spaced, wide, deep cracks however when wet they are very plastic and extremely sticky. Under these soils and adjacent to the drainage lines there is a well developed alluvial profile with thicknesses of up to 5m along the unnamed creek in the centre of the lease and along Two Mile Creek (Figure 2)[1].

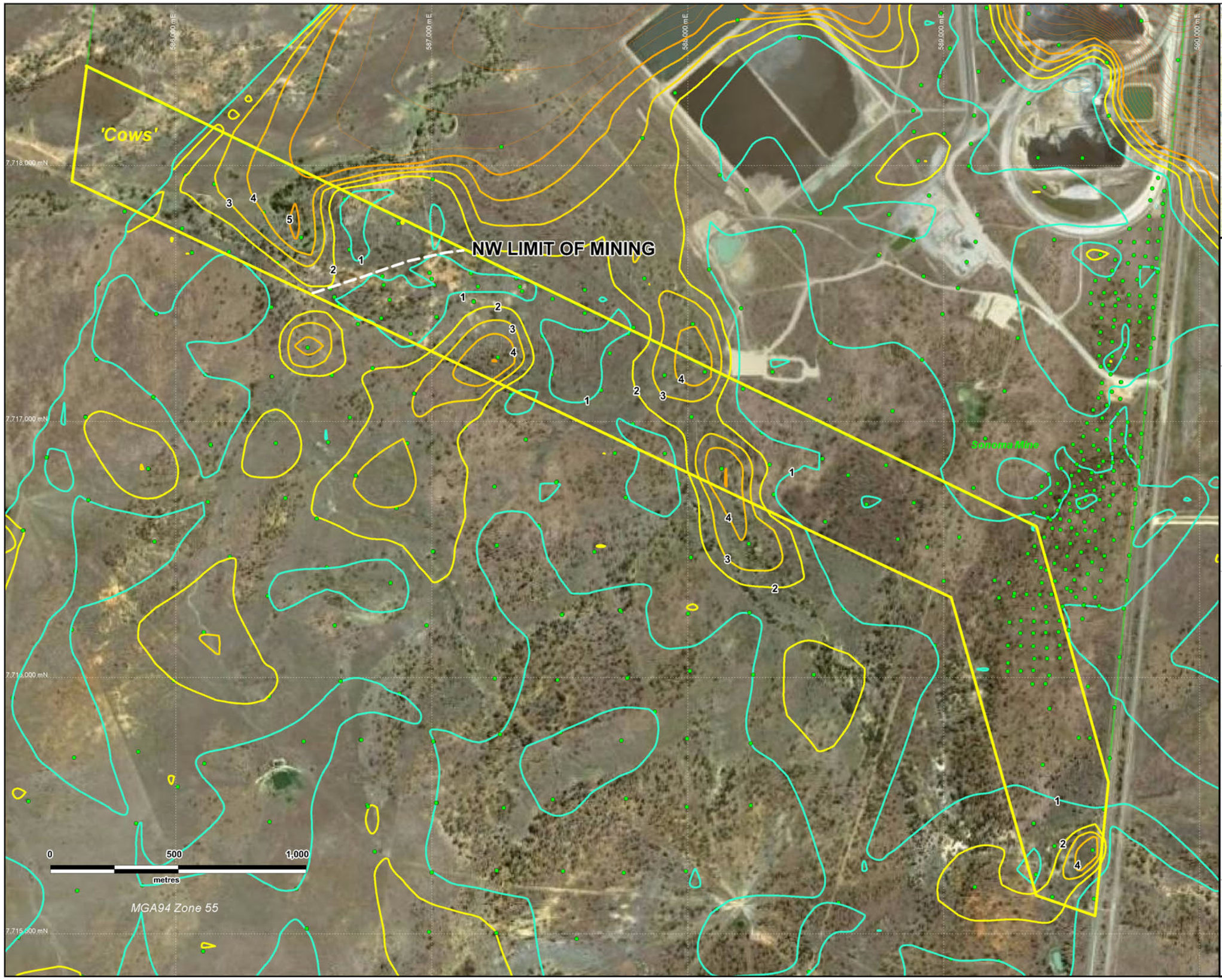
Surrounding land uses include cattle grazing, mining and quarrying and limited cropping.

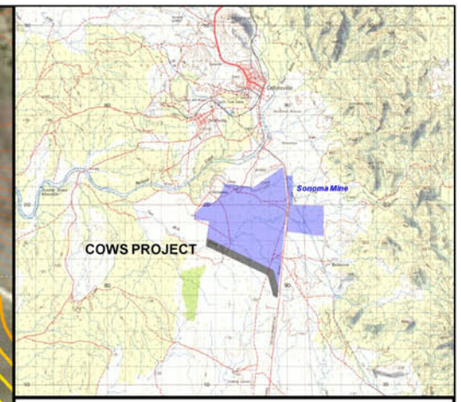
2.0 Legislative Requirements

The Cows project is not located within a declared sub-artesian groundwater management area under Queensland state legislation however the area does fall within the Bowen River sub-catchment of the Burdekin Basin Water Resource Plan (2007). If groundwater is to be extracted from new or existing monitoring bores, or if production bores are installed for project water requirements a *Development Permit,* under the *Sustainable Planning Act 2009,* needs to be submitted to DERM for approval prior to construction.

The project is not located within any declared wild river area (*Wild River Act 2005*) and any proposed water management and mining activities will not impact on any declared wild river areas.

[1] Alluvium thickness derived from exploration drilling data supplied by Energy Minerals Pty Ltd





COWS PROJECT

THICKNESS OF QUATERNARY (m)

(1m contours)

LEGEND

- Data point (drillhole)
- 2 Thickness contour (m)
- MLA boundary
- Sonoma ML boundary

Energy Minerals Pty Ltd

Figure 2

Apr 2011

3.0 Geological Setting

The Cows Project is located in the northern section of the Bowen Basin, where active subsidence and deposition during the Permo-Triassic was centred within an extensional terrain known as the Taroom Trough[2]. This depositional centre was situated marginal to the Collinsville Shelf in the west, which typically behaved as a stable platform throughout. The deformed Taroom Trough of the northern Bowen Basin is defined by the Nebo Synclinorium, where contained sediments and volcanics of the western two-thirds dip gently towards the major synclinal axis in the east. Post-depositional compression has resulted in a fold-and-thrust style of deformation, particularly on the eastern side of the basin, and sediments along this margin generally dip steeply toward the west. However, tensional structures are also present, and away from the eastern margin of the basin they are often more common than compression-related faults.

3.1 Regional Stratigraphy

The gross stratigraphy comprises the basal Lizzie Creek Volcanics and overlying marine Back Creek Group, non-marine Blackwater Group, and Tertiary sediments of the Suttor Formation and equivalents. Marine sedimentary rocks of the Back Creek Group are subdivided into the Collinsville Coal Measures and laterally equivalent Gebbie Formation, Blenheim Formation and Exmoor Formation, whilst the Blackwater Group comprises the Moranbah and Fort Cooper Coal Measures (Figure 3).

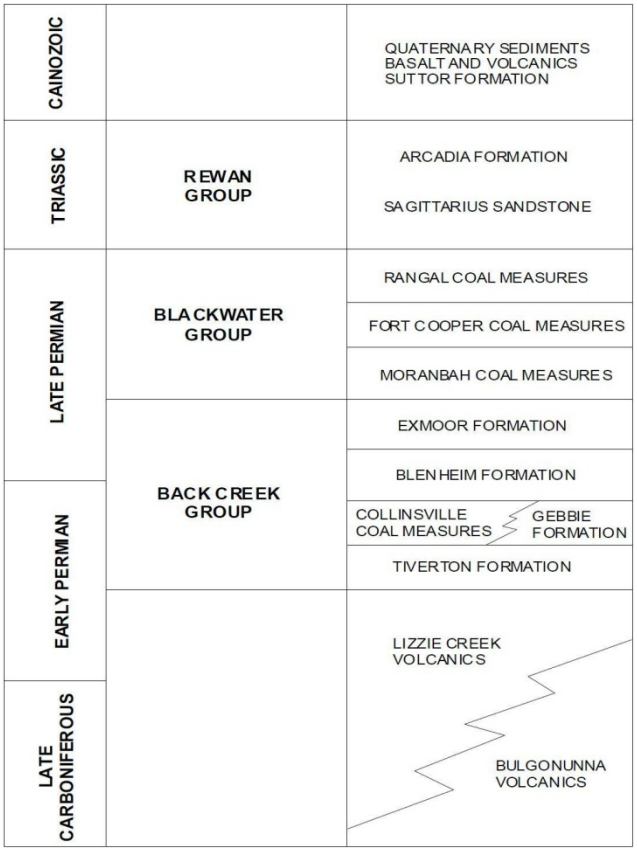


Figure 3 Generalised Stratigraphy of the Northern Bowen Basin

[2]QCoal Pty Ltd (2005). Geology of the Sonoma-Belmore Area – Unpublished company report

The coal deposits of the Sonoma and Cows deposits are part of the Moranbah Coal Measures which is comprised of cross-bedded lithic sandstone and siltstone, mudstone, coal and fossil logs. The sequence contains between three and eight major seams all of which are clean and contain only minor tuffaceous and mudstone bands as shown in Figure 4.

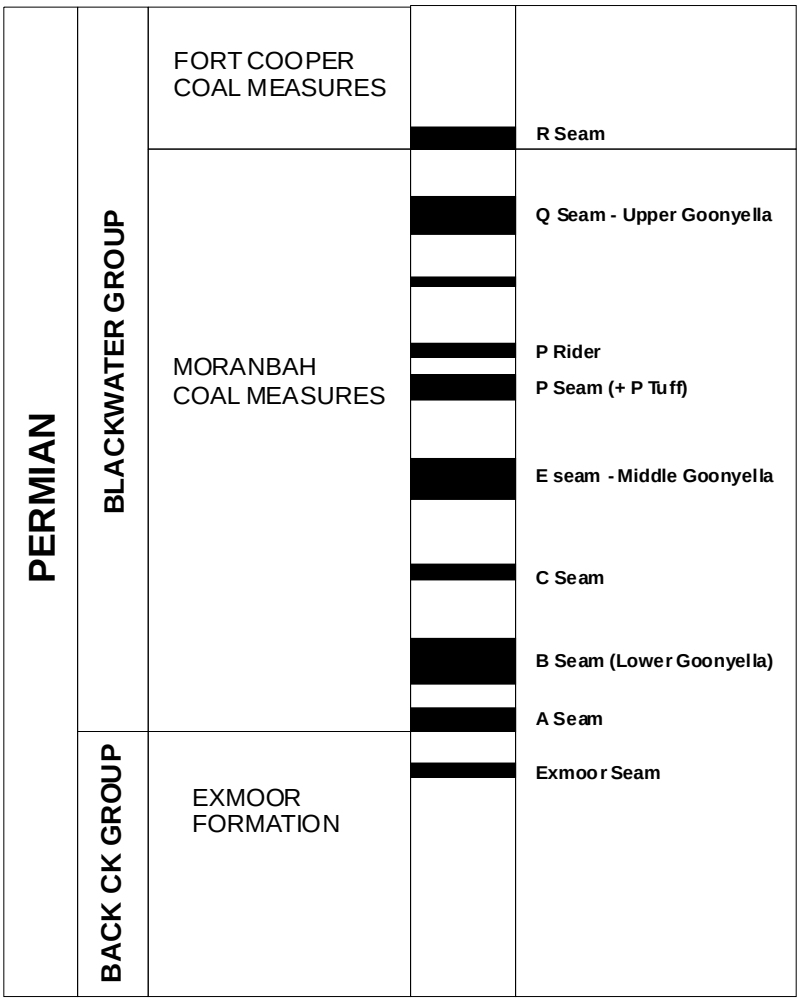


Figure 4 Coal Seams of the Moranbah Coal Measures

3.2 Geology of the Cows Area

Geological detail in the Cows area is generally obscured by a cover of quaternary alluvium and gravel especially in the vicinity of the creeks and water courses. There is relatively little alluvial cover in the eastern portion of the lease. This alluvial cover comprises unconsolidated fine to very coarse grained sand with occasional and irregularly interbedded silt clay and gravel lenses. Overall the alluvial unit ranges in thickness from a thin veneer in the east to maximum thicknesses of 5m in the central and western portions of the lease.

The base of weathering generally occurs some 5-15m below the Quaternary alluvium.

Due to northwest trending faulting through the central part of the lease a full sequence of seams is not accessible for mining within the Cows lease. Economically viable resources are being accessed in two pits with the B seam to be accessed by a pit in the western arm of the lease and the Q seam to be accessed via a smaller pit in the eastern area.

The extent of the proposed open cut pits are shown in Figure 1 and comprise an area of approximately 34Ha in the western pit and 7Ha in the eastern pit. It is proposed to access the B seam to a depth of 90 - 100mBGL in the western pit and the Q seam to a depth of 50 - 60mBGL in the eastern pit.

4.0 Hydrogeological Regime

4.1 Aquifers

The hydrogeological investigations undertaken for the Sonoma Coal Mine (AGE, 2005[3]), located immediately to the north of the Cows Project and other coal projects to the south (Geoaxiom, 2010[4]), support the conceptualisation of the local hydrogeological regime in that groundwater is confined to Cainozoic colluvial sediments and deeper confined aquifers within the Permian coal measures. Thrust faulting in the area has resulted in displacements of 20-40m (AGE, 2005) with minimal associated brecciation resulting in limited ability to transmit groundwater. Faults may locally provide connectivity between coal seams however this is of limited significance as a number of coal seams are expected to be mined thus negating the impacts of localised faulting.

The DERM Groundwater Database contains the records of 36 registered bores surrounding the Cows Project area out to a distance of some 10km. Of these bores, nine are registered monitoring bores for the Sonoma Coal Project and three are registered monitoring bores constructed for ongoing investigations by Xstrata Coal. There are no registered bores occurring within the Cows Project area. A summary of available data related to these bores is given in Table 2 and the closes bores are shown in Figure 5. A number of bores drilled during the mid 1970's and 1990's were established by DERM for monitoring of the Bowen River alluvium to the south of the Project Area.

DERM records show that shallow alluvial bores in this area are producing 0.5 – 22.5 L/s with the higher flows associated with bores in Bowen River alluvium. Bores in weathered and fractured granite appear to be producing between 0.4 and 1.5 L/S with one record of 1.3 L/s in weathered basalt. There are no records of bores in the coal measures being used for stock and domestic purposes.

No significant groundwater was encountered during exploration drilling in the Cows lease. Groundwater yields determined by airlift and "V"-notch weir during exploration drilling in adjacent leases were relatively low (<2 L/s) and variable across the area. There is also some variation in the occurrence of groundwater within individual and adjacent bores. This is consistent with exploration program yields reported during development of the Sonoma Coal Project (AGE, 2005) where yields were highly variable and ranged between 0 and 5 L/s with an average of 1 L/s. These results indicate that while the coal seams are the principal aquifers in the Permian sediments they are of low permeability.

[3] Groundwater Impact Assessment - Proposed Sonoma Coal Mine. Q Coal Pty Ltd. AGE, May 2005.
[4] Groundwater Monitoring and Quality Report – Drake Coal Project Bowen River Coal Pty Ltd. Geoaxiom, December 2010.

Table 2 Extract of Registered Bores - DERM Groundwater Database

Registered Number	Easting (mMGA25S)	Northing (mMGA25S)	Elevation (mAHD)	Date Drilled	Property or Location	Aquifer Top (mBGL)	Aquifer Base (mBGL)	Aquifer Type	Aquifer Description	Water level (mBTC)	YIELD (L/S)	Reading Date
25715	594974	7719770		16/09/1966		7	11.6	GRANITE	HARD BLUE Granite	-5.9	0.4	16/09/1966
25716	583265	7721110				0	12	ALLUVIUM	SAND AND GRAVEL	-9.7	2.5	31/03/1968
33166	595554	7719610		1/10/1969		11	15.2	BASALT	BASALT			
33167	587745	7719540		29/06/1967		12	15.8	BASALT	ROTTEN Shale WITH HARD BARS	-10.3	1.3	29/06/1967
36420	593524	7718270		10/10/1970	REEDY CREEK	8	9.8	GRANITE	GRANITE DECOMPOSED	-6.1	1.5	10/10/1970
39371	585575	7720170		12/11/1973	SONOMA	18	19.5	ALLUVIUM	SAND AND GRAVEL	-10.6	15	12/11/1973
39840	586305	7721230		1/02/1975	SONOMA	12	14.6	ALLUVIUM	GOOD SAND	-9.1	22.5	1/02/1975
39841	587605	7721060		1/02/1975		10	11.3	ALLUVIUM	SAND AND ROCKS	-6.1	0.5	1/02/1975
60105	588185	7720600		1/01/1980		14	18.5	ALLUVIUM	GRAVEL AND BROKEN ROCK WATER			
125697	595070	7714811		22/10/2005	BELMORE STATION	0.5	37.5	PERMIAN	GREY Shale HOLE ABANDONED			
125698	595687	7715912		22/10/2005	BELMORE STATION	8	37.27	PERMIAN	GREY Shale WITH FRACTURES			
140015	595975	7716281		17/05/2006	COX	15	18	GRANITE	HARD BLUE GRANITE			
140019	595077	7714752		17/05/2006	COX	12	24	GRANITE	HARD BLUE GRANITE HOLE ABANDONED			
140020	594690	7715181		18/05/2006	COX	15	18	GRANITE	DRY BLUE GRANITE			
140025	592385	7717168		19/05/2006	COX	24	30	ALLUVIUM	DRY GREY CLAYBOUND GRAVEL			
140400	587252	7720490		30/11/2007	SONOMA MINE	20	25	PERMIAN	SHALE LIGHT GREY			
140401	590426	7719297		20/11/2007	SONOMA MINE	15	21.5	PERMIAN	SHALE LIGHT GREY LENS CARBONACEOUS Shale LT / DK GREY			
140402	587389	7718142		16/11/2007	SONOMA MINE	27	30	PERMIAN	CARBONACEOUS SHALE DK GREY OXIDISED			
140403	589700	7718421		15/11/2007	SONOMA MINE	63	75	PERMIAN	SANDSTONE LIGHT GREY (Coal?)			
140404	590426	7719297		18/11/2007	SONOMA MINE	57	75	PERMIAN	SHALE / Sandstone GREY TRACES COAL			
140405	588530	7720770		23/11/2007	SONOMA MINE	21	27.9	PERMIAN	SHALE PALE GREY			
140406	586560	7721140		2/12/2007	SONOMA MINE	18.5	21.5	PERMIAN	SANDSTONE GREY (GRANITE?)			
140407	584660	7720720		6/12/2007	SONOMA MINE	18.5	27	PERMIAN	SHALE GREY			
140408	590160	7721340		3/12/2007	SONOMA MINE	21	25	PERMIAN	SANDSTONE GREY (GRANITE?)			
140529	590383	7716667		19/11/2007	XERATA COAL COMOANY	15	30	PERMIAN	ROCK GREY Mudstone (coal)?			
140530	590479	7717653		19/11/2007	EXERATA COAL COMPANY	12	20	PERMIAN	ROCK Weathered Mudstone?			
140531	590132	7717898		19/11/2007	XERATA COAL COMPANY	23.6	24	PERMIAN	ROCK GREY Mudstone (coal)?			
12020003	588851	7703750	142.53	18/06/1975	HAVILAH	15.4	18.5	PERMIAN	ROCK WEATHERED SANDSTONE	-15.6		
12020004	588856	7038255	141.6	17/06/1975	HAVILAH (STUD PADDOCK)	28	28.5	PERMIAN	ROCK V/HARD GREY SANDSTONE	-12.97		
12020005	588919	7704352	136.8	18/06/1975	HAVILAH	17.9	18.45	PERMIAN	ROCK WEATHERED M/COLOURED	-18.5		
12020007	589023	7704833	130.49	19/06/1975	BIRRALEE 12 MILE	10.35	13.9	TRIASSIC	CLAY V/SANDY BROWN	-7.52		
12020008	589075	7704956	141.71	18/06/1975	BIRRALEE 12 MILE	10.35	12.35	TRIASSIC	SANDSTONE WEATHERED GREY/YELLOW	-12.56		
12020017	588754	7703253	145.6	22/05/1996	HAVILAH	21.3	22	PERMIAN	BROWN & GREY WEATHERED & FRESH CARBONACEOUS SILTSTONE & SANDSTONE	-22.46		
12020018	588980	7702715	147.08	22/05/1996	HAVILAH	15.5	16	TRIASSIC	FRESH KHAKI SILTSTONE & SANDSTONE			
12020026	580663	7703507	131.79	25/05/1996	BIRRALEE 12 MILE	20.4	22	TRIASSIC	GREY & SOME BROWN CARBONACEOUS SILTY CLAY & MUDSTONE & SILTSTONE	-8.4		
12020027	580641	7704484	133.3	25/05/1996	BIRRALEE 12 MILE	7.1	8	TRIASSIC	BROWN, YELLOW AND GREY CARBONACEOUS SILTSTONE AND SANDSTONE	-6.44		



Figure 5 Registered bores located closest to the Cows Project Area - DERM Groundwater Database

During the Sonoma Mine groundwater study, AGE (2005) identified a number of unregistered landholders bores in the area with the closest to the Cows lease now being the site of registered monitoring bore RN140402 shown in Table 2 and Figure 5. The original bore at this site had been used for stock water.

4.2 Water Levels and Flow Direction

Measurement of groundwater levels has been undertaken during exploration drilling on an intermittent basis in the area since 2001. It appears that groundwater levels are typically measured at the completion of drilling and prior to geophysical logging and some water levels are also picked from geophysical logs. The variation in observed groundwater levels as assessed by both AGE (2005) and Geoaxiom (2010) indicate changes of less than 0.5m.

Since the development of the Sonoma Coal Mine regular monitoring has been undertaken on a 3 monthly basis. Recent data from this monitoring program has been supplied by QCoal and in presented in Table 3 with the bore locations shown in Figure 6. The field data collected at Sonoma confirms the low variability in groundwater levels throughout the area.

Table 3 Sonoma Coal Project - Groundwater Monitoring Data

Bore	RN	12/03/2010			16/06/2010			8/10/2010		
		SWL (mBGL)	pH	EC (µS/cm)	SWL (mBGL)	pH	EC (µS/cm)	SWL (mBGL)	pH	EC (µS/cm)
1	140400	12.31	7.13	884.2	12.21	7.07	972.0	12.49	7.08	883.8
2	140401	15.67	7.36	1188.0	15.88	6.95	13.89.0	15.61	6.96	1593.0
3	140402	11.62	6.69	2874.0	11.0	6.42	3006.0	10.44	6.73	3231.0
5	140404	14.48	7.17	1471.0	13.57	6.67	1521.0	13.13	6.92	1535.0
6	140408	12.0	7.06	1353.0	12.0	7.17	1410.0	11.54	6.98	1450.0
8	140406	11.5	7.19	1260.0	11.2	6.96	1191.0	11.42	7.08	1189.0
9	140407	10.09	7.41	1635.0				10.15	7.51	1627.0

Monitoring of groundwater levels in alluvial monitoring bores during the 2009/10 wet season was undertaken to on a coal project to the south of Cows (Geoaxiom 2010). This monitoring indicated very limited connectivity of groundwater response within the alluvium related to significant flow events in the Bowen River to the south and this connectivity was not laterally wide spread and certainly not observable as far north as the Cows. Similarly, Age (2005) noted that groundwater monitoring across the alluvium in the Sonoma area suggested that the alluvial aquifer was not continuous and is confined to low areas (possibly palaeo-channels) incised in the Permian sediments.

The direction of groundwater flow indicated by the recorded water levels as a composite of both coal seam and alluvial aquifers is to the west and is consistent with the surface topography. The base of the alluvium indicates a more north-westerly flow direction (Figure 7). Ultimately, however, any groundwater flow within the alluvium will tend towards the major drainage lines.

4.3 Yields

Groundwater flow rates have been measured in a number of exploration drill holes throughout the area (AGS 2005; Geoaxiom 2010) using a “V”-notch weir at the completion of drilling. The flow rates are composite flows which include both alluvial and coal seam water though the majority of flow (if any) appeared to have been derived from the alluvium. Airlift yields vary between 0 L/s and 5 L/s with an average recorded yield of about 1 L/s. The yields are relatively low given the exploration drill hole depths ranged between 23 and 170m with an average of about 77m indicating that the coal seams are of low permeability.



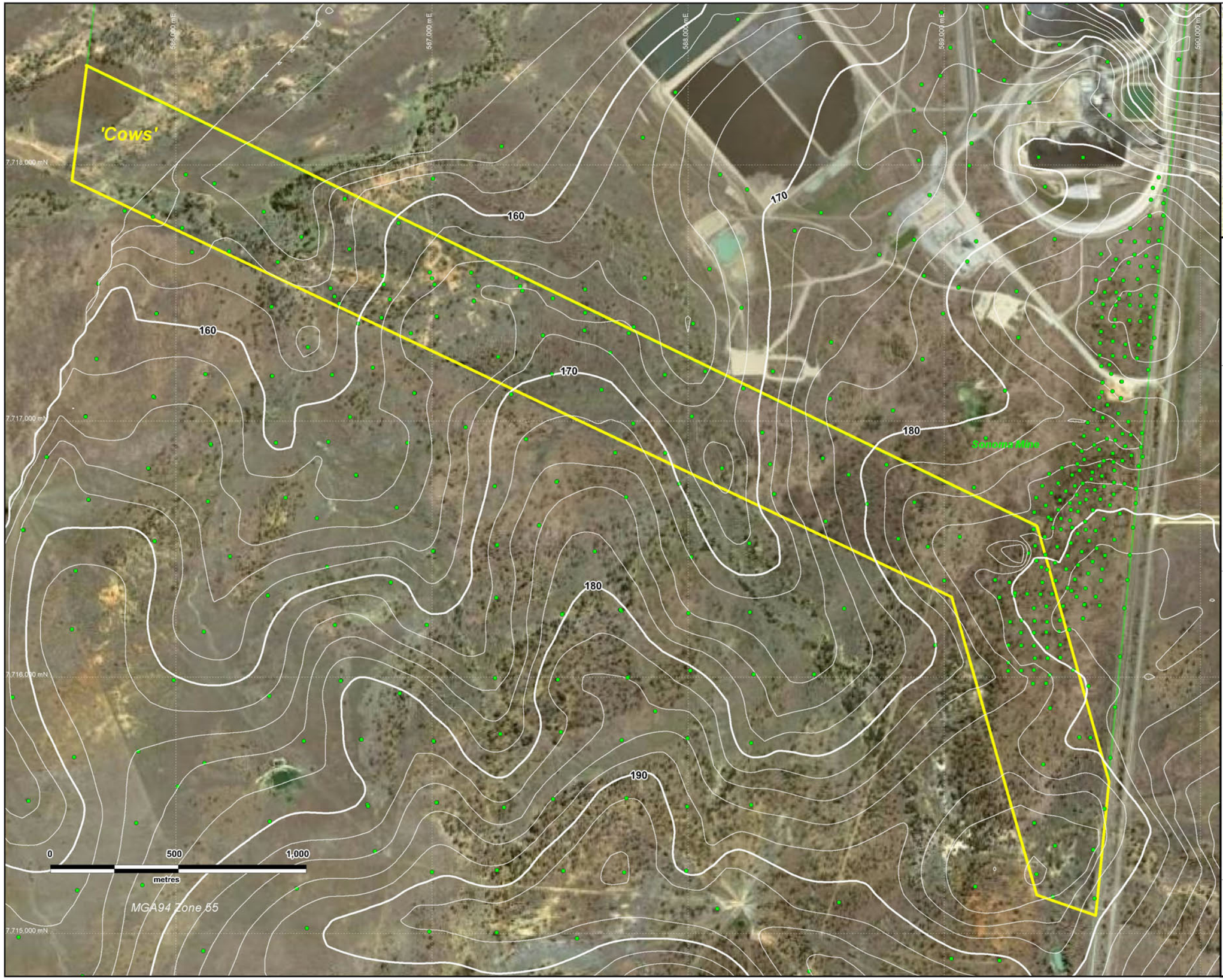
SONOMA • COAL

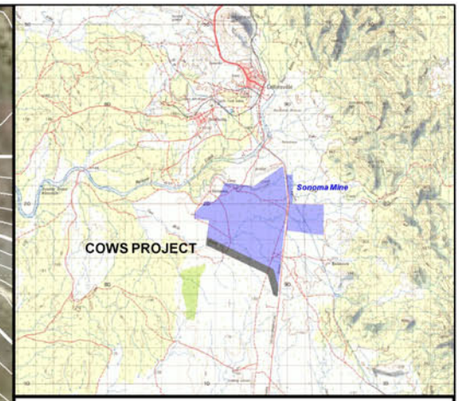
TECSOL

FIGURE 6

Groundwater Monitoring Locations

Data Source: Google Earth





COWS PROJECT

BASE OF QUATERNARY mRL

(2m contours)

LEGEND

- Data point (drillhole)
- 40 Base contour (mRL)
- MLA boundary
- Sonoma ML boundary

Energy Minerals Pty Ltd

Figure 7

Apr 2011

4.4 Recharge

In the Cows project area recharge to the alluvium is expected to occur directly through the base of Two Mile Creek and its tributaries and to a lesser extent through deep drainage through overlying soils. Experience across the Bowen Basin suggests that recharge through the black clay soils is negligible as the permeability is greatly reduced when the clays swell after rainfall.

Recharge to the coal seam aquifers is expected to occur via drainage from the alluvial aquifer and also directly through the bed of major creeks. Given the low permeability of the coal seams and interburden it is expected that vertical recharge will be negligible with the dominant recharge mechanism being direct recharge to sub-cropping seams in creek beds.

4.5 Groundwater Quality

The results of laboratory analysis undertaken during the Sonoma Coal Project EIS (AGE 2005) and other local coal projects (Geoaxiom 2010) indicate that the groundwater and surface waters have a neutral pH and the groundwater found in alluvial aquifers was relatively fresh. Analysis of water from coal seam monitoring bores to the south of Cows shows this groundwater is unsuitable for domestic or irrigation use due to the high chloride and sodium levels. EC and pH data are given for monitoring bore to the north of Cows in Table 3 above.

The concentration of nutrients are reported as being relatively low in both groundwater and surface water samples as were the concentrations of metals. In general groundwater, particularly where available from the alluvial aquifer, is suitable for stock use.

5.0 Potential Groundwater Impacts

5.1 Mining Phase Impacts

The standing groundwater level across the area varies from 150mAHD in the south to 170mAHD in the east and 154-158mAHD north of Cows. The proposed pit floors of both Cows pits will be below this standing water level. During the mining phase, dewatering of these open pits will be required, however, due to the low permeability of the coal seam aquifers and base on experience form the Sonoma Mine to the north there will be requirement for active pit dewatering.

The reduction of groundwater levels caused by pit dewatering is not expected to have significant impact as there are no bores in the area known to be extracting groundwater from the coal seam aquifers.

The effect of pit dewatering on the alluvial aquifer is expected to be minor given that the basal gravels in the alluvium are not saturated throughout the area (AGE 2005). Although there is insufficient data to determine a cone of depression in the alluvial aquifer, the discontinuous nature of the gravel and sand lenses (Geoaxiom 2010) suggests impacts will be limited to the pit area. Given this expected limited zone of influence and the

significant distance to known users of alluvial bore water (>1.5km) there are expected to be no impacts on alluvial groundwater users.

5.1.1 Groundwater quality

An assessment of the acid forming potential of the waste rock has been undertaken for the Cows project and is reported elsewhere. This study confirms that the coal measures are freshwater sequences and have a low potential to produce acid rock drainage. The alluvial aquifer is considered to have a low vulnerability to contamination from mining operations due to the protective cover of black clay soil throughout much of the area. Where the surface clays are removed the alluvial aquifer will have little protection from potential surface contaminants.

5.2 Post Mining Impacts

Upon cessation of mining groundwater inflow will continue into the pit until a point of equilibrium is reached with the potential development of a pit lake. It is expected that the majority of this inflow will be derived from the alluvial aquifer and surface runoff. Given that average evaporation exceeds rainfall in this region it is expected that the two pit lakes will provide a permanent cone of depression in the surrounding aquifers.

5.2.1 Groundwater Quality

A study of final void water quality has not been undertaken. Given that the majority of inflow is expected to be derived from the alluvial aquifer and surface runoff it is anticipated that the resultant pit water quality will be slightly brackish and may still be suitable for limited stock use. Given the pit lake will be a provide a permanent cone of depression there is very little likelihood of contamination of surrounding aquifers from pit lake water.

6.0 Summary and Conclusions

Two aquifers were identified in the Cows Project Area; a shallow and unconfined alluvial aquifer and a deeper multi-coal seam confined aquifer. Drilling data suggests subtle palaeo-topography in the Permian surface resulting in variations in the saturation and groundwater flow directions within the alluvial aquifer. The coal measures at the site form a poor and low yielding aquifer system.

Overall groundwater found within the area is not potable and groundwater from the coal seams has limited stock use due to salinity. Groundwater levels vary with topography (alluvium) and with the regional dip of the coal seams which is consistent with the current geological understanding of the area.

Groundwater is limited within the alluvium despite localised recharge from Two Mile Creek and its tributaries. The coal seam aquifers are “tight” with low permeability and with no significant groundwater flows reported during exploration drilling.

Mining will dewater the alluvial aquifer and partially dewater the coal seam aquifers in the area of the proposed pits however the zone of influence will be limited. There is no known use of groundwater within the expected zone of influence of the mining operation.

The extent of dewatering of the coal seam aquifers is expected to be limited by faulting which interrupts the continuity of the aquifers and is expected to limit the extent of drawdown. When mining operations cease groundwater levels are not expected to recover fully and the mine pit lakes which will develop will become the focal points of permanent cones of depression in the surrounding aquifers. Quasi-equilibrium will be reached where inflows, predominantly from the alluvial aquifer and surface runoff, will balance the high regional evaporation. Pit water quality will be brackish but may be suitable for limited stock use.

7.0 Recommendations

Although the long term impact of the Cows project will be negligible on the local aquifer systems it is prudent to establish baseline and ongoing monitoring to supplement that currently undertaken for the Sonoma Mine to the north. It is likely that this will be a regulatory requirement as part of the site environmental authority. To this end it is recommended that the following be undertaken:

- Installation of two monitoring bores (50mm PVC) in the alluvial aquifer targeting deeper sections of the alluvium in the central and western areas of the lease prior to any mining development
- Water levels and field water quality parameters should be collected on a quarterly basis for, at least, the life of the mine.
- Conversion of at least two exploration holes or new holes for the installation of vibrating wire piezometer sensor installations into the coal seams to monitor piezometric heads. One hole in the west should target the various B seam splits with 2 – 3 sensors in the hole while the eastern hole should target, at least, the Q seam.
- Each coal seam hole will be fitted with an appropriate data-logger and monitored or at least the life of the mine.
- Monitoring of groundwater quality in the alluvial aquifer should be undertaken on an annual basis with samples analysed for pH, EC and major cations/anions. It is not anticipated that water quality in the coal seam aquifers will be adversely affected by the project thus negating the need to install dedicated bores for water sampling purposes.

Sonoma Mine Management Pty Ltd

Sonoma Coal Mine Flood Study

Two Mile Creek



24 May 2013

M4100_004

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Rev 0	Client Issue	Sean Frazer	Scott Moffett	Andrew Vitale	24/05/2013
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1. INTRODUCTION

Engeny Water Management (Engeny) is assisting Sonoma Mine Management Pty Ltd (SMM) with ongoing surface water management as part of the integrated Sonoma Coal Mine (SCM)/Cows Coal Mine (CCM) project. The project includes the mining of coal from the CCM mining lease and processing and exporting the coal within the existing SCM operations.

Figure 1.1 presents the layout of the SCM and CCM sites.

SMM have identified a need for a better understanding of flooding in the vicinity of proposed mine infrastructure including B pit, Q pit and the Sediment Dam 12/13 development. Engeny has been commissioned to undertake a flood study of the lower reaches of Two Mile Creek and its associated tributaries to identify risk to infrastructure from flooding.

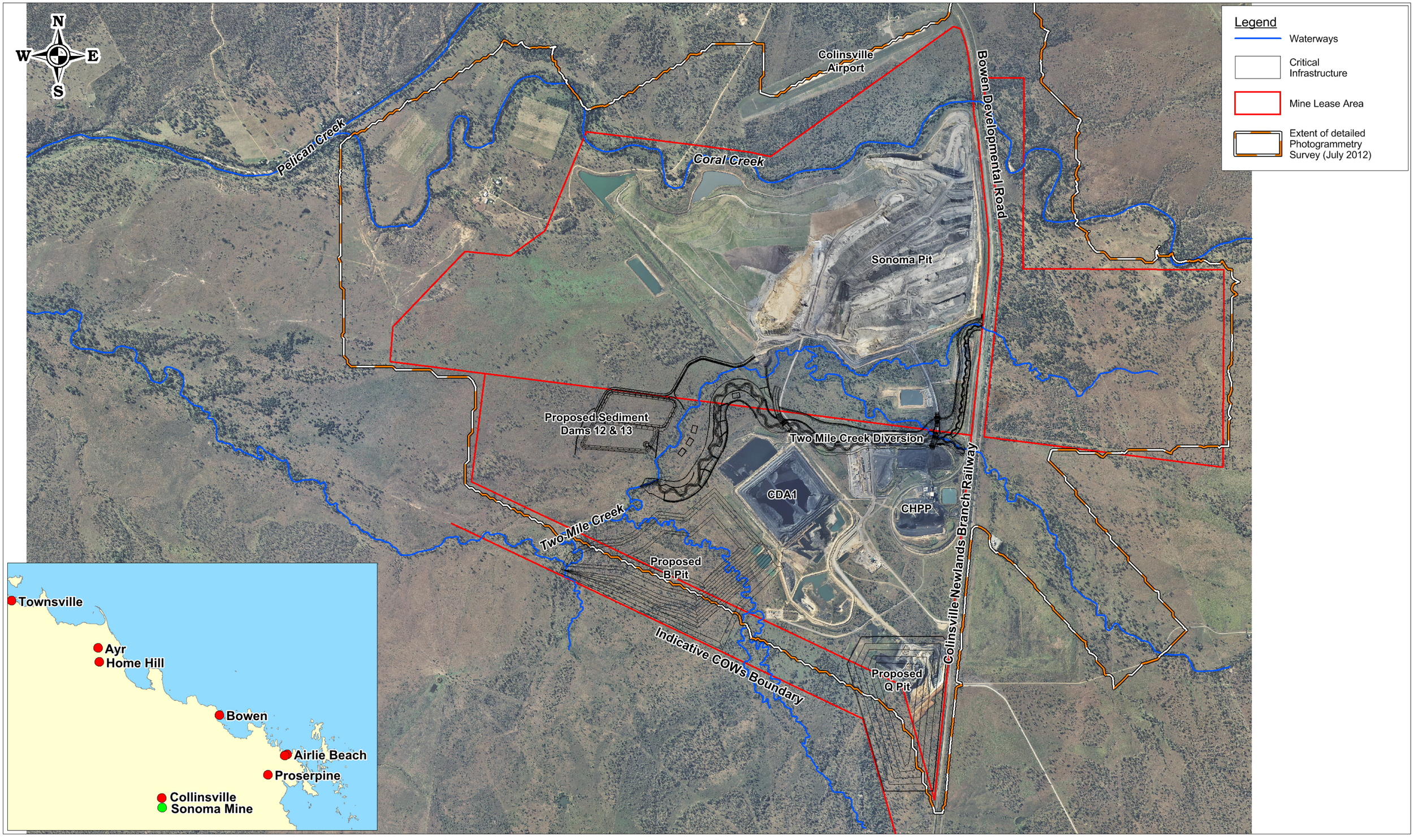
The primary objectives of the flood study are:

- To provide an improved understanding of flooding in the vicinity of proposed mine infrastructure, including B Pit, Q Pit and Sediment Dams 12 & 13;
- To provide an improved understanding of flow behaviour and flood interactions between the Two Mile Creek diversion channel and the pre-existing Two Mile Creek channel;
- Assess flood immunity of critical infrastructure in accordance with the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DEHP 2012)*;
- To provide an assessment of existing flow magnitudes and flood extents associated with the unnamed tributary of Two Mile Creek that passes through the proposed footprint of B Pit; and
- To provide an assessment of flood characteristics including flow velocity for input into design of infrastructure.

The scope of work undertaken to deliver these objectives consisted of:

- Data collection and review including previous one-dimensional hydraulic modelling undertaken for the design of the Two Mile Creek diversion;
- Develop and validate an URBS hydrologic model of the Two Mile Creek system to obtain design flow hydrographs;
- Develop a two-dimensional (2D) TUFLOW hydraulic model of the Two Mile Creek system through the mine site; and

- Undertake model simulations and provide flood mapping results for the 2, 50, 100 and 1,000 year average recurrence interval (ARI) events to estimate flood levels, depths and velocities.



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Sonoma Coal Mine Flood Study

Figure 1.1

Sonoma Mine Layout

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2. STUDY DATA

A range of data sources have been utilised for the purposes of the current study and are documented in the following sections.

2.1 Previous Studies

A previous one-dimensional hydraulic study of Two Mile Creek was undertaken for the *Design of Two Mile Creek Diversion* (BSM 2012). Key components of the study included:

- Hydrologic modelling using URBS and validation against the ACARP guidelines and Rational Method. ACARP was found to give a low flow estimate for larger ARIs; and
- Hydraulic modelling using Extran and HEC-RAS software.

2.2 Topographic Data

A number of topographic data sources were available with variable extents and accuracy. The following table provides a summary of the available data and its use in the study.

Table 2.1 Topographic Data Sources and Accuracy

Description	Source	Vertical Accuracy	Comment
Photogrammetry (Jul 2012)	QCoal	0.1m	Greatest accuracy; Extent limited
Photogrammetry (Feb 2013)	QCoal	0.5-1.0m [1]	Comparison against Jul 2012 indicated consistent shape and typically 1m higher.
Burdekin 25m DEM	DERM	10m [2]	Not used for detailed hydraulic modelling
1m Contours	Geoscience Australia	Unknown	Inconsistent data; not used

1: Metadata unavailable. Vertical accuracy is approximate only as supplied by site.

2: Dependent upon accuracy of source data. Average accuracy of 10m provided for source data.

Delineation of catchments for hydrologic modelling was undertaken using the Burdekin 25 m DEM and site photogrammetric survey data.

In order to develop a digital elevation model (DEM) with sufficient coverage for the hydraulic model extent, several data sources were combined. The following summarises the prioritised development of the DEM adopted for the hydraulic model:

- Design levels were adopted for the Two Mile Creek Diversion as construction commenced after the July 2012 photogrammetry capture;
- Site photogrammetric survey (Jul 2012);
- Adjusted site photogrammetric survey (Feb 2013). Adjustments undertaken were:
  - Elevations lowered by 1m to better match the more accurate site photogrammetry (Jul 2012); and
  - Inconsistent anomalies in south-eastern corner of data removed.

It should be noted that no design surfaces of B pit, Q pit or SD12/13 have been included in the surface DEM. That is, these structures are only graphically represented on mapping.

2.3 Aerial Photography

The latest site aerial photography from July 2012 was used for the study. This was supplemented by aerial photography available through Microsoft Bing where required.

2.4 Design Rainfall Data

Design rainfall data has been sourced in accordance with both *Australian Rainfall and Runoff* (IEAust 1987, 1997), through the Bureau of Meteorology (BoM) online Rainfall IFD Data System, and the Queensland CRCForge project (DNRM 2005). The following rainfalls have been adopted for this study:

- CRCForge rainfalls were approximately 30% larger than the BoM IFD values and have been adopted for all Average Recurrence Intervals (ARI) events greater than 2 years; and
- CRCForge does not provide rainfalls for the 2 year ARI event. BoM IFD values have been adopted for the 2 year ARI.

2.5 Temporal Patterns

The Sonoma Coal Mine is located within Zone 3 for the purpose of design rainfall temporal patterns and this temporal zone has therefore been adopted for design events up to and including the 100 year ARI event.

The design temporal pattern for short duration PMP specified in the *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method* (BoM 2003) has been adopted for the 1,000 year ARI event.

3. HYDROLOGY

The hydrologic assessment undertaken for this study involved the development of an URBS hydrologic model for the Two Mile Creek catchment and validation against a range of methodologies. Design inflow hydrographs were then derived from the validated URBS model.

3.1 Model Development

Catchment delineation of the Two Mile Creek system was undertaken to a point approximately 3.5 km downstream of the Two Mile Creek diversion. Both photogrammetry data sets and the Burdekin 25 m DEM (refer Section 2.2) were used for the delineation.

The resulting catchment has a total area of approximately 49.7 km^2, which was divided into 33 sub-catchments. The layout of the hydrology model is presented in Figure 3.1.

The Basic Model of URBS was utilised and initial model parameters were adopted in accordance with those reported for the *Design of Two Mile Creek Diversion* (BSM 2012).

3.2 Validation

Model results were validated against a range of methodologies. The validation was undertaken at a point along the Two Mile Creek Diversion downstream of the junction of the north and south branches of the diversion. This location was consistent with that adopted by BSM (2012) and represents the largest contributing catchment to flow through the mine site. The catchment area to the validation point is approximately 27.8 km^2.

The following methodologies were utilised to assess the hydrology of Two Mile Creek:

- A flood frequency analysis was undertaken for 40 water years of combined data at two DERM stream flow stations on Pelican Creek (120220A & 120206A) and scaled by catchment area to estimate peak flows at the validation point;
- The Australian Coal Association Research Program (ACARP) flood estimation method documented in *Bowen Basin River Diversions: Design and Rehabilitation Criteria* (ACARP 2002);
- *Regional Flood Fequency for Queensland using the Quantile Regression Technique* (TMR, n.d.) developed by the Department of Transport and Main Roads;
- Rational method calculations; and
- The documented results of the BSM URBS model (2012).

URBS parameters were initially adopted as per those reported by BSM (2012) and adjusted to improve the validation. The final parameters are summarised in Table 3.1.

Table 3.1 Adopted URBS Parameters

URBS Parameter	Adopted Value
Alpha (α)	1.4
Initial Loss (mm)	0 - 30 (Q100 – Q2)
Continuing Loss (mm/hr)	3.0

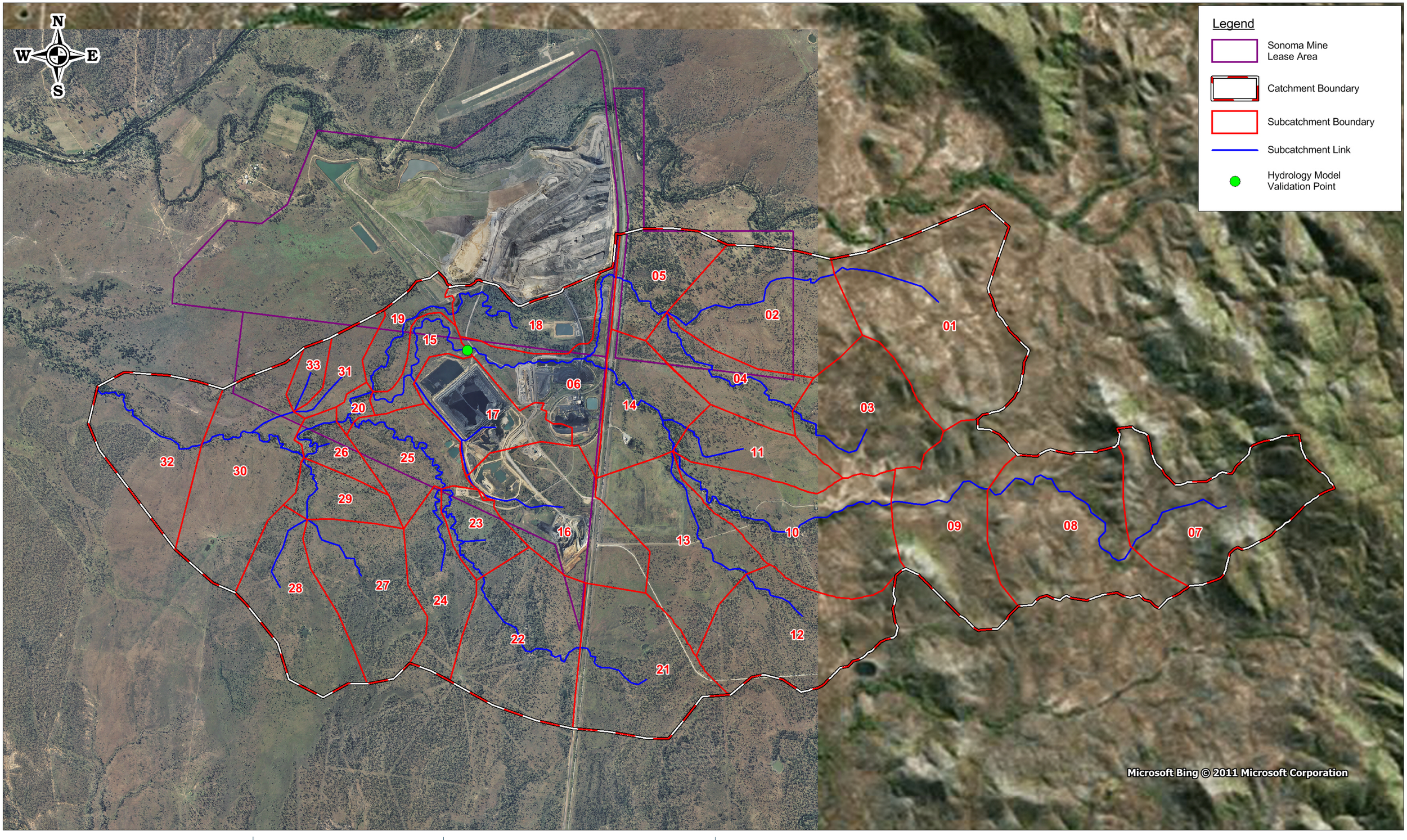
The results of the hydrology validation are presented in Table 3.2. The key findings of the validation are:

- ACARP values consistently underestimate flows for larger ARIs. This is consistent with the BSM findings and Engeny's previous experience;
- Flows from the BSM URBS model are consistently larger than all other methodologies;
- The Engeny URBS model compares well to the range of validation methodologies, particularly the Quantile Regression Technique (QRT) and the scaled flood frequency.

The adopted parameters are considered to provide a good validation for the range of design events.

Table 3.2 Hydrology Validation

Average Recurrence Interval (ARI)	Scaled Flood Frequency	ACARP	QRT	TMR Rational	BSM (Mar 2012) URBS	Engeny URBS - Adopted
100	196	126	267	198	302	252
50	179	100	209	162	252	199
20	150	72	142	123	193	152
10	123	52	96	94	144	115
5	N/A	75	61	83	103	87
2	N/A	31	21	51	38	25



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Figure 3.1

Hyrdrology Model Layout

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4. HYDRAULICS

A two-dimensional (2D) TUFLOW hydraulic model has been developed for the SCM. TUFLOW is an industry accepted software package that is highly suited to the investigation of flood behaviour in complex flow scenarios. It is particularly suited to simulation of complex interaction between waterway systems that occurs in flat floodplain areas, such as is evident in the vicinity of the Sonoma Coal Mine.

It is noted that flood behaviour predicted by the TUFLOW hydraulic model is inherently reliant on the underlying baseline data used in its development. As such, the flood levels provided in this report, and in any digital data provided, rely upon the accuracy of the baseline topographic data provided for use as part of this investigation. A detailed summary of the available topographic data and adopted design DEM is presented in Section 2.2.

4.1 Model Development

The extent of the hydraulic model is from the lower half of the Two Mile Creek Diversion in the north to approximately 3.5 km downstream of the diversion. The model extent also includes the unnamed tributaries that enter Two Mile Creek from the south-east in order to simulate flood behaviour in the area identified for future mine development.

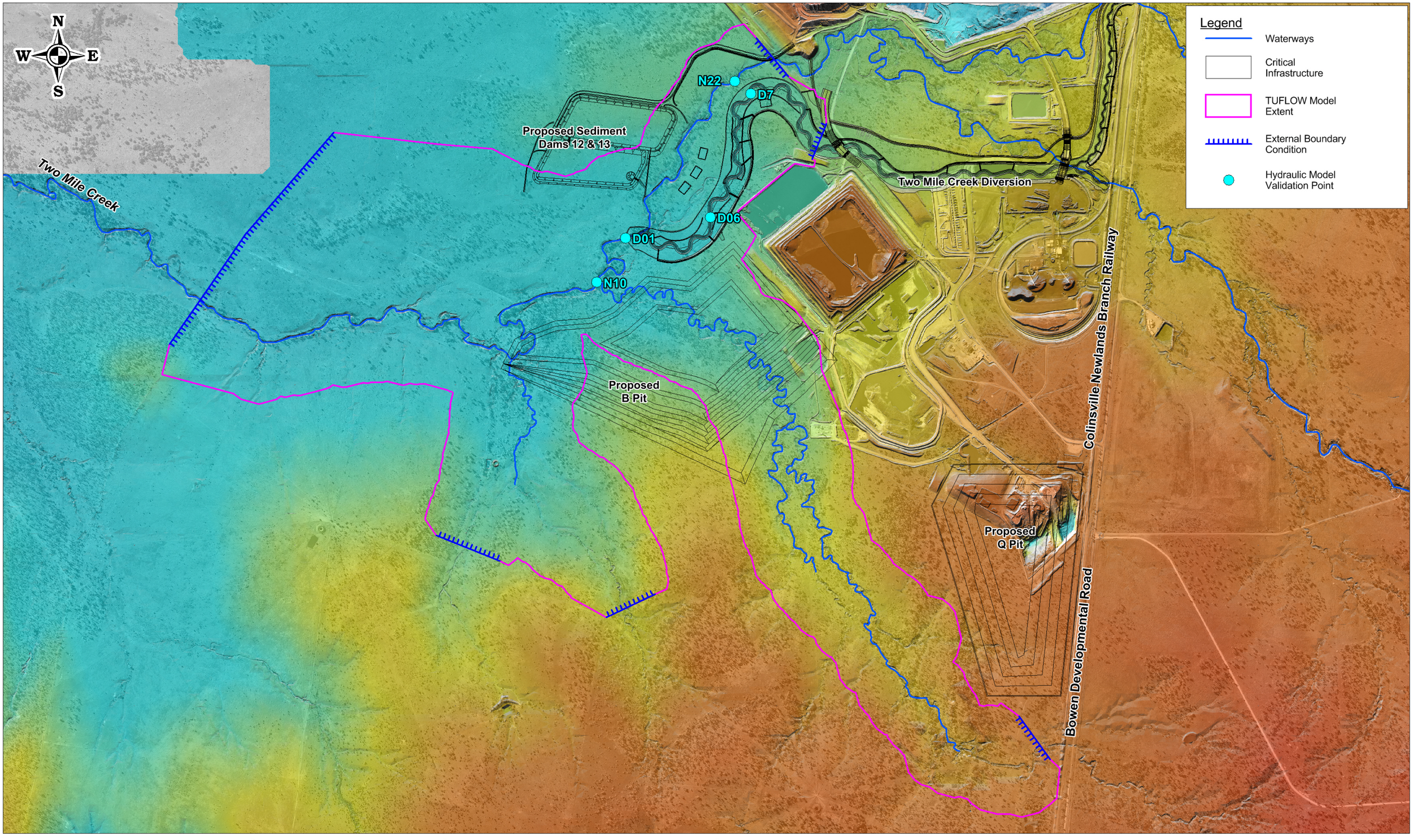
The model development includes:

- Inflow hydrographs determined using the URBS hydrologic model (refer Section 3);
- A normal depth downstream boundary based on representative waterway slopes. The boundary has been positioned far enough downstream to avoid boundary impacts on model results in the area of interest;
- A 4 m cell size has been adopted for the model and is considered to provide a good balance between the required resolution and the resulting model simulation times; and
- Areas of different roughness characteristics were delineated based upon available aerial photography of the site (refer Section 2.3) and representative Manning's 'n' roughness values were applied as summarised in Table 4.1.

The hydraulic model layout is presented in Figure 4.1.

Table 4.1 Adopted Manning's 'n' Roughness Coefficients

Material Description	Manning's 'n' Roughness Coefficient
0.030	Water body (minimal vegetation)
0.045	Minimal trees / Long grass
0.060	Regular trees / Long grass
0.090	Dense trees / Long grass
0.025	Road / Paved Area
0.500	Buildings / Obstructions
0.045	Two Mile Creek Diversion Low-Flow Channel
0.055	Two Mile Creek Diversion Overbank



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Figure 4.1

Hyrdaulic Model Layout

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4.2 Model Results and Validation

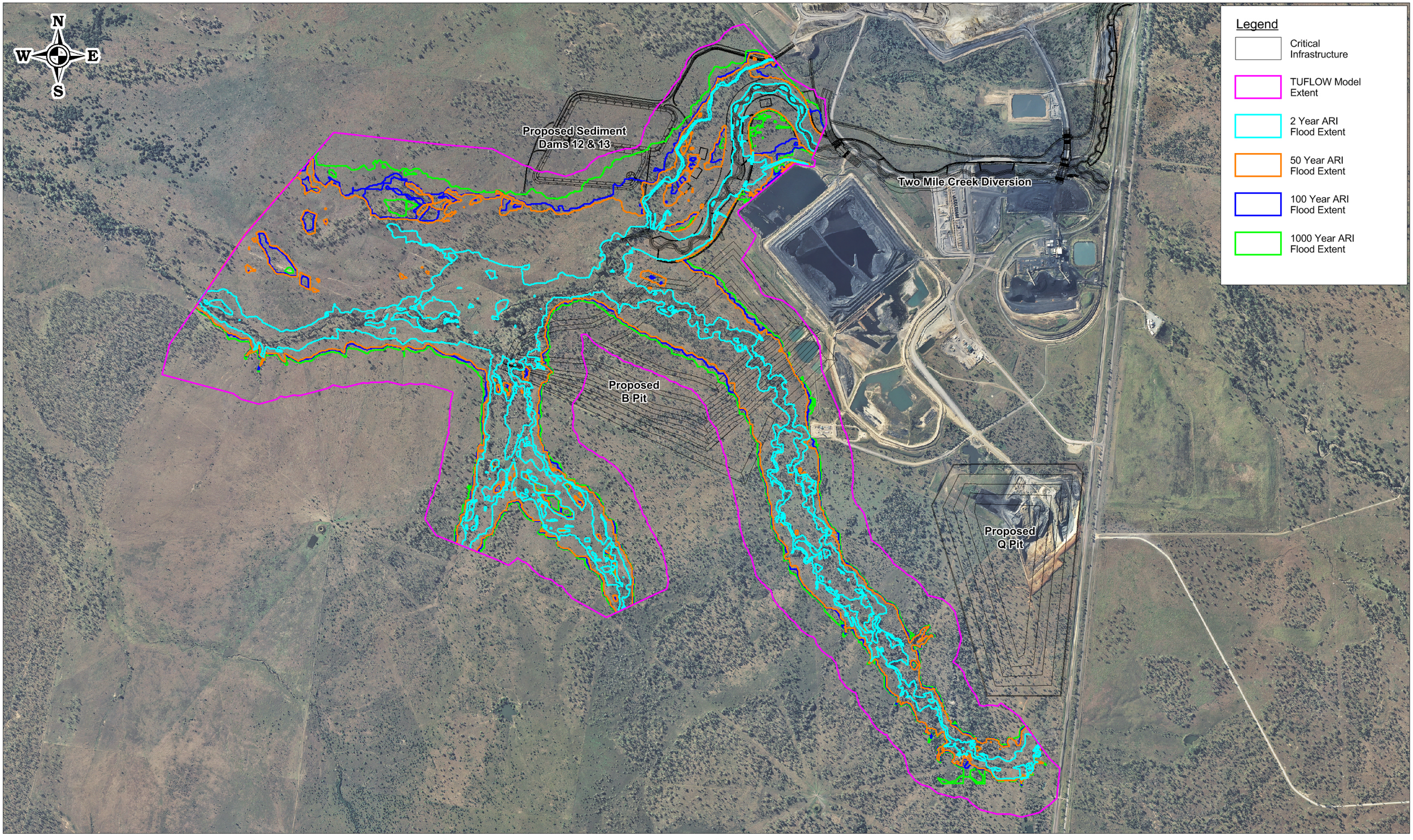
The hydraulic model was simulated for the 2, 50, 100 and 1,000 year ARI events. The model results have been validated against those reported in the *Design of Two Mile Creek Diversion* (BSM 2012) at a number of key locations. A summary of the validation results is provided in Table 4.2. The location of the validation points is presented in Figure 4.1.

The results of the two studies compare well and are generally within 300 mm. The largest discrepancy occurs at Node N22 in the pre-existing channel of Two Mile Creek upstream of the diversion. This location compares well for the larger events but is significantly different for the 2 year ARI. This was found to be the result of variation in the adopted flows. The BSM peak flow of less than 0.1 m^3/s seems unreasonably low compared to the 2.2 m^3/s for the current study. Refer to Section 3.2 for the validation of design inflows.

Table 4.2 Hydraulic Model Validation

BSM Extran Node ID	Peak Flood Level (m AHD) - BSM (Mar 2012) Ultimate			Peak Flood Level (m AHD) - Engeny TUFLOW			Peak Flood Level Difference (m)		
	2 year ARI	50 year ARI	100 Year ARI	2 year ARI	50 year ARI	100 Year ARI	2 year ARI	50 year ARI	100 Year ARI
D01	160.03	161.21	161.30	160.38	161.19	161.30	0.35	-0.02	0.00
D06	161.22	162.05	162.11	161.21	162.21	162.29	-0.01	0.16	0.18
D7	163.74	164.59	164.70	163.66	164.74	164.87	-0.08	0.15	0.17
N10	159.36	160.83	160.96	159.56	160.55	160.66	0.20	-0.28	-0.30
N22	161.62	164.58	164.69	163.01	164.29	164.51	1.39	-0.29	-0.18

Flood mapping results have been prepared for the range of design events simulated and are presented in Figure 4.2 to Figure 4.6. A discussion of flood behaviour and flood impacts on critical mine infrastructure is presented in Section 5.



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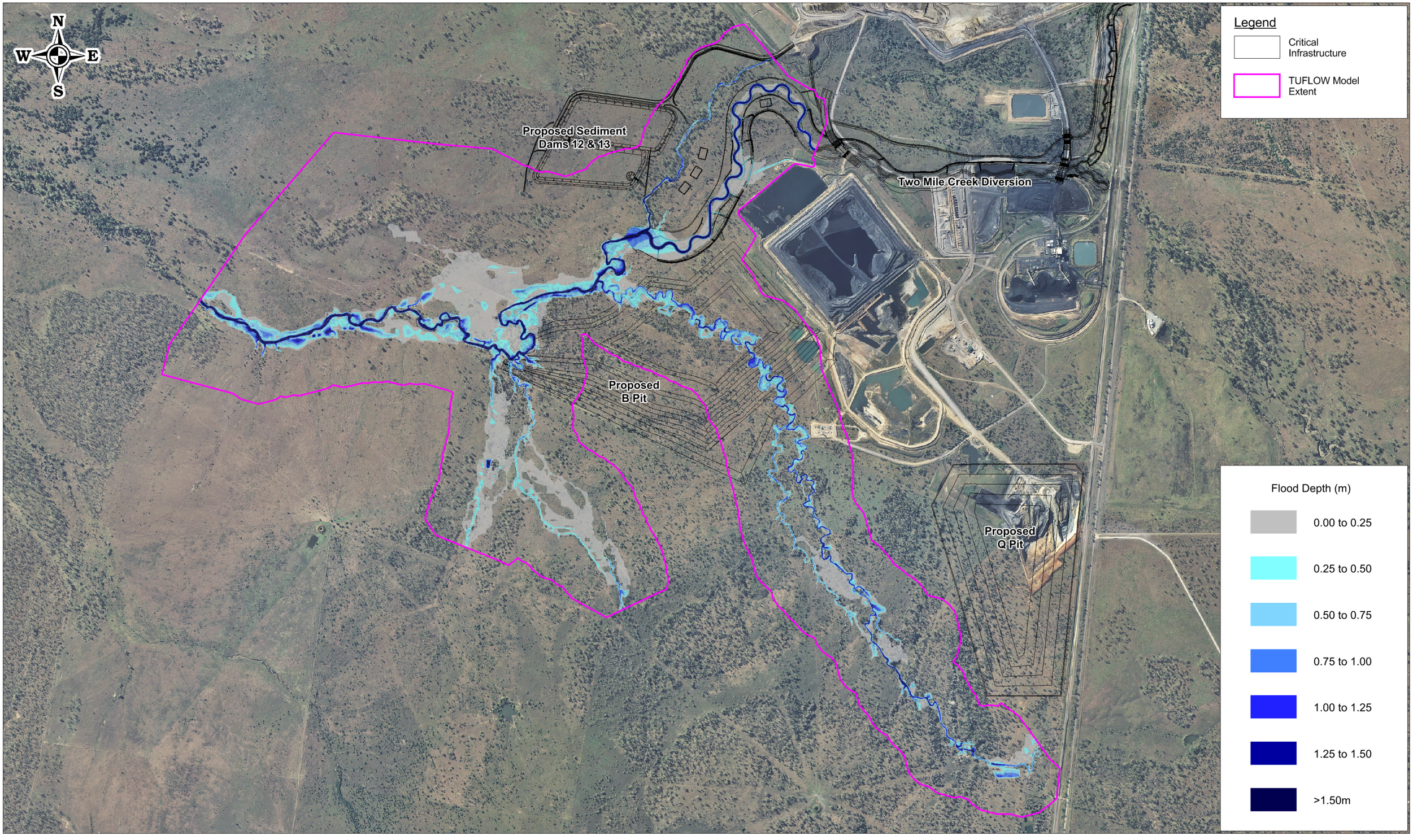
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Figure 4.2

Modelled Flood Extents

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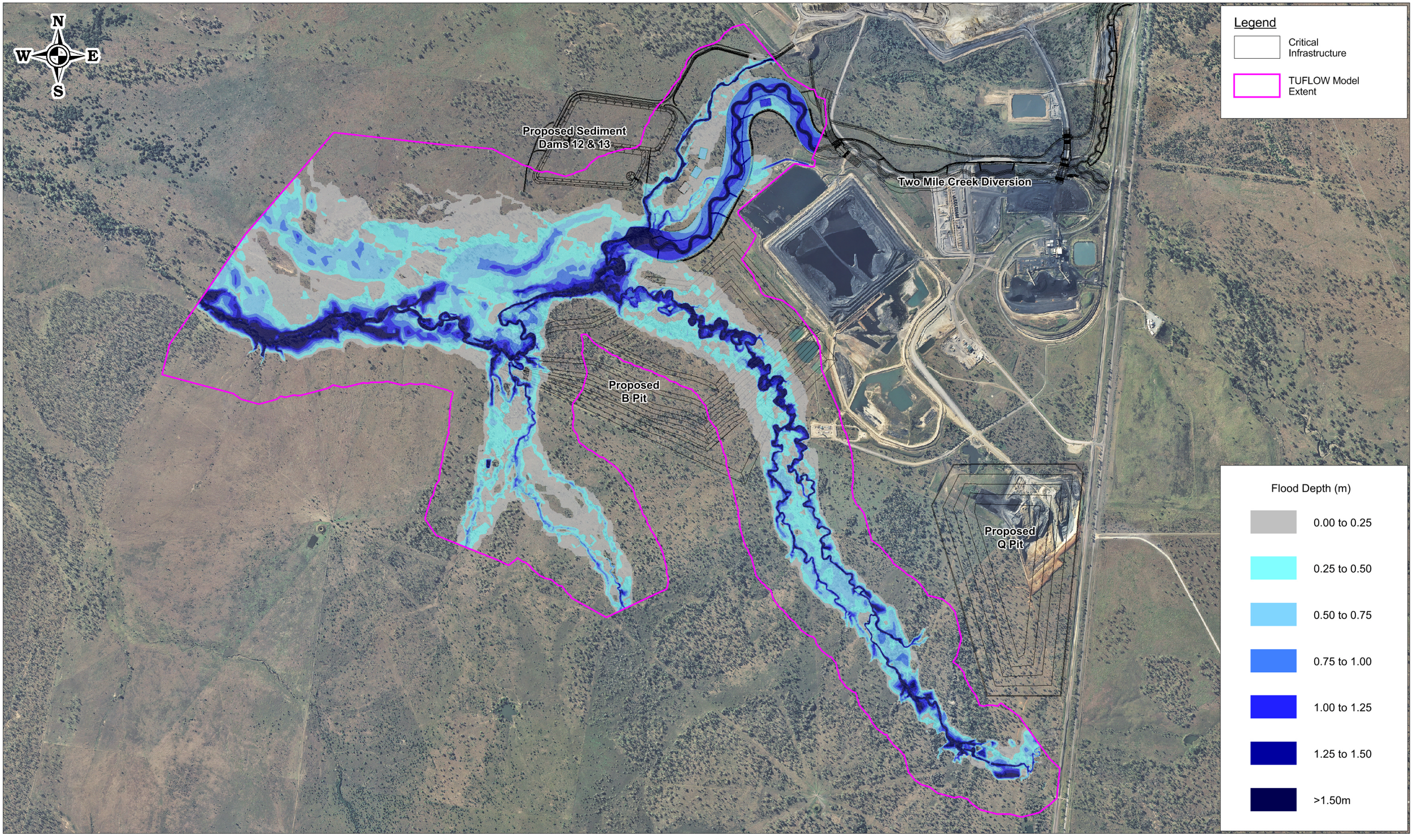
Sonoma Coal Mine Flood Study

2 Year ARI Peak Flood Depth

Figure 4.3

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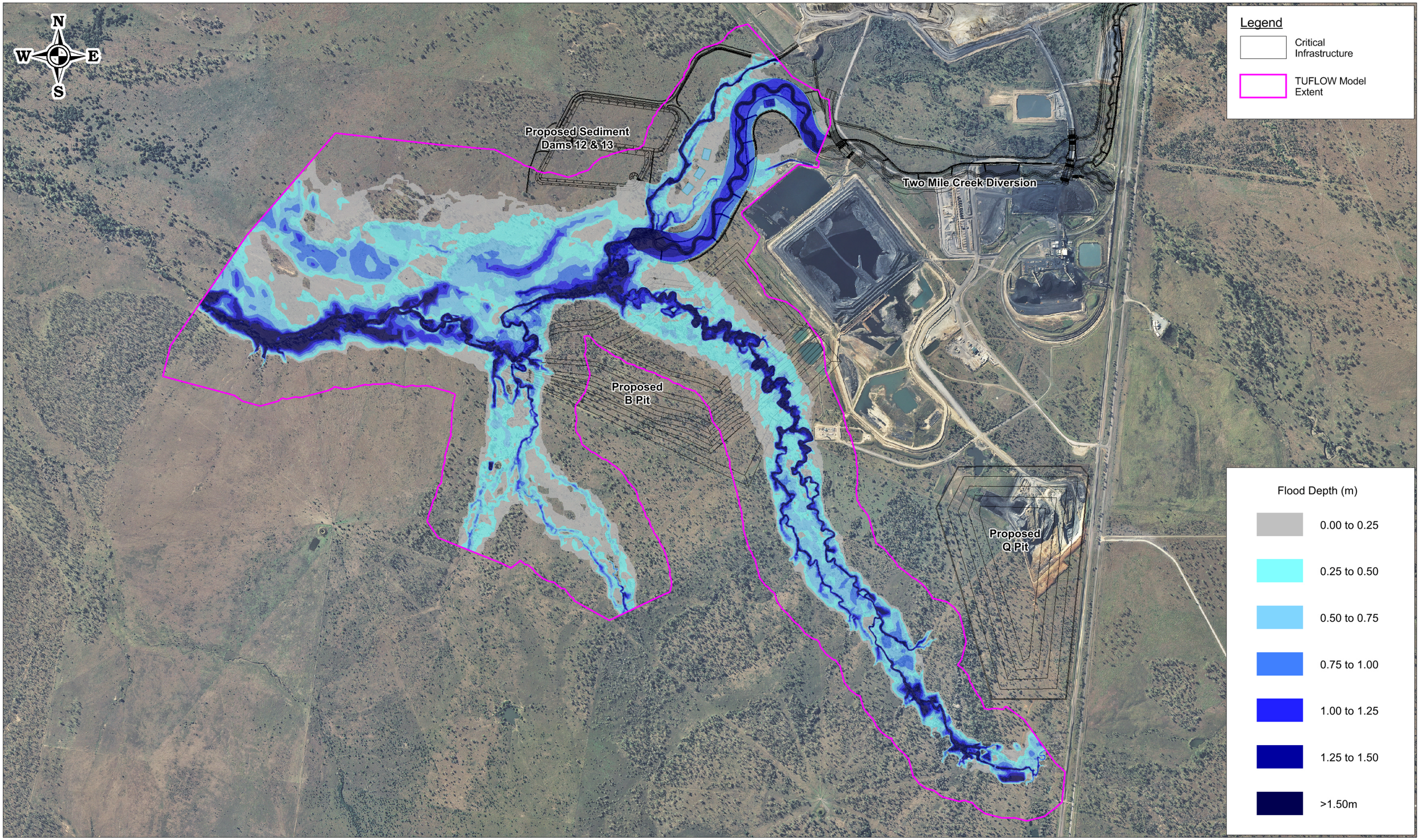
Sonoma Coal Mine Flood Study

50 Year ARI Peak Flood Depth

Figure 4.4

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Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

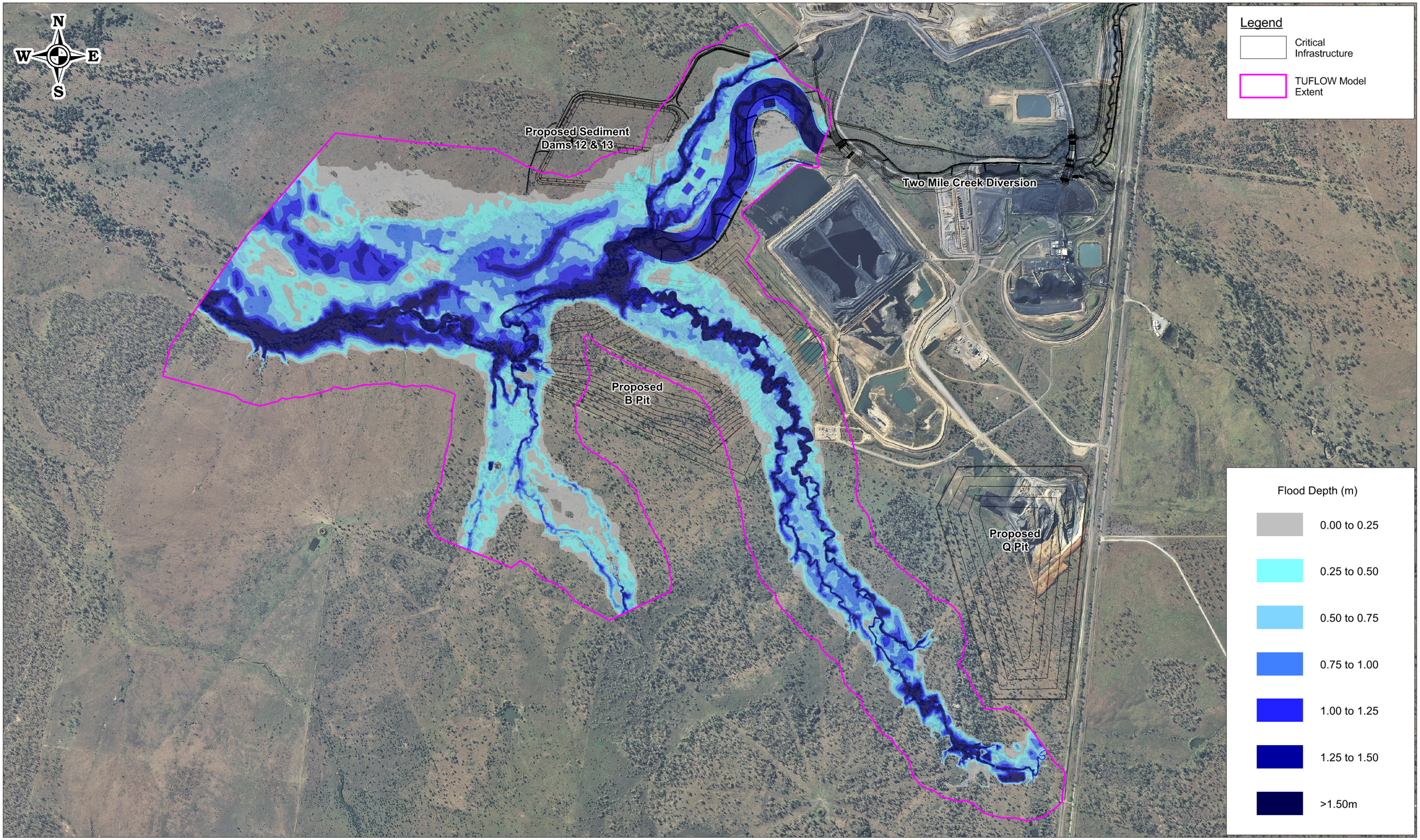
Sonoma Coal Mine Flood Study

100 Year ARI Peak Flood Depth

Figure 4.5

Job Number: M4100_004
Revision: 0
Drawn: JNA
Date: 21 May 2013

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0 400 800

Scale in Meters (1:20,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Australian Geodetic Datum 1984. (AGD84)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Sonoma Coal Mine Flood Study

Figure 4.6

1000 Year ARI Peak Flood Depth

Job Number: M4100_004
Revision: 0
Drawn: JNA
Date: 21 May 2013

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5. DISCUSSION AND RECOMMENDATIONS

The following key flood impacts have been identified from the results of the SCM Flood Study:

- The flood extent for the 2 year ARI event is generally confined to the waterway channels with some shallow floodplain inundation on the right bank of Two Mile Creek to the west of B Pit. Larger events cause significant inundation of the floodplain, particularly in the lower reaches of the waterway system;

- Flood extents for the 50, 100 and 1,000 year ARI events are very similar in the more well-defined upper reaches with greater variation in the lower reaches;

- Q Pit is shown to be outside the flood extent for all design events simulated. The south-western edge of the pit is approximately 3 m above the 1,000 year ARI flood level in the nearby un-named creek;

- The proposed footprint of B Pit extends over two un-named tributaries of Two Mile Creek. The 1,000 year ARI flood extent of the eastern tributary is approximately 400-500 m wide through B Pit while the western tributary inundates approximately 300 m of the eastern corner of B Pit. This eastern corner also extends over the main channel of Two Mile Creek, which is generally within 200 m the eastern edge of the B Pit footprint. It is noted that B Pit may be impacted by flooding from each of these tributaries as well as from flows in Two Mile Creek;

- Existing infrastructure on the right bank of the eastern tributary in the vicinity of B Pit is shown to be immune from flood inundation up to the 1,000 year ARI. The flood extent does reach the toe of some bunds in this area;

- The northern extent of the model is a complex landform area including the pre-existing Two Mile Creek channel, the Two Mile Creek Diversion, the existing Return Water Dam and the proposed Sediment Dams 12 and 13. The following has been observed from the model results in this area:

    - Break-out flow and interaction between the Two Mile Creek Diversion and the pre-existing Two Mile Creek channel occurs from the 50 year ARI event;
    - The 100 year ARI event begins to short-circuit the northern bend of the diversion by breaking out onto the left bank approximately 70 m from the inflow boundary;
    - The 50 year ARI event indicates some inundation against the embankment of the Return Water Dam embankment. This increases in the 100 and 1,000 year ARI events and is due to both tailwater in the diversion and flow from the spillway;
    - The proposed Sediment Dam 12 and 13 are outside of the 2 and 50 year ARI flood extents. The 100 year ARI event inundates the southern corner of one of the proposed storage footprints while the 1,000 year ARI event inundates a larger plan area of both proposed storages;

- The south-western corner of the sediment dams is not shown to be inundated by regional flooding in Two Mile Creek for the design events simulated.

Engeny recommends the following to minimise and manage flood impacts on site:

- Refer to the flood study results (flood level and velocity) when designing proposed dam infrastructure to prevent flood ingress in accordance with the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DEHP 2012)* and provide adequate protection against erosion and scour along the dam embankments and spillway channels;
- Assess the adequacy of the Return Water Dam spillway to pass the required design flow taking account of tailwater impacts resulting from the Two Mile Creek Diversion;
- Assess the suitability of the erosion and scour protection of the Return Water Dam embankment where shown to be inundated;
- Assess options for the diversion of the two un-named tributaries of Two Mile Creek around the proposed B Pit footprint;
- Assess the flood levees required to prevent inundation of B Pit from the two tributaries and Two Mile Creek;
- Assess the cost-benefit of allowing the western corner of the B Pit footprint to extend over Two Mile Creek as it is noted that this would require a Water License as per the existing Two Mile Creek Diversion; and
- Continue to update the current flood study and possibly increase the model extents as required to provide an ongoing flood assessment tool for the SCM.

6. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Management Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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QCOAL GROUP

QCoal Northern Hub

Mine Waste Management Plan



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1 Introduction

QCoal Pty Ltd (QCoal) manages four adjacent open cut coal mines located approximately 6km south of the town of Collinsville in central Queensland. The four mines are the Sonoma Coal Mine (SCM), Cows Coal Mine (CCM), Drake Coal Mine (DCM) and Jax Coal Mine (JCM), and pits, dumps, roads and water management infrastructure span the boundaries of the various mining leases (MLs). Each mine has its own environmental authority (EA); however, as with physical infrastructure, the operational and environmental management (and resources) are integrated across the four mines.

Accordingly, these four mines are collectively managed and operated as a single multiple-pit operation, which is referred to as the QCoal Northern Hub (QNH).

1.1 Background

The QNH is located approximately 6 km south of the town of Collinsville, and 78 km southwest of the regional centre of Bowen (see **Figure 1**). The four QNH mines are directly adjacent to one another on the western side of Bowen Development Road and the parallel Newlands rail line, apart from JCM, which is on the eastern side.

The QNH sites each have separate ownership makeups as follows:

- SCM is a joint venture between QCoal Sonoma Pty Ltd, JS Sonoma Pty Ltd, CSC Sonoma Pty Ltd and Watami (Qld) Pty Ltd.
- DCM is a joint venture between Northern Hub (Drake) Pty Ltd and Drake Coal Pty Ltd.
- CCM is owned by Bowen River Coal Pty Ltd.
- JCM is owned by Jax Coal Pty Ltd.

QCoal Sonoma Pty Ltd, Northern Hub (Drake) Pty Ltd, Drake Coal Pty Ltd, Bowen River Coal Pty Ltd and Jax Coal Pty Ltd, are wholly or majority owned subsidiaries of QCoal Pty Ltd.

The QNH is run by a standard industry model of contract mining, with contractors providing most of the mining workforce and plant.

Mining operations on the QNH comprise multi-pit extraction of waste rock and Run-of-Mine (ROM) coal, subsequent processing, and railing of product coal. Mining methods involve standard drill and blast operations, and conventional excavator and truck movements.

Stripped topsoil is either stockpiled for later use in rehabilitation or placed on areas already shaped and prepped for rehabilitation works. Waste rock materials are placed in either out-of-pit or in-pit dumps.

The QNH mines share water management infrastructure, haul roads, equipment, resources, and other infrastructure. ROM coal from all sites is sent to the Coal Handling and Processing Plant (CHPP) and train load-out facility located on the SCM. Processed coal is transported to Abbott Point Coal Terminal for shipment to customers.

Coal rejects material generated during processing at the CHPP are placed into a co-disposal facility located on the SCM.

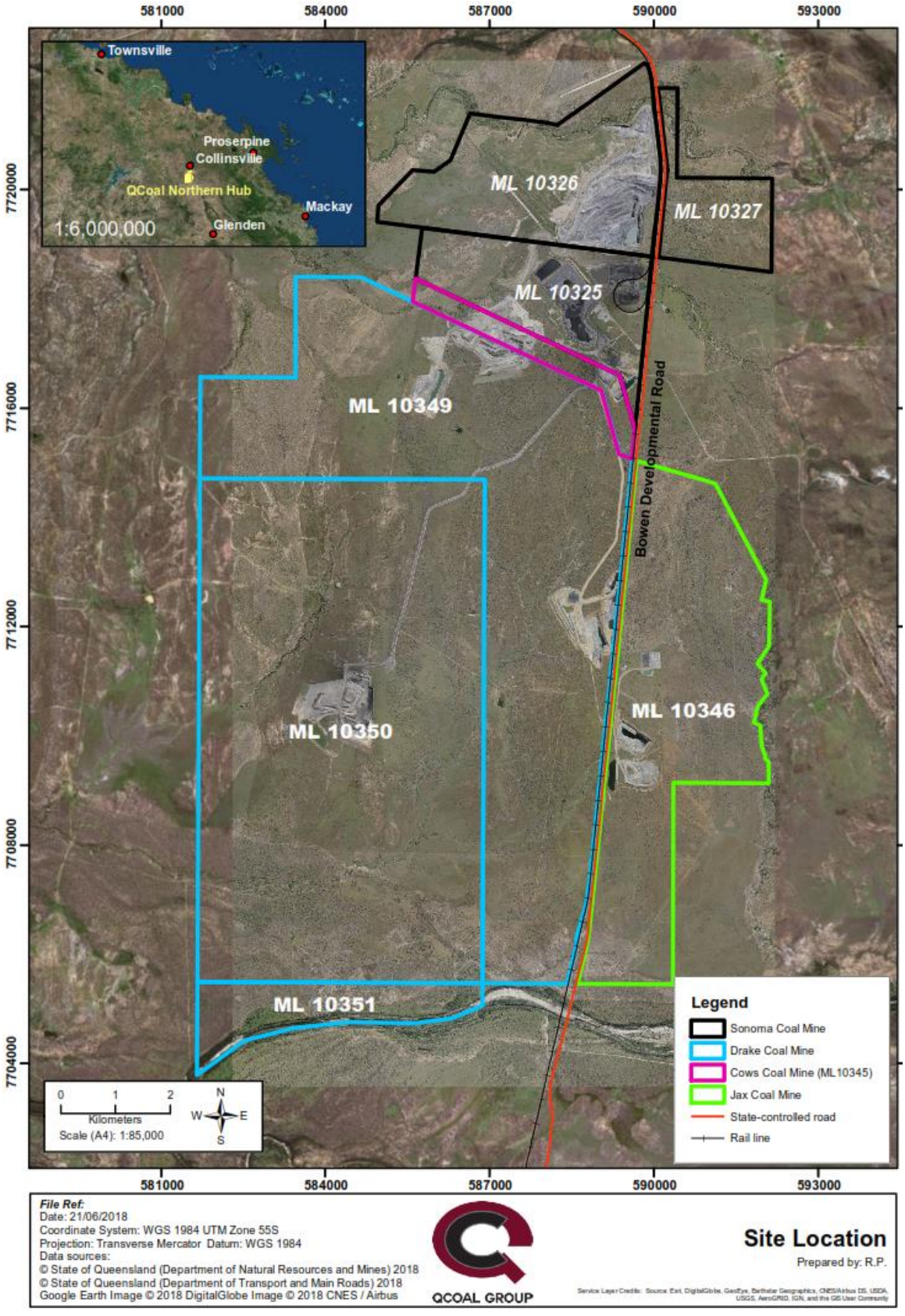


Figure 1 – QCoal Northern Hub Location

1.2 Purpose of this Management Plan

The *QCoal Northern Hub Mine Waste Management Plan* (MWMP) has been prepared to inform the operational management of mining waste at the QNH mines. Rehabilitation of mine waste disposal structures is not addressed in this document, as all QNH rehabilitation is addressed in the current version of the *QCoal Northern Hub Rehabilitation Management Plan*.

1.3 Legislative Requirements

Each QNH mine has an associated EA which it must comply with, as follows:

- SCM – EPML00707713 (dated 6 March 2020);
- CCM – EPML00334613 (dated 3 March 2020);
- DCM – EPML00393013 (dated 9 March 2020); and
- JCM – EPML00337613 (dated 5 June 2020).

Condition H7 is identical between the four QNH EAs, with the exception of H7(h), which relates to the management of tailings and is only present in the SCM and DCM EAs (where processing of coal is authorised). It is noted however that only the SCM actively processes coal and manages tailings. **Table 1** duplicates the conditions of Condition H7 and identifies where they are addressed in this MWMP.

Table 1 – QNH EAs Condition H7

QNH EAs Condition H7	Section of MWMP
Mining Waste Management A waste rock and spoil disposal plan must be developed and include, where relevant, at least:	
a) effective characterisation of the waste rock and spoil to predict under the proposed placement and disposal strategy the quality of runoff and seepage generated concerning potentially environmentally significant effects including salinity, acidity, alkalinity and dissolved metals, metalloids and non-metallic inorganic substances;	**Section 3**
b) a program of progressive sampling and characterisation to identify dispersive and non-dispersive spoil and the salinity, acid and alkali producing potential and metal concentrations of waste rock;	**Section 6**
c) a materials balance and disposal plan demonstrating how potentially acid forming and acid forming waste rock will be selectively placed and/or encapsulated to minimise the potential generation of acid mine drainage;	**Section 4**
d) where relevant, a sampling program to verify encapsulation and/or placement of potentially acid-forming and acid-forming waste rock;	**Section 6**
e) how often the performance of the plan will be assessed;	**Section 8**
f) the indicators or other criteria on which the performance of the plan will be assessed;	**Section 8**
g) rehabilitation strategy; and	**Section 4.7**
h) identification of areas proposed to contain tailings*.	**Section 4.6.2**
Monitoring or rehabilitation, research and/or trials to verify the requirements and methods for decommissioning and final rehabilitation of the placed materials, including the prevention and management of acid mine drainage, erosion minimisation and establishment of vegetation cover.	**Section 6**

* - Condition H7(h) is only present in the Sonoma and Drake EAs.

2 Background

2.1 Mining Waste Definition

As part of the mining process at the QNH, overburden, interburden, sub-economic coaliferous material and ROM coal are excavated. ROM coal is then either washed at the CHPP (located on the SCM), or crushed by a mobile bypass crusher to generate product coal for sale. The overburden, interburden and in some cases sub-economic coaliferous material is referred to as waste rock, which is disposed of in either in-pit or out-of-pit waste rock dumps.

The CHPP washing process generates a waste stream of coal rejects, which primarily comprise material from the coal seam roof, parting and floor, which gets mined along with the ROM coal extraction. Coal rejects are categorised by particle size, with fine rejects <1.4 mm (typically called tailings) and coarse rejects >1.4 mm. Fine rejects are further categorised as Ultra-Fine Rejects when rejects material is smaller than 0.25 mm. At the QNH, all rejects from the SCM CHPP are generally disposed of together in a co-disposal facility, with some minor quantities of coarse reject disposed of in waste rock dumps (in-pit or out-of-pit).

Crushed ROM coal does not generate any mining-related wastes requiring management.

Mine waste, for the purpose of this MWMP, is therefore defined as waste rock (overburden and interburden) and coal rejects (coarse and fine tailings).

2.2 QNH Geology

The QNH is located in the northern Bowen Basin, where active subsidence and deposition during the Permo-Triassic was centred within an extensional terrain known as the Taroom Trough. This deposition centre was situated marginal to the Collinsville Shelf in the west, which typically behaved as a stable platform throughout. The deformed Taroom Trough of the northern Bowen Basin is defined by the Nebo Synclinorium, where contained sediments and volcanics of the western two-thirds dip gently toward the major synclinal axis in the east. Post-depositional compression has resulted in a fold-and-thrust style of deformation, particularly on the eastern side of the basin where sediments along this margin tend to dip steeply west.

The QNH is underlain by the late Permian Blackwater Group consisting of lithic sandstone, siltstone, shale, conglomerate, dolomite and tuff, and minor coal. This is surrounded and underlain by the low to upper Permian Blenheim Subgroup described as a succession of siltstone, sandstone, conquite and limestone (i.e. the Blackwater Group is an outlier surrounded by the Blenheim Subgroups). The Collinsville Coal Measures underlie the Blenheim Group.

Regionally, the statigraphic sequence is summarised as follows: the Permo-Triassic sediments of the Bowen Basin are overlain by a veneer of unconsolidated Quaternary alluvium and colluvium, poorly consolidated Tertiary sediments and, in places, remnants of Tertiary basalt flows. The stratigraphy comprises basal Lizzie Creek Volcanics and overlying marine Back Creek Group, non-marine Blackwater Group, and Tertiary sediments of the Suttor Formation.

Geological detail in the QNH area is intermittently obscured by a cover of alluvium and gravel, especially adjacent to creeks and watercourses. This recent (Cainozoic) cover comprises unconsolidated fine to very coarse-grained sand, along with occasional irregularly interbedded silt, clay and gravel lenses. The most persistent gravel bed occurs at the base of the unit and generally comprises markedly rounded pebble to cobble-sized clasts of predominantly andesitic to basaltic composition, set in a silt to clay-rich matrix. Generally, the alluvial unit is a thin veneer becoming thicker along rivers and watercourses in the region.

QNH stratigraphy is presented in **Figure 2** (please note that both the Fort Cooper Coal Measures and Moranbah Coal Measures are mined on the QNH). The geology of the QNH is well understood and comprises a consistent contiguous geology across the four mines. Throughout the QNH area, the geological structure has been subject to igneous intrusions which, where present, have either intruded or otherwise rendered sections of the target coal seams uneconomic.

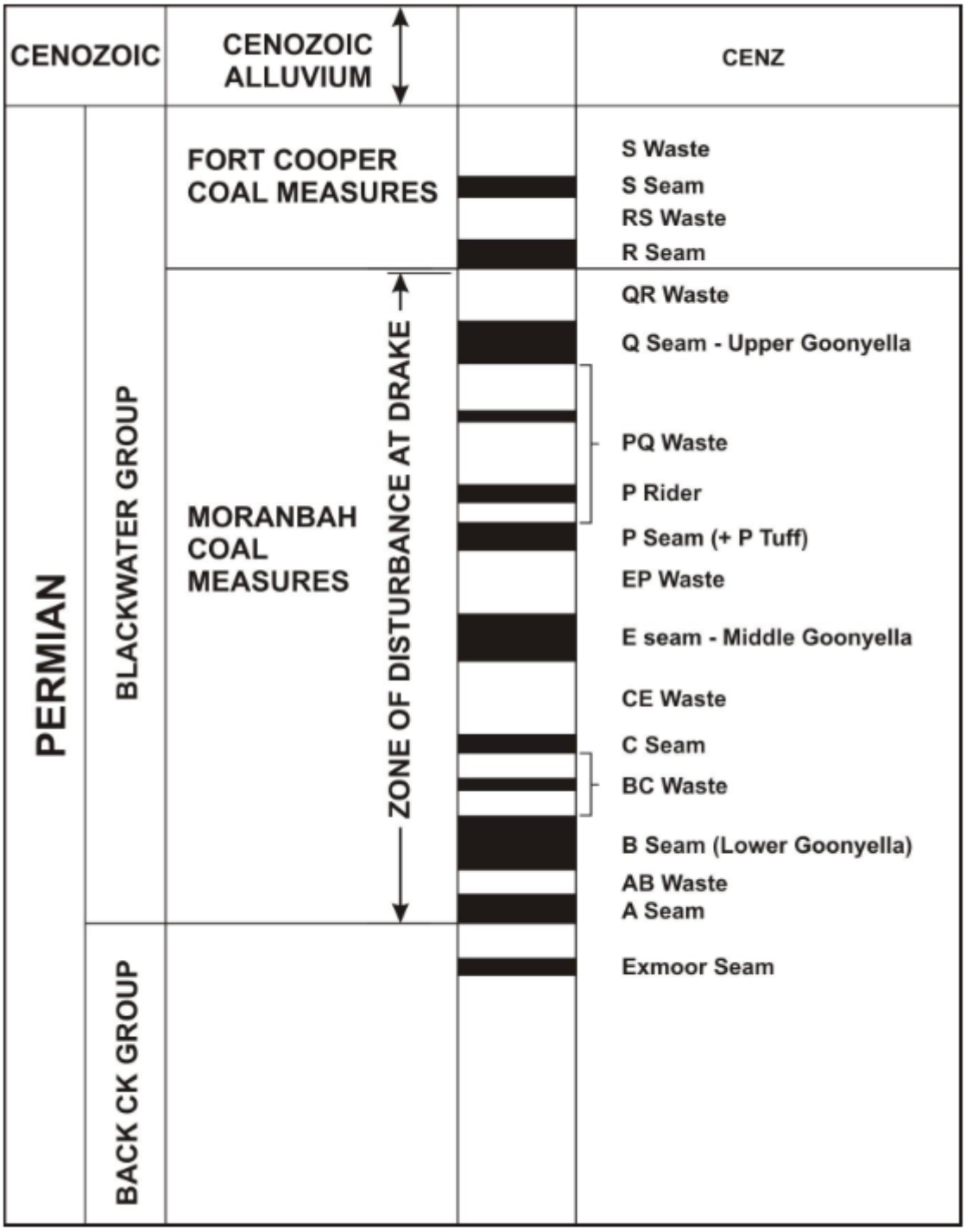


Figure 2 – Schematic of Targeted Stratigraphy (Drake EIS, 2013)

2.3 Mining Process and General Mining Waste Management

Coal is mined at the QNH by conventional drill and blast, truck and shovel bench-mining methods. Overly intruded coal is avoided where possible to maximise ROM coal extraction and minimise load contamination from poor-quality coal or non-coal materials. Where overly intruded, heat-affected, or otherwise uneconomical coal, including thin seams, is mined, it is handled as waste rock.

Topsoil is stripped and stockpiled for future use in rehabilitation. Waste rock is then mined, trucked and disposed of in waste rock dumps (out-of-pit or in-pit), from the surface to the first economic extraction seam.

2.4 Coal Processing

ROM coal from all QNH mines is processed at the SCM CHPP through a series of washing steps, which produces coal product, and coal rejects (coarse and fine) by-product. Coase and fine coal rejects are pumped to a co-disposal facility on the SCM. The co-disposal facility at the SCM is an in-pit co-disposal located in the Sonoma Main pit where mining has ceased. Previously coal rejects were pumped to an above-ground (out-of-pit) co-disposal facility on the SCM, which has reached the end of its operational life and, at the time of issue of this MWMP, is being rehabilitated.

Depending on the coal seam being processed, fine rejects typically account to 20-60% (by weight) of coal rejects pumped to the co-disposal facility, with coarse rejects making up the remainder. Occasionally coarse rejects are recovered at the CHPP separately from the co-disposal stream (referred to as bunkered reject) and used in the construction of ROM and product pads or roads, disposed of separately in waste rock dumps (out-of-pit or in-pit), or campaign trucked to the co-disposal.

3 Geochemical Characteristics of QNH Mining Wastes

3.1 Waste Rock Results

Waste rock is broadly categorised as either overburden or interburden material. Overburden material is rock removed to access the uppermost coal seam, and interburden is the rock material between the targeted coal seams.

As part of the DCM EIS, geochemical data from analyses undertaken at the JCM and SCM were collated with the data collected for the DCM EISs, to provide a characterisation of waste rock across the QNH. Waste rock was found to be Non-Acid Forming (NAF), with only one sample found in carbonaceous shale returning an Uncertain classification (see **Figure 3**). Waste rock was also found to have a low potential for metal leaching and saline runoff. Therefore, the conclusive majority of waste rock materials on the QNH is classified as low risk, with the bulk waste rock material having a net buffering capacity.

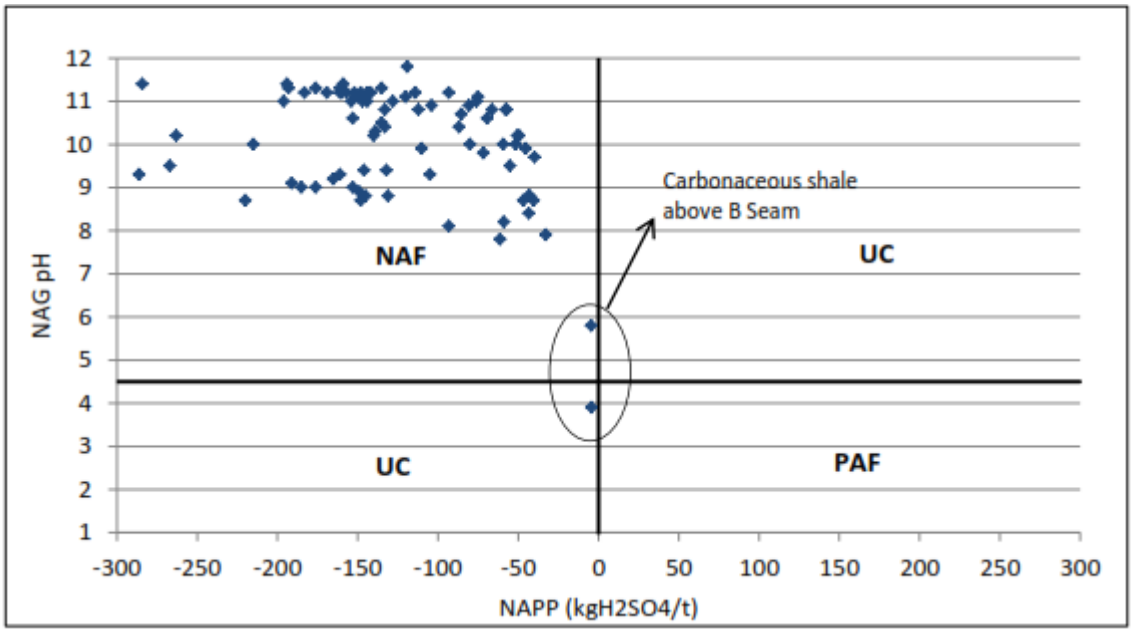


Figure 3 – QNH Waste Rock Categorisation (Drake EIS, 2013)

3.2 Coal Reject Results

Based on the analysis of 89 coal reject samples by Terrenus (2013), the general observations, found below, were made regarding bulk coal reject material as sampled on the SCM. These observations were confirmed by additional sampling and analysis undertaken by Terrenus in late 2013.

- Coal reject will generate alkaline, generally low-salinity run-off and seepage following surface exposure (see **Figure 4**).
- Total sulfur concentration in coal rejects is generally low (median sulfur content of 0.21%) (see **Figures 5** and **6**); however, in approximately 5% of samples, sulfide concentrations were sufficient to generate acid. Sulfide-sulfur comprises between 14% and 99% of the total sulfur concentration of coal reject; however, for most coal reject material, sulfide-sulfur comprises about 50% of the total sulfur concentration.

- Conservatively, 90% of coal reject materials are expected to be NAF, with a third of these NAF samples classified as 'barren' with respect to sulfur concentration.
- Approximately 5% of coal reject materials are anticipated to be Potentially Acid Forming (PAF) and Potentially Acid Forming – Low Capacity (PAF-LC). Coal rejects are likely to have relatively low total sulphur concentrations (typically less than 1%), and therefore are regarded as low risk, with the main potential for environmental impact likely to be the generation of sulfate salts (see **Figure 7**).
- Approximately 5% of coal reject materials are anticipated to be classified as Uncertain, with low sulphur concentrations, making these materials low risk.
- Total metal and metalloid concentrations in coal rejects are expected to be low, and below the applied health-based investigation levels for soils. However, there is potential for the concentrations of some metals (particularly Ba, Co, Cu, Mn, Ni, and V) to exceed the applied ecological investigation level. Some coal reject materials may produce leachate containing slightly elevated soluble Al, Se, and potentially As concentrations, as is common in Permian coal measures in the Bowen Basin.

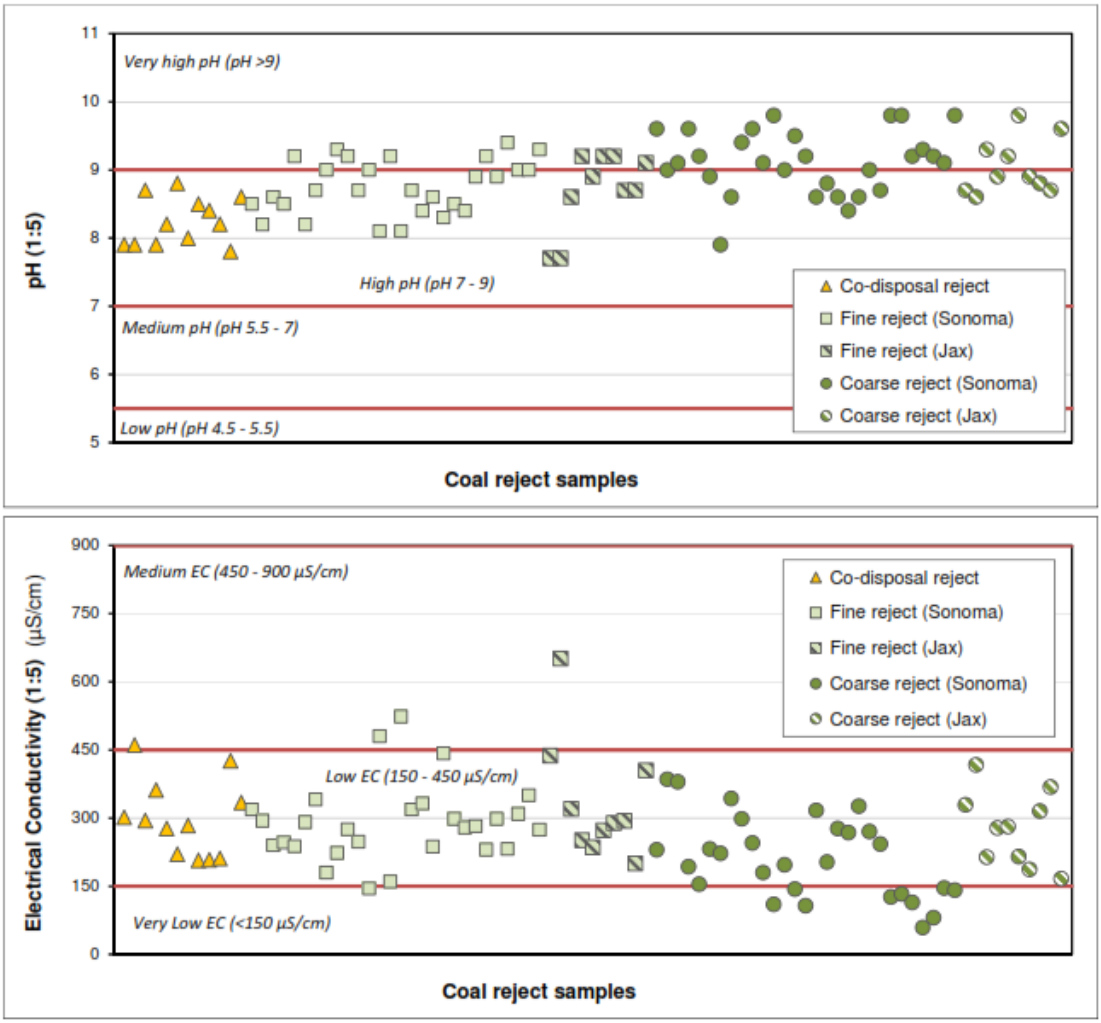


Figure 4 – Coal Rejects pH and Electrical Conductivity (Drake EIS, 2013)

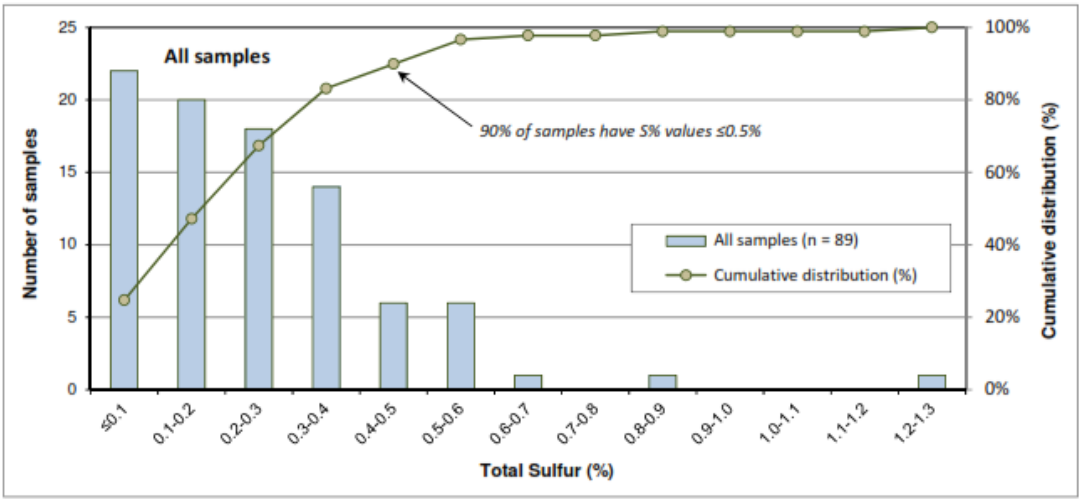


Figure 5 – Coal Rejects Total Sulfur (Drake EIS, 2013)

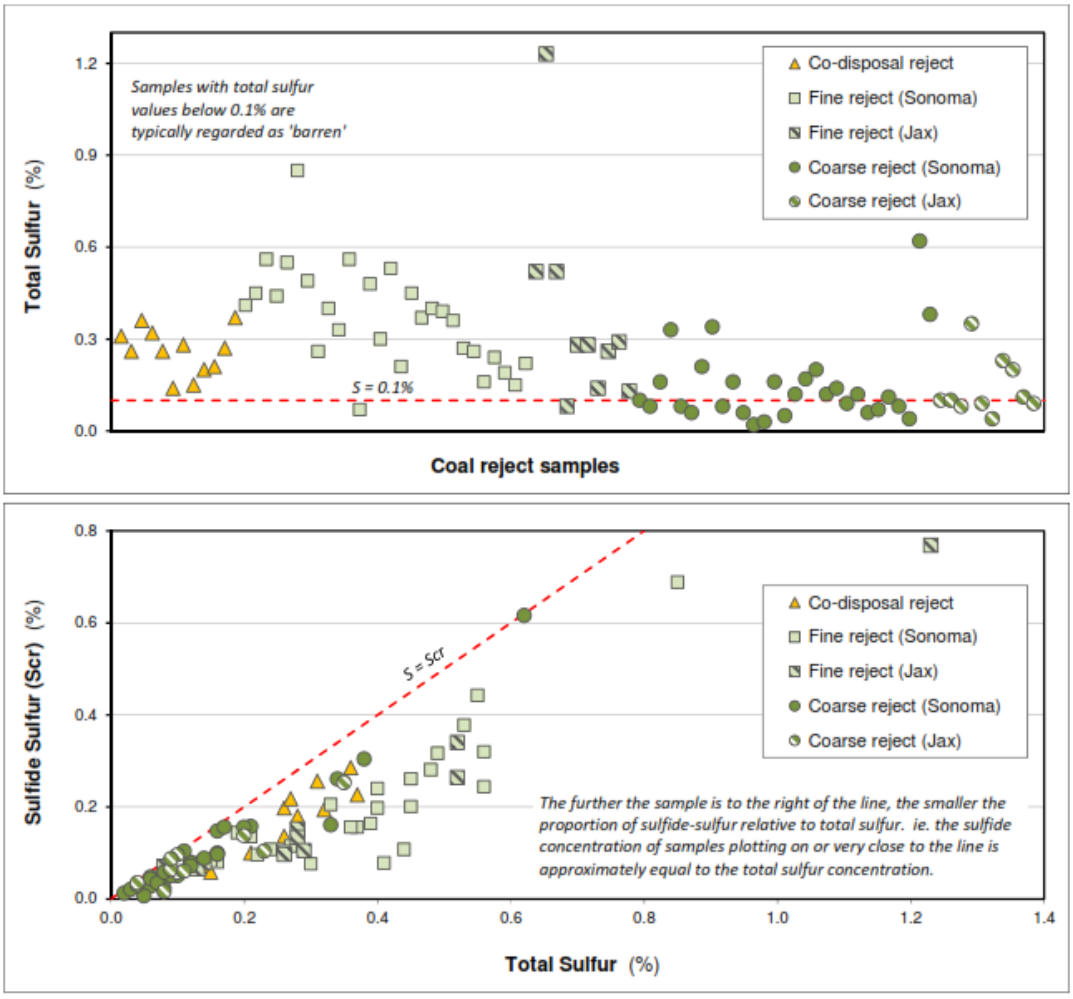


Figure 6 – Coal Rejects Total Sulfur and Sulfide Sulfur (Drake EIS, 2013)

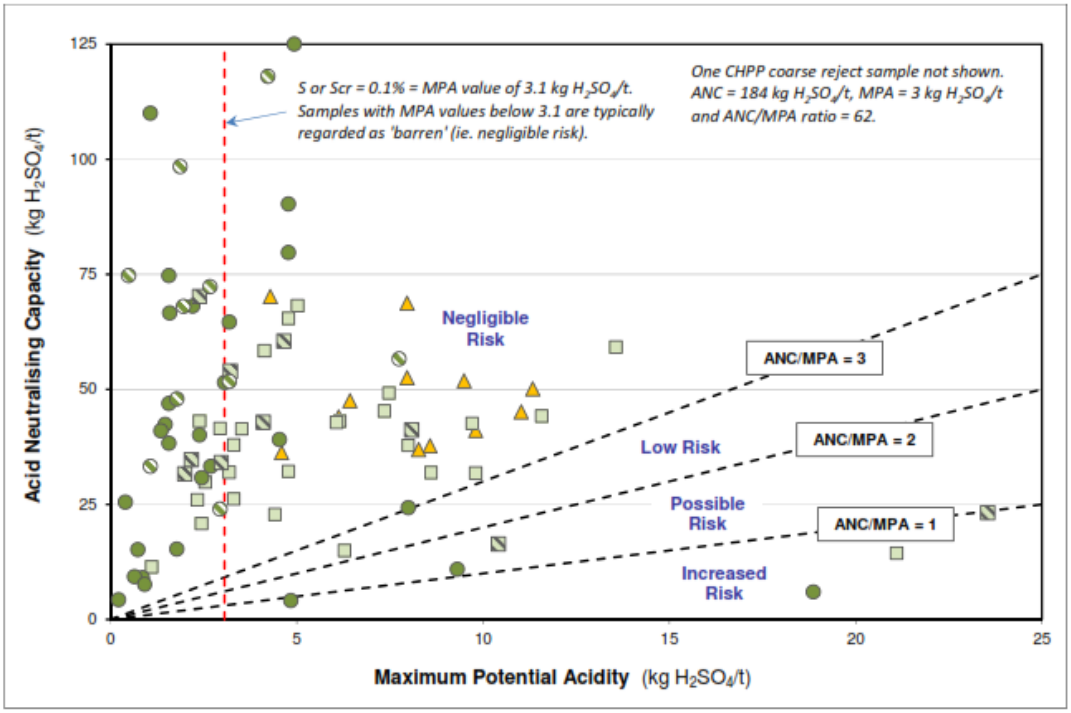


Figure 7 – Coal Rejects ANC vs MPA (Drake EIS, 2013)

3.3 Environmental Risk Categories

Potential environmental risks associated with mining waste and coal rejects are mainly associated with Acid Mine Drainage (AMD), the related mobilisation of metals, and saline drainage. Waste rock and coal rejects material is classed qualitatively as having low, medium or high risk of generating AMD as follows:

- **Low Risk**: Non-Acid Forming (NAF) material. Where geochemical testing of mining waste and coal rejects shows that materials have a very low likelihood of generating AMD.
- **Medium Risk**: Material with some capacity to generated AMD. This is referred to as Potentially Acid Forming – Low Capacity (PAF-LC). Geochemical testing of these materials indicate that these wastes may or will generate small quantities of AMD. A medium risk classification applies to all mining waste and coal rejects material not classed as low or high risk.
- **High Risk**: Potentially Acid Forming (PAF) material. Geochemical testing of these materials shows that these materials will almost certainly generate AMD. This classification may also apply to materials of less acid generating capacity, but with a short lag period until the onset of AMD.

All waste rock and coal rejects materials on the QNH have been classified as **Low Risk** NAF (with some buffering capacity) with the exception of *Fine-grained and carbonaceous material associated with coal seams* (some materials found immediately adjacent to coal seams are commonly carbonaceous such as carbonaceous siltstone, which can contain reactive sulphide materials, and are therefore classified as Medium Risk).

No mining waste materials of the QNH have been classified as high risk.

Waste rock and coal rejects are handled and dumped in bulk, as such when classified in bulk (as is appropriate for the handling methodologies) mining waste (both waste rock and coal rejects) has been classified as **Low Risk** NAF with relatively low salt and metals concentrations.

4 Management Strategies

Results of geochemical studies across the QNH have indicated that the majority of mining wastes (including waste rock, waste coal, and coal rejects) are classified as low-risk, and, as such, will not require selective handling, placement or additional management.

When considered in bulk, the medium risk materials will be buffered by the low-risk materials (buffering capacity and overwhelming percentage by volume) and therefore QNH mining wastes are considered to have a low AMD risk overall (see **Section 3.3**); as such, minimal active management of mining waste is required.

4.1 Management Categories

In order to assist the management of mining wastes on the QNH, mining wastes are grouped into four (4) management categories based on risk classification, as shown in **Table 2**. Management categories have been adapted from Terrenus 2012, in consideration of actual practical handling limits and observed material properties over the last 13 years of mining at QNH.

Table 2 – Mine Waste Categories

Management Category	Risk Classification	Material	Estimated Percentage of Waste Rock
Topsoil	Low	Soil (including sub-soil) to a nominal depth of 1 m below natural surface. Three types of topsoil typically occur across the site including: • Grey uniform clay • Brown gradational sandy loam • Red duplex sandy loam	na
Waste Rock - Category 1	Low	Waste rock – Upper: • Non-coal and non-carbonaceous material above the coal seams, and not within 1 m above or below ROM coal. • Typically weathered or moderately weathered.	>96%
	Low-Medium	Waste rock – Lower: • Non-coal and non-carbonaceous material below the upper seam, and not within 1 m above or below ROM coal. • Typically fresh or slightly weathered.	
Waste Rock - Category 2	Medium	Carbonaceous waste rock and unsuitable coal: • Carbonaceous material, material located within 1 m of ROM coal seams. • Sub-economic coal, intruded coal or heat-affected coal.	<4%
Coal Rejects	Low	CHPP rejects (coarse and fine) as co-disposal slurry.	na

An example of categorised waste rock mining wastes is presented in **Figure 3**.

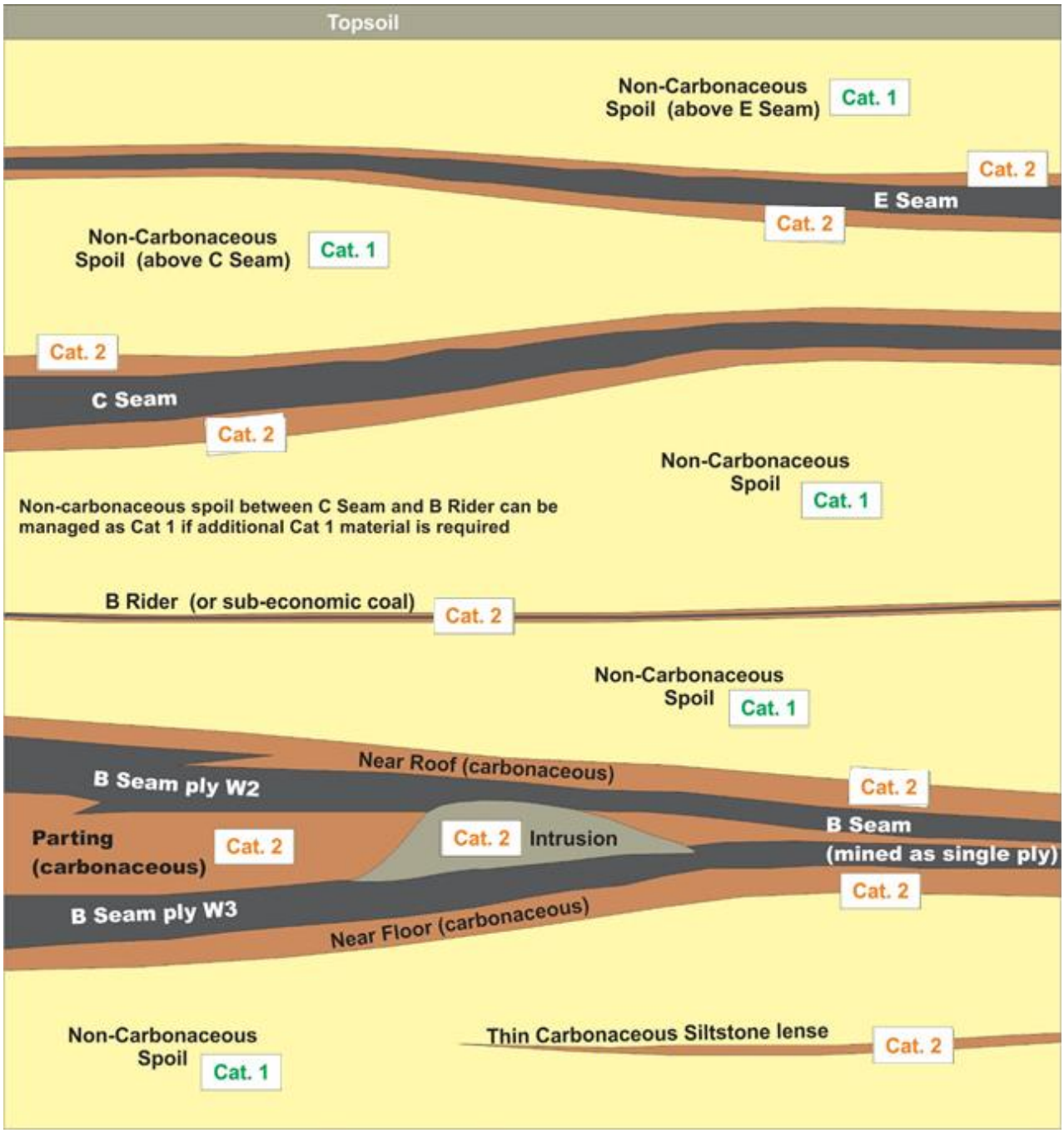


Figure 8 – Conceptual Mining Waste Classification (adapted from Terrenus, 2013)

Strategies are provided in the following sub-sections for each of the Management Categories identified.

4.2 Topsoil

Topsoil is to be managed in accordance with the current version of the *QCoal Northern Hub Topsoil Management Plan*,

4.3 Waste Rock - Category 1

The majority of waste rock excavated on the QNH will be designated as Category 1, and should be managed as follows:

- Materials are to be identified by a mine geologist and communicated to excavator and haul truck operators.
- Place material in overburden dumps (out-of-pit and/or in-pit).
- Materials may be used as site construction material, provided it meets geotechnical and engineering specifications.
- Materials may be used as a sub-soil cover material for rehabilitation of co-disposal facilities, ROM pads, and sediment dams at mine closure, prior to application of topsoil.
- Possible use as a final growth medium, should the geochemical and geophysical composition designate as suitable for such an application.
- Materials should be blended/diluted with Waste Rock – Category 2 during normal excavation, haulage and dumping.
- Where there is insufficient blending/dilution of Waste Rock - Category 2 with Waste Rock - Category 1, (such as instances where there is a significant volume of Waste Rock – Category 2 being mined and dumped for an extended period without any accompanying Waste Rock – Category 1), then Waste Rock – Category 1 should be used to encapsulate Waste Rock – Category 2 to a depth of at least 5m.

4.4 Waste Rock - Category 2

A minimal proportion of excavated waste rock (by volume) will be classified as Category 2. The material is to be managed as follows:

- Materials are to be identified by a mine geologist and communicated to excavator and haul truck operators.
- Materials should be blended/diluted with Waste Rock – Category 1 during normal excavation, haulage and dumping.
- Where there is insufficient blending/dilution of Waste Rock - Category 2 with Waste Rock - Category 1, (such as instances where there is a significant volume of Waste Rock – Category 2 being mined and dumped for an extended period without any accompanying Waste Rock – Category 1), then Waste Rock – Category 1 should be used to encapsulate Waste Rock – Category 2 to a depth of at least 5m.
- Traffic compact material (where practical) prior to encapsulation (where required).

4.5 Coal Rejects

The emplacement of rejects at the QNH occurs only on the SCM.

Previously rejects disposal was undertaken in an above ground (out-of-pit) co-disposal, which has ceased operation and at the time of this MWMP is being rehabilitated. As such this facility is not considered further as part of this MWMP.

Rejects are currently disposed of in an in-pit co-disposal, located in an SCM pit where mining has ceased. Specific tailings disposal procedures are required by the SCM EA and are in place for the

in-pit co-disposal. Therefore, this MWMP defers to the relevant documents with regard to management strategies for co-disposal rejects.

4.6 Water and Leachate Management

4.6.1 Waste Rock Dumps

Water management associated with waste rock dumps is generally related to surface runoff. Runoff from fresh (un-rehabilitated) waste rock is considered mine-affected and is required to be captured and managed under the approved QNH water management plan (WMP). The WMP for mine-affected water includes consideration of capture, storage capacity requirements, and quality in relation to releases. Monitoring of waste rock dump runoff is discussed in **Section 6.3**.

4.6.2 Co-disposal

The in-pit co-disposal includes a “decant” or “return water” lake, which is located at the lowest point of the pit. The water in the lake comprises a blend of supernatant water separating from the rejects stream (the majority of water is from this source), a small portion of direct rainfall into the pit and a small portion of pit-inflow from the surrounding coal seams, all flowing to the “return” lake.

Water from the “return” lake is pumped back to the CHPP for re-use.

The mining pit in which the in-pit co-disposal has been located, has previously been determined to be a groundwater sink (as per the *Residual Voids on the QCoal Northern Hub Mining Complex (QCoal, 2020)*). As such leachate does not require specific management consideration in terms of either structural stability (as it is an in-pit disposal not requiring reject walls) or in terms of environmental management as leachate is contained within the pit.

A Consequence Category Assessment (CCA) undertaken by an RPEQ (in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*) determined that the in-pit co-disposal is not a regulated structure.

4.7 Rehabilitation

Rehabilitation of waste rock dumps (out-of-pit and in-pit) and the above ground (out-of-pit) co-disposal facility (including capping requirements) is to be undertaken in accordance with the current version of the *QCoal Northern Hub Rehabilitation Management Plan* (RMP).

The in-pit co-disposal does not require specific rehabilitation as the pit itself remains a final void without a specific post mining land use and has been modelled to be a void lake with declining water quality. This detail is also captured in the RMP. The RMP will be informed by the management strategies outlined in this document for the various mine waste categories.

5 Mine Planning and Control

5.1 Waste Rock

As part of ongoing operations at the QNH, a 16 week rolling schedule is used to plan material movements including planning of what materials (waste rock, interburden, intrusions, roof/floor, or coal) is mined in what location and at what time.

The rolling schedule and the quantities therein as well as the mine plan (layout) can be used where required to confirm that sufficient blending/dilution of Waste – Rock Category 2 materials is being achieved, or to ensure that areas of Waste Rock - Category 2 material will ultimately be encapsulated by Waste Rock - Category 1 materials.

The rolling schedule and quantities can also be used to plan any required confirmatory geochemical sampling.

5.2 Coal Rejects

The co-disposal facility should be operated as per the procedures referenced in **Section 4.6.2**.

6 Mine Waste Sampling and Analysis

6.1 Rehabilitated Areas (Topsoil applied)

Rehabilitated areas are to be managed and monitored in accordance with the current version of the *QCoal Northern Hub Rehabilitation Management Plan.*

6.2 Waste Rock

6.2.1 Waste Rock - Category 1

Monitoring of runoff and/or seepage from active waste rock dumps for water quality is undertaken in accordance with the QNH EAs.

Where evidence of potential AMD (being acid, metalliferous and/or saline drainage) is observed from active waste rock dumps, actions will be taken to minimise and mitigate the AMD. Such actions are not designated in this MWMP, as they would be issue specific and will be addressed on an as needed basis at the direction of QCoal environmental staff and the Mining Superintendent in consultation with a geochemist as required.

6.2.2 Waste Rock – Category 2

Waste Rock - Category 2 material will either be adequately blended/diluted or encapsulated by Waste Rock – Category 1 materials. As such, this material does not report to final land surfaces, and, ongoing sampling, analysis and monitoring of these materials is not required

The results of ongoing mining waste characterisation and assessment program will dictate whether changes to the mining waste management strategy are required.

6.2.3 Ongoing Classification of Waste Rock

6.2.3.1 Sampling Program

Waste rock geochemical characteristics at the QNH are well understood and as such no specific ongoing sampling/analysis is required, except under the following circumstances:

- Evidence of potential AMD (acid, metalliferous and/or saline) is observed originating from waste rock dumps;
- A new, previously un-sampled geology is encountered during mining operations; or
- Mining operations is being undertaken in areas where there is no knowledge of the geochemical characteristics of the material.

Should one of these circumstances occur, representative samples of overburden, interburden, immediate[1] coal seam roof, parting and floor shall be collected for geochemical analysis to assess the waste designation categories as follows.

- A representative number of samples (drilling cores or from active mining areas) shall be collected by the mine geologist.
- Collect 1 kg of each sample, and place into a strong plastic bag, seal and store out of the weather prior to transport to the laboratory.
- Record the sample ID, location, type, depth, seam and any other relevant observations.
- Samples will undergo testing for a ‘standard’ suite of static geochemical tests.

6.2.3.2 Laboratory Analysis

Each sample shall undergo analysis at a laboratory that is NATA-certified for the following analytes:

- NAPP (Acid Neutralising Capacity, Acid Production Potential and Total Sulfur);
- pH and electrical conductivity (EC) 1:5
- Major Cations (Ca, Mg, Na, K) 1:5
- Major Anions (Cl^-, SO_4, and alkalinity) 1:5
- Total Metals (Al, As, B, Ba, Be, Cd, Cr, Co, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, V, Zn);
- Water soluble metals as above.

Additionally, for Category 1 waste, the following analyses are also to be undertaken:

- Exchangeable cations (Al, Ca, Mg, Na, K)
- Emerson class.

6.3 Coal Rejects

Operation and monitoring of the CHPP is outside of the scope of this MWMP.

The CHPP and co-disposal facility operators will be responsible for regularly assessing the condition of the in-pit co-disposal facility and will revise the operational procedures strategy as required.

[1] “immediate” coal seam roof, parting and floor refers to the zone up to 0.5 m immediately above and below ROM coal.

Operations of the co-disposal cells and decant dam will be monitored on a daily basis and information recorded on a daily operator's log.

6.3.1 Ongoing Classification of Coal Reject

6.3.1.1 Sampling Program

Rejects geochemical characteristics at the QNH are well understood and as such no specific sampling/analysis is required, except under the following circumstances:

- Evidence of potential AMD (acid, metalliferous and/or saline) is observed originating from rejects;
- A new, previously un-sampled coal type is encountered during mining operations; or
- Mining operations is being undertaken in areas where there is no knowledge of the geochemical characteristics of the material.

Should one of these circumstances occur, representative samples of rejects material shall be collected for geochemical analysis to assess the waste designation categories as follows.

- A representative number of samples shall be collected by the mine geologist.
- Collect 1 kg of each sample, and place into a strong plastic bag, seal and store out of the weather prior to transport to the laboratory.
- Record the sample ID, location, type, depth, seam and any other relevant observations.
- Samples will undergo testing for a 'standard' suite of static geochemical tests.

6.3.1.2 Laboratory Analysis

Each sample shall undergo analysis at a laboratory that is NATA-certified for the following analytes:

- NAPP (Acid Neutralising Capacity, Acid Production Potential and Total Sulfur)
- pH and electrical conductivity (EC) 1:5
- Major Cations (Ca, Mg, Na, K) 1:5
- Major Anions (Cl^-, SO_4, and alkalinity) 1:5
- Total Metals (Al, As, B, Ba, Be, Cd, Cr, Co, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, V, Zn)
- Water soluble metals as above

6.4 Water and Leachate Sampling

Sampling of water from the waste rock dumps and in-pit co-disposal dams should target the following separate streams:

- Out-of-pit waste rock dump
    - Runoff from fresh waste rock collected in dams located at the toes of waste rock dump slopes
    - Runoff from topsoiled rehabilitated areas collected in dams located at the toes of waste rock dump slopes
- In-pit Co-disposal

- “Decant/Return water” lake – rejects water collected at the “return water” lake and re-used in the CHPP

Sampling and analysis are to be undertaken in accordance with the QNH EAs.

6.4.1 Field Analysis

Each sample is to be analysed in-situ by a suitably qualified environmental professional for pH, EC and turbidity using a calibrated water quality meter.

6.4.2 Laboratory Analysis

Each sample shall be analysed at a laboratory which is NATA-accredited for the following:

- pH and EC
- Total suspended solids
- Major Cations (Ca, Mg, Na, K)
- Major Anions (Cl-, SO4, and alkalinity)
- Total and dissolved metals (Al, Be, B, Ba, Be, Cd, Cr, Co, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, V, Zn).

6.5 Interpretation of Results

The results of mine waste and water quality monitoring are to be assessed by a suitably qualified person. Ongoing reviews of the MWMP are to be undertaken based on the interpreted results (see **Section 8**).

7 Roles and Responsibilities

7.1 Waste Rock

The roles and responsibilities for waste rock management at the QNH are presented in **Table 3**.

Table 3 – QNH Waste Rock Responsibilities

Role*	Responsibility
QNH Environmental Officer	• Ensure the MWMP is effectively implemented, including audits. • Ensure compliance against the site EA. • Undertake sampling as per **Section 6**.
QCoal Environment Manager or Delegate	• Approve and periodically review the MWMP. • Ensure adequate resource are available for the implementation of the MWMP.
Mine Geologist and/or Engineer	• Identify zones of Category 1 and Category 2 mining waste to allow adequate resourcing and planning for waste disposal strategies. • Work with the Mining Superintendent to plan and implement correct management as per the MWMP. • Quantify the various categories as part of the rolling schedule. • Plan a dumping schedule to accommodate the various disposal requirements of Category 1 and Category 2 materials.
Mining Manager	• Work with the Mine Geologist and/or Engineer to plan and implement correct management as per the MWMP. • Provide the MWMP to mining contractors and brief them about the principles of the MWMP, including their roles and responsibilities. • Provide training or instruction to mining contractors about specific MWMP tasks. • Implementation of strategies to address audit non-compliances and prevent future non-compliances. • Provide feedback to the Environmental Officer regarding improvements to the MWMP.
QNH Manager	• Periodically review the MWMP. • Provide adequate resources to facilitate the implementation of the MWMP.

* - Note: While these roles may not exist by these names on site, these responsibilities are designated to those site personnel who would be reasonably assumed to fit these descriptions.

7.2 Coal Reject

The roles and responsibilities for coal reject management at the QNH are presented in **Table 4**.

Table 4 – QNH Coal Rejects Responsibilities

Role*	Responsibility
QNH Environmental Officer	• Ensure the MWMP is effectively implement, including audits. • Ensure compliance against the site EA.
QCoal Environment Manager or Delegate	• Approve and periodically review the MWMP. • Ensure adequate resource are available for the implementation of the MWMP
CHPP/Co-disposal Engineer	• Work with the CHPP Manager to plan and implement the management of coal rejects as per the MWMP and/or co-disposal procedures.
CHPP/Co-disposal Manager	• Work with the Mine Geologist and/or Engineer to plan and implement management of coal rejects as per the MWMP and co-disposal procedures. • Provide the MWMP to CHPP operators and brief them on the principles in the MWMP, including their roles and responsibilities. • Provide training or instruction to CHPP operators regarding specific MWMP tasks. • Implementation of strategies to address audit non-compliances and prevent future non-compliances. • Implement a monitoring program for ongoing characterisation of coal reject materials. • Provide feedback to QNH Environmental Staff regarding potential improvements to the MWMP.
QNH Manager	• Periodically review the MWMP. • Provide adequate resources for the implementation of the MWMP.

* - Note: While these roles may not exist by these names on site, these responsibilities are designated to those site personnel who would be reasonably assumed to fit these descriptions.

8 Review and Revision

This MWMP is designed to be a dynamic document and should be regularly reviewed to determine its ongoing suitability based on:

- The results of mine waste monitoring (as per **Section 7**);
- Any change in mining methodology;
- Changes to the CHPP;
- When a previously un-sampled geology is encountered; and
- When mining in previously un-sampled areas of the MLs.

Where a review has identified the MWMP is no longer suitable, an update should be prepared and distributed to relative parties as per **Section 7**.

Cows Coal Project
Waste Rock Report

Mining Lease 10345

10 May 2011

QCoal Pty Ltd

ACN: 010 911 234

Level 15, 40 Creek Street
BRISBANE QLD 4000

Ph: (07) 3002 2900
Fax: (07) 3002 2999



QCOAL PTY LTD

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Appendix 2 **Belmore-Pipeline Coal Mine Geochemical Analyses and Particle Size Distribution**

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Appendix 3 **Sonoma Coal Mine Surface Water Quality and Groundwater Monitoring Data**

Table 14: Surface Water Monitoring Data

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Figure 5 Surface Water Sampling Points

Figure 6 Groundwater Sampling Points

EXECUTIVE SUMMARY

A review of previous waste rock characterisation studies was undertaken for the adjacent Sonoma Coal Mine and former Belmore-Pipeline Coal Mine. The review provided a bench mark for the Cows waste rock characterisation investigation, as both mines have been developed in the identical and continuous geological formations and stratigraphic sequences to those identified in the Cows Project area. These previous investigations in the Moranbah Coal Measures have shown that waste rock has a negligible potential for formation of acid mine drainage.

In order to confirm the earlier results, QCoal has undertaken further testing to assess the geochemical characteristics for a wide range of lithologies from the Q-seam pit at Sonoma which abuts the northern boundary of the Cows Project area. The acid-base accounting (ABA) analyses further indicates that waste rock or spoil materials from the Moranbah Coal Measures for the Project area will be non-acid forming (NAF).

Coal and other carbonaceous sediments (siltstone and mudstone) have a low potential for acid formation (PAF), however, the impacts of any potentially acid forming (PAF) materials will be negated by the higher neutralising capacity of other lithologies such as quartzose sandstone placed in the overburden dumps or spoil heaps. Carbonaceous sediments (siltstone and mudstone) which may be potentially saline occur interbedded the coal seams and will be removed from site as raw coal.

Immediately south of the Cows Project area, overburden materials from the Drake area and adjacent Jax Project areas recorded an average EC value of 281.1 µS/cm, which is within the low salinity range of 150 to 450 µS.cm (DME, 1995b). In view of the stratigraphic similarities between mining operations in this region, specific requirements to manage salinity are not likely to be required for overburden dumps in the Project area, however ongoing ABA analyses should continue during the operational phase of the Project.

These findings are supported by previous investigations at Sonoma coal mine (Parsons Brinckerhoff, 2006) and Belmore-Pipeline coal mine (Collinsville Coal Company, 1999). Operational procedures at Sonoma coal mine do not require segregation or encapsulation of any overburden materials. Potentially acid forming and saline overburden have not been an operational issue at Sonoma. Overburden materials for Sonoma and Belmore-Pipeline were found to be slightly alkaline.

Waste rock/soil materials are more likely to disperse as calcium/magnesium ratios are less than 2 and exchangeable sodium percentages (ESP) are greater than 6%. The current analyses has confirmed the presence of high Ca/Mg ratios and low ESPs, and therefore dispersion of fine materials from overburden dumps will not cause significant environmental harm. Where practicable, construction of sediment control dams will be sufficient to capture any products of dispersion generated on the overburden dumps. These structures are currently limiting the release of sediment at Sonoma and Belmore-Pipeline mines.

Total sulphate levels were found to be low. Together, the low sulphate and low EC values provide evidence to support the findings that the overburden materials will not be saline and therefore cannot be classed as hazardous materials.

1.0 OVERVIEW

The regional location of the Cows Project area is shown in **Figure 1**.

Mineral sulphides, in particular pyrite (FeS_2), may form in sedimentary formations under low oxygen or reducing environments of deposition.

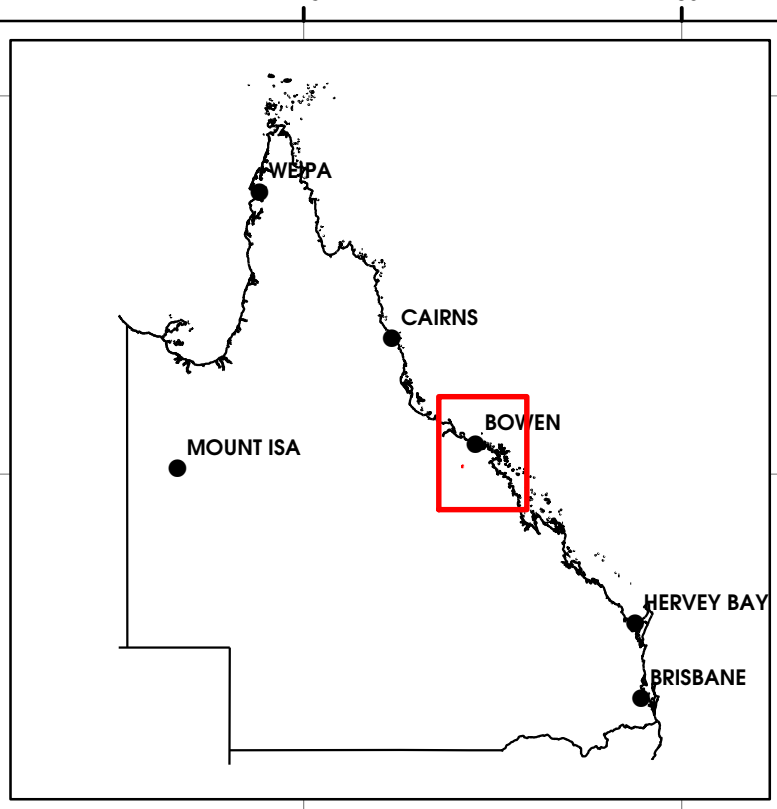
Acid rock drainage (ARD) or acid mine drainage (AMD) is produced when mineral suphides are exposed to atmospheric oxygen and water, such as in waste rock or spoil stockpiles associated with mining activities.

Any resultant ARD has the potential to:

- Inhibit rehabilitation (revegetation);
- Increase the solubility and/or the release of metals; and
- Increase the salinity or solute load downstream from the mine site.

1.1 Purpose

The purpose of this investigation is to assess the geochemical characteristics of any future overburden materials from coal mining activities in the Cows Project area.



148 148 149 149 150

-19 -20 -21 -22

AYR
HOME HILL
BOWEN
Bogie River
Whitsunday
Proserpine
Don River
Collinsville
COLLINSVILLE
SONOMA
COWS
Bowen River
O'Connell River
Calen
Bucasia
MACKAY
Marian
Walkerston
Bakers Creek
Sarina
EASTERN CREEK
NEWLANDS
SUTTOR CREEK
Suttor River
HAIL CREEK
WARDS WELL
BURTON
NORTH GOONYELLA
RIVERSIDE
Isaac River
SOUTH WALKER CREEK
GOONYELLA RIVERSIDE BROADMEADOW (UG)
BROADLEA NORTH
COPPABELLA
MORANBAH NORTH
CARBOROUGH DOWNS

148 148 149 149 150

QCOAL PTY LTD

0 10 20 30 40 50
Kilometres

Scale: 1:1,000,000 @ A3

Datum: GDA 1994

N W E S

Legend

- Town
- Operational Coal Mine
- Railway
- Drainage
- Cows Coal Project

COWS COAL PROJECT (ML 10345)

FIGURE 1: REGIONAL LOCATION

Date: 29 April 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM & DEEDI

1.2 Previous Investigations

1.2.1 Sonoma Coal Mine (Mining Leases 10325, 10326 & 10327)

In 2006, QCoal commissioned an overburden assessment for the Sonoma Coal Project (**Figure 2**) in the Moranbah Coal Measures as part of the EIS investigations (Parsons Brinkerhoff, 2006).

The assessment was undertaken to define overburden characteristics relevant to environmental management mine planning and reusability potential of overburden materials. The field work for the investigation comprised drilling and sampling of 4 boreholes located within SCP site.

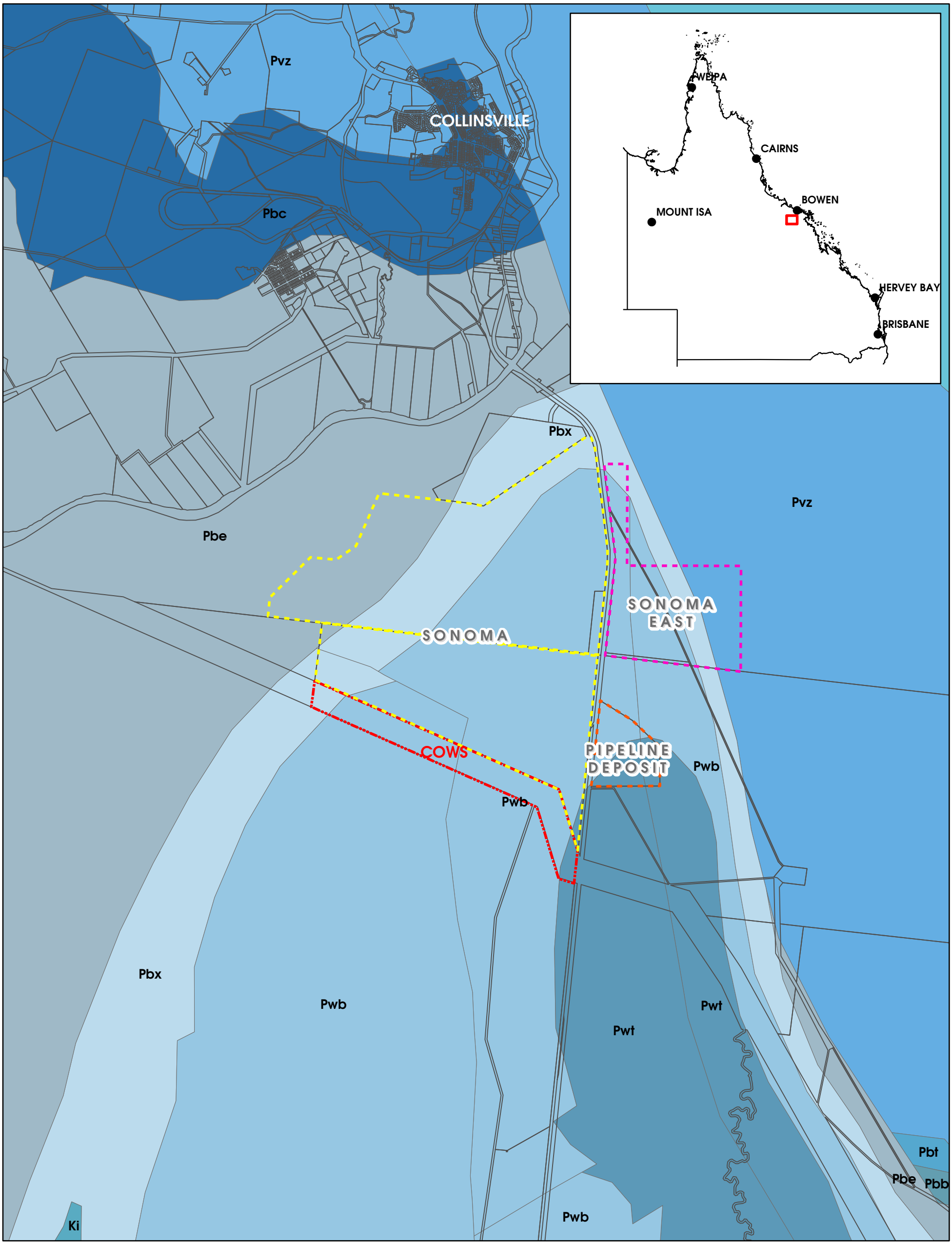
In general terms the bore holes of the current and previous investigations encountered the following geological units:

- Tertiary/Quaternary age clay. silt and silty, clayey and/or gravely sand was encountered from surface to between 13 m and 19.5 m depths;
- Permian age claystone, mudstone, carbonaceous mudstone, siltstone and sandstone were encountered as distinct layers or interbedded sequences underlying the Tertiary age sediments. The sandstones ranged from lithic-feldspathic, quartz-feldspathic to tuffaceous. The degree of weathering, strength and chemical characteristics of these rocks varies both laterally and with depth.
- Acid to intermediate intrusions forming localised sills and dykes.
- The SCP is located approximately 6 km south of Collinsville in Central Queensland. The proposed mine site is located west of Collinsville - Mt Coolon Road and south of Coral Creek.

The field work for the investigation was undertaken in April 2006 and comprised drilling and sampling of 4 boreholes at SCP site:

1. BR215 drilled to 64 m depth in the western central part of the site
2. PC138 drilled to 87 m depth in the northern part of the site
3. BR204 drilled to 150 m depth in the central part of the site
4. BR194 drilled to 129 m depth in the southern part of the site.

All field activities were supervised and all samples were delivered to PB by Energy Minerals Pty Ltd personnel.



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0 0.4 0.8 1.2 1.6 2
Kilometres

Scale: 1:60,000 @ A3

Projection: UTM Zone 55
Datum: GDA 1994

N W E S

Legend

Geology

- Cg (Cg-BBG)
- Ki (Ki-BBG)
- Pbb (Gebbie Subgroup)
- Pbc (Collinsville Coal Measures)
- Sonoma
- Pipeline Deposit
- Sonoma East
- Pbe (Blenheim Subgroup)
- Pbt (Tiverton Formation)
- Pbx (Exmoor Formation)
- Pvz (Lizzie Creek Volcanics)
- Pwb (Moranbah Coal Measures)
- Pwt (Fair Fill Formation, Cooper Coal Measures)
- Cows Coal Project
- DCDB

COWS COAL PROJECT (ML 10345)

FIGURE 2: REGIONAL GEOLOGICAL SETTING

Date: 13 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM & DEEDI

Selected soil and rock samples were tested in a NATA registered laboratory for particle size distribution and dispersivity in accordance to Australian Standard: Testing of Soils for Engineering Purposes, AS 1289; and chemical characteristics by validated analytical laboratory methods:

- Particle size distribution, (AS 1289. 3.6.1).
- Emerson Class number, (AS 1289.3.8.1).
- Conductivity (EC), pH and Cation Exchange Capacity (CEC) of soils, (Australian Laboratory Services methods).
- Net acid generation at pH7 (NAG); pH after oxidation; Acid production potential (APP);
- Acid neutralising capacity (ANC); Net acid producing potential (NAPP);
- Total S content of overburden; and
- Exchangeable sodium percentage (ESP) calculated from the above laboratory results.

Overburden and interburden encountered at Sonoma comprised the following soil and rock types:

- Tertiary/Quaternary age clay, silt and silty, clayey and/or gravely sand was encountered from surface to between 13 m and 19.5 m depths.
- Permian age claystone, mudstone, carbonaceous mudstone, siltstone and sandstone were encountered as distinct layers or interbedded sequences underlying the Tertiary age sediments. The sandstones ranged from lithic-feldspathic, quartz-feldspathic to tuffaceous. The degree of weathering, strength and chemical characteristics of these rocks varies both laterally and with depth.
- Interburden (rocks between coal seams) material comprises the same rock types as the overburden.

Previous investigations also encountered acid (quartz rich) to intermediate intrusions forming localised sills and dykes.

The acid mine drainage generating potential of Sonoma overburden material was assessed by comparison of the materials acid generating potential with its acid neutralising capacity. The parameters assessed and their brief description is detailed below:

- The pH represents the acidity of the soil or rock as it occurs (i.e. without any induced oxidation or treatment).
- The oxidation pH is the acidity of the sample determined after rapid oxidation with hydrogen peroxide. The process is simulating prolonged exposure to atmospheric conditions. Materials with values below pH 4.0 are considered acid producing and above pH 4.0 not acid producing
- Acid neutralising capacity (ANC): ANC is due to the presence of carbonate minerals, exchangeable bases and silicate minerals that may break down in the subsurface material. Carbonate minerals (calcite, aragonite and dolomite) are most significant in terms of acid neutralisation.
- Net acid producing potential (NAPP): NAPP is the difference between measured acid producing potential (APP) and ANC (i.e. NAPP=APP-ANC) and gives an indication of subsurface materials potential to generate acid. A positive result shows acid generating potential and a negative result indicates that the material is non-acid producer.
- Total sulphur (%) is a measure of the total sulphur content of the rock. Materials with more than 0.5% total sulphur are considered potentially acid producing materials.
- Net acid generation (at pH 7) (NAG): NAG differs from NAPP by measuring actual acid production and neutralisation of the rock and not the total theoretical potential.

- Exchangeable sodium percentage (ESP): Chemically exchangeable sodium can weaken the bonds between clay particles thus acts as a dispersing agent. Soils with ESP of more than 15% are considered highly dispersive and soils with ESP less than 5% are commonly considered as non-dispersive.
- Cation exchange capacity (CEC): A soil capacity to hold nutrients is estimated by CEC. Low values (below 5) are indicating that the soil is prone to leaching and therefore is likely to be a poor growth medium.
- Acidity and conductivity: Actual acidity and electrical conductivity was determined on selected overburden and interburden samples. The Sonoma results shown in **Appendix 1** are indicative of likely behaviour and suitability of the rocks and soils as spoil stockpile capping layers.

1.2.2 Belmore-Pipeline Coal Mine (Mining Lease 10350)

At the Belmore-Pipeline coal mine (**Figure 2**), overburden materials extracted from the Moranbah Coal Measures were analysed for pH, electrical conductivity, total sulphur, soluble sulphur and gross neutralization (Collinsville Coal Company, 1999). The following extracts are reproduced from this report:

"The principal overburden on top of the Pipeline Deposit, below the base of weathering, consists of light grey, fine to medium, moderately strong, quartz-lithic sandstone. Minor rock types also in the overburden include light-grey siltstone and igneous material.

The maximum economic stripping ratio for the Pipeline Deposit was 6: 1.

Of the 58 holes drilled during the 1999 resource definition program of the Pipeline Deposit, seven holes located across the deposit were used to determine overburden characteristics with reference to rehabilitation and are identified as R1026, R1030, R1031, R1033, R1041 and R1044.

As the geological sequence of the area was known from the 1992 drilling program to be mostly uniform sandstone, samples were collected from each metre from the nominated drill holes (total of 110 samples). The samples were then analysed to determine pH, electrical conductivity, total sulphur, soluble sulphur and gross neutralisation potential with the results shown in **Appendix 2** (**Table 10**). The analyses were conducted on the overburden samples to determine whether there are any limiting factors to rehabilitating the mined area, for example high mineralisation or the potential for acidic drainage.

Further north at the Collinsville operations, the weathered portion of the profile (up to 20 metres below surface level) is mined separately and used to cover overburden that has the potential to produce acid drainage due to the sulphide (pyrite) levels."

The results indicated a "neutral, uniform, non-saline geochemistry throughout the profile with no potential for acid drainage." The overburden at Belmore-Pipeline had a low pyrite and sulphur content (pyritic sulphur < 0.016%).

2.0 PROJECT DESCRIPTION AND REGIONAL GEOLOGY

2.1 Site Location

The Cows Project (the Project) is being developed by Bowen River Coal Pty Ltd (BRC), a subsidiary of QCoal Pty Ltd ("QCoal"), approximately 13 km south of Collinsville in the north Bowen Basin. The regional location of the Cows Project is illustrated in **Figure 1**.

The Cows Coal Project lies immediately adjacent to the southern boundary of the Sonoma Coal Mine (ML 10325) which is operated by Sonoma Mine Management Pty Limited (SMM). The former Belmore-Pipeline Coal Mine (ML 10250) held by Xstrata Coal Queensland Pty Ltd is 2.6 km east of Cows, and at its closest point only 500m to the east.

Collinsville has a population of approximately 2,200 and provides the area with accommodation, hospital and medical services, education, shopping, sporting and recreation facilities. It also services the Sonoma Coal Mine, Collinsville Mine and the Collinsville Power Station.

Access to the Project is by way of a sealed two-land road, known as the Bowen Developmental Road.

The Cows Project is ideally located to take advantage of established infrastructure in the region. The Abbot Point Coal Terminal (APBT) lies 106km by rail to the northeast. The local government body administer the Project area is the Whitsunday Regional Council.

2.2 Project Proposal

BRC proposes to extract the coal for off-site processing and sale of coking and thermal coal products. An indicative mine concept plan is outlined in **Figure 3**. The washing of coal will not take place within the boundaries of the Project lease (MLA 10345). Mining activities will target the Moranbah Coal Measures, specifically the Q-seam and the B seam, using conventional open-cut mining methods. The Project will involve the mining of 2.5 million tonnes (Mt) of Run of Mine (ROM) coal over 15 years from two pits; the Q-seam pit (0.5 Mt ROM at an average strip ratio of 8:1) and the B-seam pit (2 Mt ROM at an average strip ratio of 6:1). The annual rate of mining will vary to coincide with SMM's progression of the Q-seam pit within ML 10325 "Belmore West". The proposed lease term of 15 years includes the construction, operation and decommissioning phases of the Mine.

The total coal resource and estimate overburden volumes for Cows Project are detailed in **Table 1**.

Table 1: Coal Resource and Estimated Overburden Volume

Pit	**Coal Resource** *(In situ* Mt)	**Overburden Volume** (Mbcm)
Q Seam Pit	0.5	4.2
B Seam Pit	2.0	11.8
TOTAL	**2.5**	**16.0**

The Mine will be a contract operation functioning on a 24-hour, seven days per week basis. Approximately 20 personnel will be employed for the construction, operation and decommissioning of the Project.

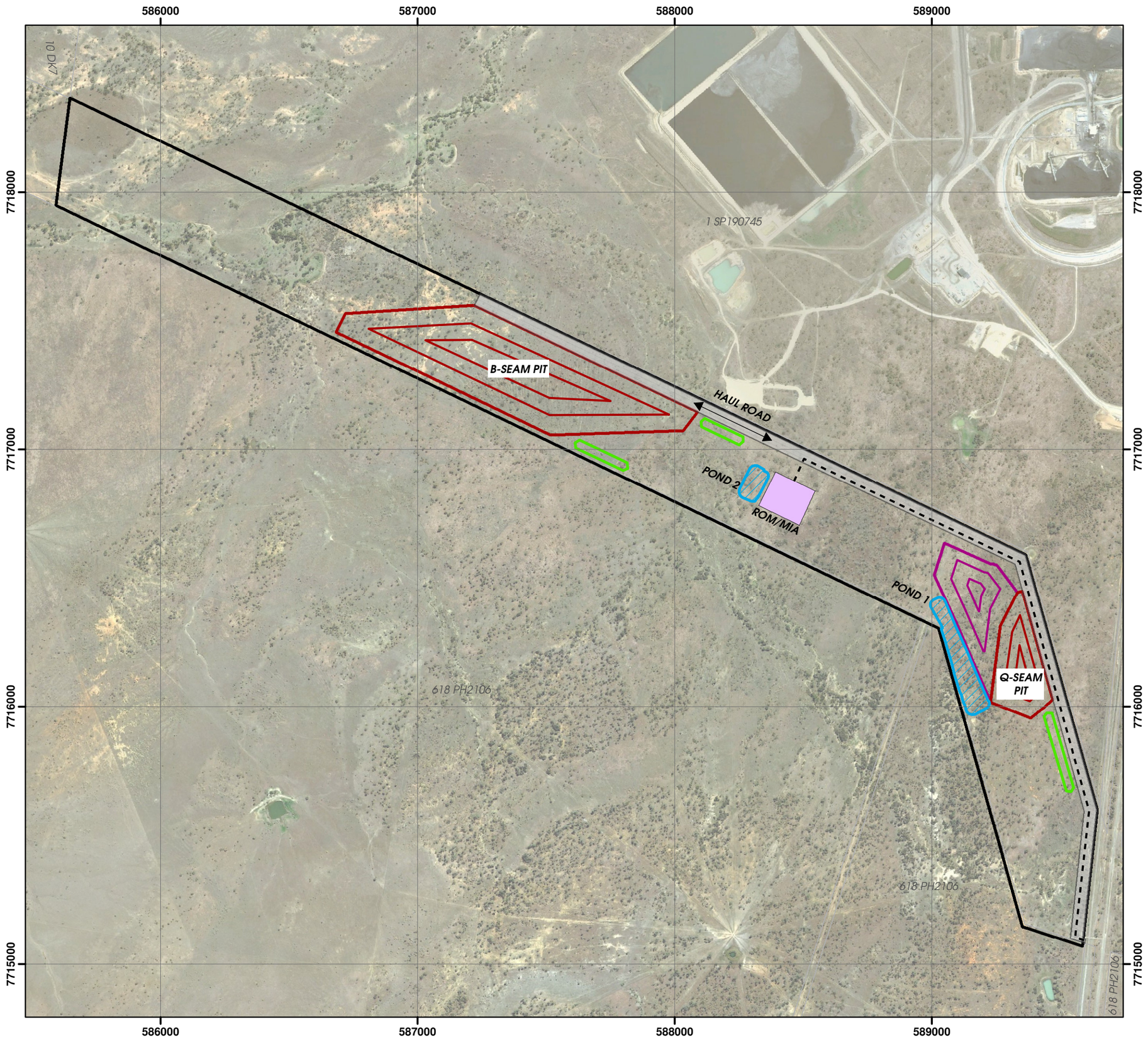
The following program summarises the works required for the Project:

- Ongoing coal resource definition (code-compliant exploration activities);
- Topsoil removal and stockpiling;
- Construction of haul roads and mine infrastructure areas;
- Development of out-of-pit overburden dumps;
- Extraction of coal from both the Q-seam pit and the B-seam pit;
- Commencement of in-pit overburden dumping once sufficient void is created;
- Transport of coal to an off-site Coal Handling & Preparation Plant (CHPP) and rail facility for processing and export; and
- Rehabilitation in line with the rehabilitation strategy.

An estimate has been made of the relative proportions for each lithology comprising the overburden materials (**Table 2**) by reviewing the drill logs of 30 bore holes for a transect across the Moranbah Coal Measures in the Drake Project area. In view of the continuity of the stratigraphic profiles between the Drake Project area and Cows Project area, it is reasonable to use this estimate for relative proportions in the Cows Project area. The overburden comprises will comprise mainly interbedded quartzose sandstones and siltstones (74.5%), with far lesser quantities of finer-grained sediments such as mudstone/shale/carbonaceous shale (9.0%) and intrusive lithologies (6.6%). Coal seams have been excluded from these determinations as product coal will be removed from site and only small quantities will report to the overburden dumps.

Table 2: Cows Waste Rock Balance

Overburden Lithologies	Sandstone	Siltstone	Mudstone (Carbonaceous)	Igneous	Coal
Ratio to Total Depth Drilled (%)	53.5	21.0	9.0	6.6	9.85
Indicative Overburden Tonnage (Mbcm) on Cows	**8.48**	**3.36**	**1.44**	**1.05**	**Product coal**
Number of Samples	**42**	**23**	**6**	**4**	**0**



QCOAL PTY LTD

COWS COAL PROJECT (ML 10345)

FIGURE 3: CONCEPT LAYOUT DRAWING

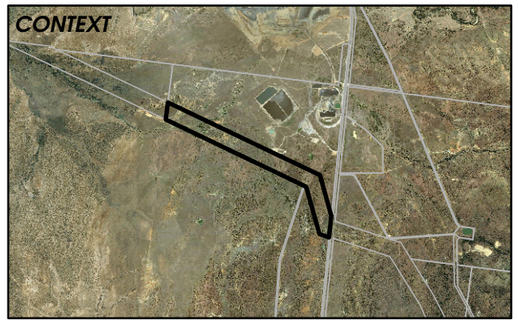
0 250 500 750 1,000
Metres @ A3

Scale: 1:15,000
Projection: UTM Zone 55
Datum: GDA 1994

N W E S

Legend

- Internal Access Road (2.5 km)
- Pit (34 ha & 7 ha)
- Out of Pit Waste Dump (9.2 ha)
- Run Of Mine/Mine Infrastructure Area (2.5 ha)
- Pond (1 ha & 3.3 ha)
- Topsoil Locations (2.3 ha)
- Haul Road Corridor (50 m wide; 19 ha)
- Cows ML 10345
- Digital Cadastral Database



Date: 10 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DEEDI, DERM & Google

3.0 REGIONAL AND SITE GEOLOGICAL SETTING

The Project area is situated in the northern part of the Bowen Basin (**Figure 4**)

3.1 Regional Geological Setting

Coal accumulation in the Bowen Basin has occurred in a wide variety of depositional environments (**Figure 5**).

The Lizzie Creek Volcanics (Early Permian) form the basal unit of the Bowen Basin and comprise andesitic to dacitic flows and pyroclastic rocks, conglomerate and black siltstone.

They are unconformably overlain by the Collinsville Coal Measures which comprises up to nine persistent coal seams. Depositional environments vary from initial fluviatile sediments that pass up into marginal marine sandstones. Coal seams grade into carbonaceous shale to the west of Collinsville. The Collinsville Coal Measures are conformably overlain by the Blenheim Formation.

Overlying this Back Creek sequences are the Moranbah Coal Measures, which represents the lowermost unit of the Blackwater Group (**Figure 4**). This unit comprises cross-bedded sandstone, siltstone, mudstone, and coal. Coal seams include only minor tuffaceous and mudstone bands. The sequence contains eight major seams (**Figures 6 and 7**). Historically the seams have been given the letter designations from A to R in accordance with stratigraphic order for the Bowen Basin. The Moranbah Coal Measures are overlain by the Fort Cooper Coal Measures near the eastern margin of the Project area.

Cainozoic		Sediments & volcanic rocks; and Suttor Formation
Triassic	Rewan Group	Arcadia Formation
		Sagittarius Formation
Late Permian	Blackwater Group	Rangal Coal Measures
		Fort Cooper Coal Measures (NAF)
		Moranbah Coal Measures (NAF)
	Back Creek Group	Exmoor Formation
		Blenheim Formation
Early Permian		Collinsville Coal Measures (PAF) / Gebbe Formation
		Tiverton Formation
		Lizzie Creek Volcanics / Bulgunnuna Volcanics
Late Carboniferous		

(NAF – Non-acid forming; PAF – Potentially acid forming)

Figure 5: Generalised Stratigraphy of the Northern Bowen Basin



QCOAL PTY LTD

0 20 40 60 80 100
Kilometres

Scale: 1:2,000,000 @ A3

Datum: GDA 1994

N W E S

Legend

- Cows Coal Project
- Bowen Basin

COWS COAL PROJECT (ML 10345)

FIGURE 4: BOWEN BASIN COAL MAP

Date: 13 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM & DEEDI

The Fort Cooper Coal Measures comprise lithic sandstone, conglomerate, mudstone, carbonaceous shale, inferior coal and numerous tuff horizons.

The Tertiary Suttor Formation rests unconformably on the underlying Permian Formations and consists predominantly of unconsolidated, fluviatile and lacustrine quartz-rich sediments.

Minor Tertiary volcanism in the form of volcanic sills and dykes occur in the Project area.

Economic coal measures within the Basin have been classified into four groups (Mutton, 2003):

I. The oldest (Early Permian) coals are restricted to the southwest areas of the Bowen Basin (e.g. at Minerva, south of Emerald).

II. The Group II (Early Permian) coal measures comprise several unconnected deposits around the northern and western margins of the Bowen Basin which have been mined by open-cut and underground methods. Group II coal measures occur as several unconnected but discreet deposits located around the northern margins of the Bowen Basin and in this region it includes the Collinsville Coal Measures (Mutton, 2003).

   Martini and Johnson (1987) have identified six sedimentary environments are in the Collinsville Coal Measures: fluvial, fluvial to paralic, barrier-strand plain, back-barrier, tidal flat and open marine. The basal coal formed from peat of swamps of abandoned areas of gravelly braided streams; the coals are massive, dull and sulphur contents are low (1%). Overlying coals developed from peats formed in fluvial to paralic and paralic environments; these thicker coal seams are generally brighter and have moderate to high total sulphur contents (1-6%). Seams associated with coastal deposits show high sulphur levels (up to 21%).

III. The Group III (Late Permian) coals were deposited on the Collinsville Shelf under conditions which fluctuated between marine-influenced deltaic environments to a fluvial flood-plain environment.

   The Moranbah Coal Measures (a Group III coal sequence) were deposited in a deltaic environment during the early stage of foreland basin development (Hodgkinson, 2008). This important coking coal bearing Measures were overlain by the heavily tuff banded Fort Cooper Coal Measures

   Geochemical analyses for the Moranbah Coal Measures have show significantly lower total sulphur content in comparison to the Collinsville Coal Measures described above.

   The Cows Project area, the former Belmore/Pipeline coal mine and Sonoma coal mine occur within the Group III – Moranbah Coal Measures. The stratigraphic profile for the Moranbah Coal Measures is mirrored in each of the three project areas. Detailed correlation is possible with a high degree certainty between all three project areas at scale which can facilitate mining of the B Seam and Q seam of the Moranbah Coal Measures.

IV. Late Permian coal measures of Group IV are the most widely distributed in the Basin and were deposited under fluvial, lacustrine and paludal environments. They include the Rangal Coal Measures, Baralaba Coal Measures and equivalents which have been extensively mined since the 1960s.

The wide variety of depositional environments is reflected in the diversity of coal measures (seam thickness, lateral extent and coal quality) but for Group III the physical and chemical characteristics of the non-productive geological sequences

(waste rock or spoil materials) are similar. It should be noted that Sonoma, Belmore and Drake Project area are restricted to the Moranbah Coal Measures, and therefore the stratigraphic sequences are mirrored at each project. The coal seams together with the interburden and overburden are readily correlated between all three sites. Analysis of the overburden at each of the three sites will demonstrate similar overburden characteristics with regard to acid-base accounting and geochemistry.

3.2 Site Geological Description

The stratigraphy of Cows Project area comprises the basal Blenheim Formation and overlain by the marine Exmoor Formation, non-marine Blackwater Group, and Tertiary sediments of the Suttor Formation and equivalents (**Figure 4**). The Blackwater Group in the Project area comprises the Moranbah and Fort Cooper Coal Measures.

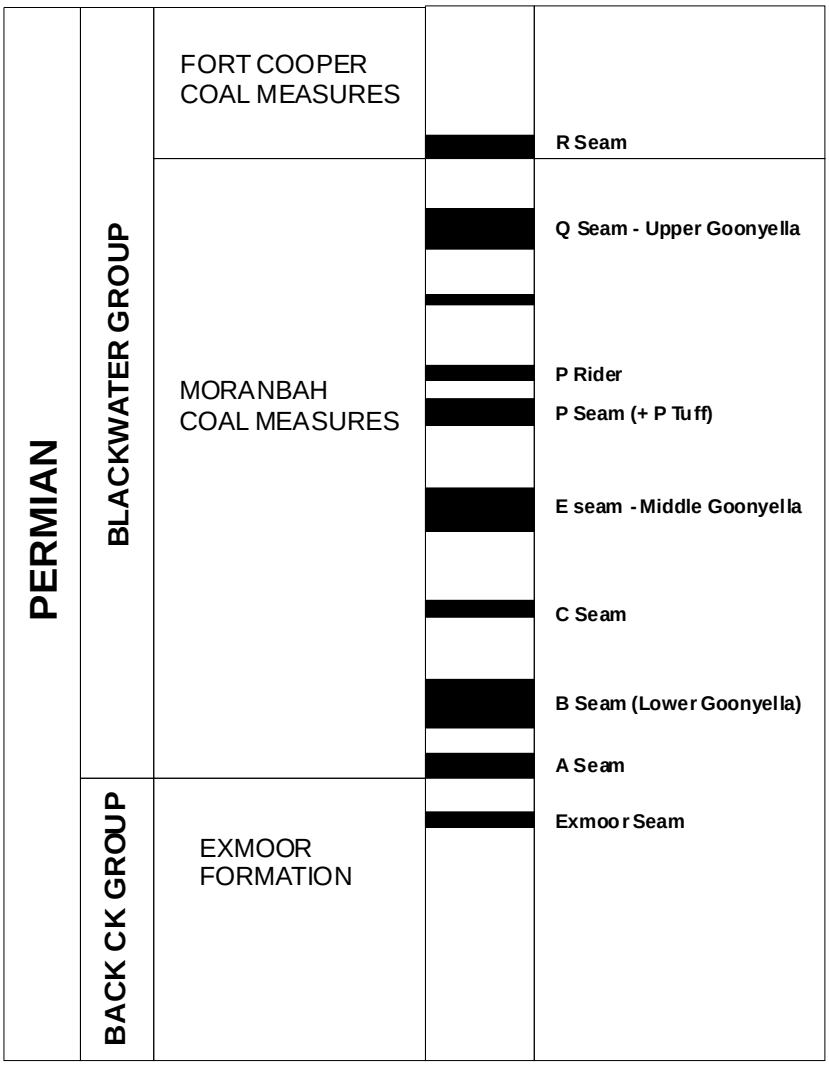


Figure 6: Coal-seam Nomenclature – Northern Bowen Basin

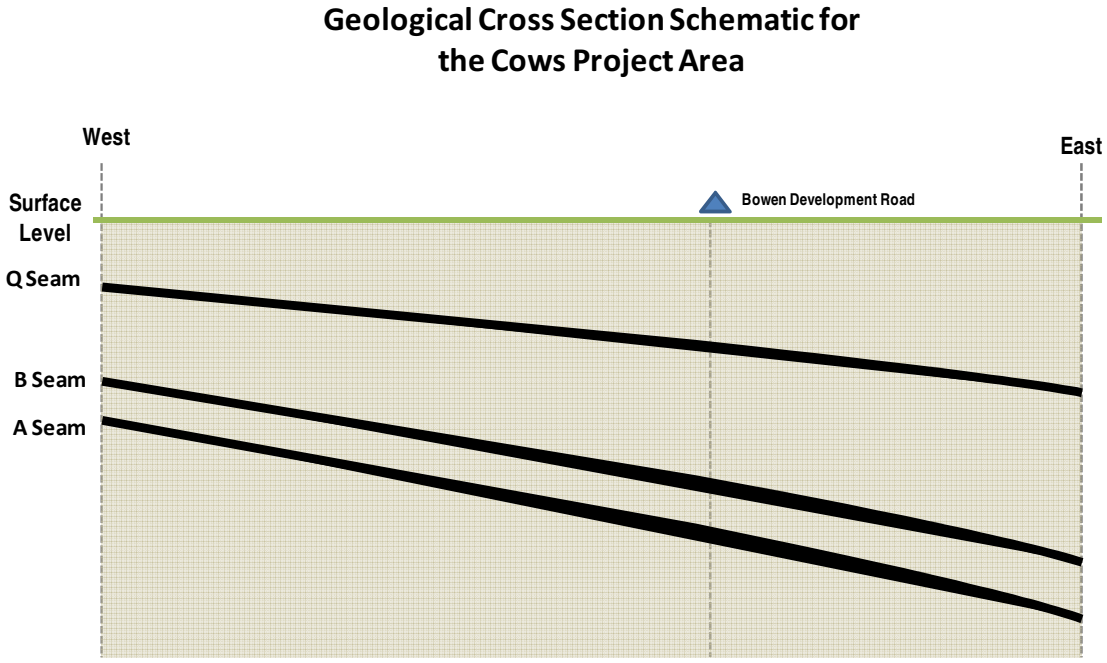


Figure 7: Representative Cross Section of the Moranbah Coal Seams

3.3 Sedimentary Iron-Sulphide Formation and Oxidation

Iron occurs in two valence states - ferrous (Fe^{2+}) and ferric iron (Fe^{3+}). The change from one oxidation state to another is dependent on changes in Eh and pH of the depositional environment. One factor affecting Eh is the amount of organic matter present. As the organic material is decomposed by bacterial action, oxygen is consumed thereby creating reducing conditions.

Ferric iron (Fe^{3+}) is stable under oxidising and alkaline conditions and conversely ferrous iron (Fe^{2+}) is stable under more reducing and acidic conditions.

The sulphide source for the precipitation of pyrite (Fe^{2+} S^{-}_{2}) in sedimentary sequences comes mainly from the bacterial reduction of dissolved sulphate in pore waters. As seawater also contains dissolved sulphate, pyrite is a typical authigenic mineral in organic-rich marine muds, that is, a mineral likely to form at the site of sediment deposition. Pyrite can also form in association with the bacterial reduction of sulphate in gypsum. In all cases, the precipitates are black, finely crystalline and can occur as disseminated or framboidal crystal growths.

In freshwater, dissolved sulphate is present in lower concentrations and therefore, pyrite is less likely to form in non-marine sediments.

Any activity that exposes common sulphide minerals to air has the potential to generate acid and metalliferous drainage (AMD) which has traditionally been referred to as *'acid mine drainage*' or *'acid rock drainage*' (DITR, 2007). The abundance of sulphide minerals in a sedimentary sequence is a key indicator of AMD risk. The generation of sulphuric acid (H^{+}) occurs typically when iron sulphide minerals are exposed to both oxygen (from air) and water. This reaction can be strongly catalysed by bacterial activity. The Global Acid Rock Drainage (GARD) guide (INAP, 2011) has three broad

categories (**Figure 8**) of mine drainage resulting from the oxidation of sulphides – acid mine drainage (AMD), neutral or alkaline mine drainage (NMD) or saline mine drainage (SD).

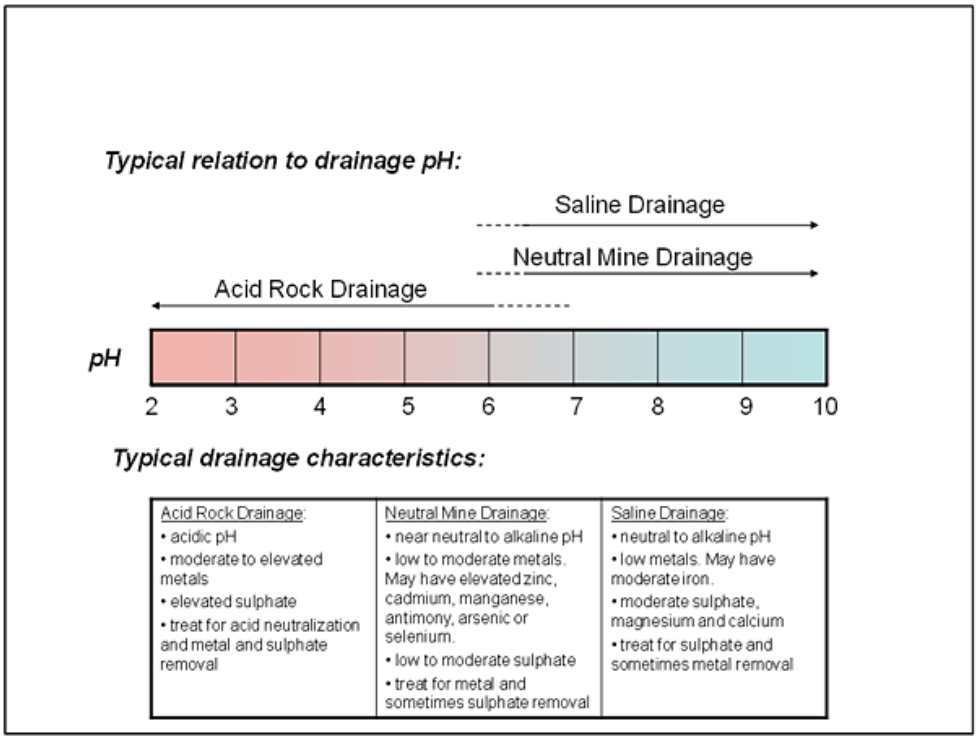


Figure 8: Types of drainage produced by sulphide oxidation

Sulphide oxidation (**Figure 9**) produces sulphuric acid and an orange precipitate, ferric hydroxide ($Fe(OH)_3$), as summarised in the reaction below:

$$FeS_2 + 3.75\ O_2 + 3.5\ H_2O \Longleftrightarrow Fe(OH)_{3\,(s)} + 2\ SO_4^{2-} + 4\ H^+$$

Iron sulphide + oxygen + water ⟺ Ferric hydroxide + Sulphate + Acid
(an orange precipitate)

Figure 9: Iron Sulphide Oxidation and Acid Generation

4.0 INVESTIGATION METHODOLOGY

A number of procedures have been developed to determine the acid forming characteristics of mine waste or spoil materials (AMIRA, 2002). The most widely used assessment methods are the acid-base account and net acid generation (NAG) tests. These methods are referred to as static procedures as each test involves a single measurement in time under laboratory conditions. Conversely, kinetic tests involve a number of measurements over time, usually under laboratory and field conditions during the life of mine operations.

Guidelines have been published by the Queensland Department of Mines and Energy (DME, 1995a) for the assessment and management of acid drainage. This assessment of AMD of overburden materials has followed this guideline.

The Cows Project area, the former Belmore/Pipeline coal mine and Sonoma coal mine all occur within the Moranbah Coal Measures. As the stratigraphic profile for the Moranbah Coal Measures is mirrored in each of the three project areas, detailed correlation is possible with a high degree certainty between all three project areas at a scale which can facilitate mining of the B seam and Q seam of the Moranbah Coal Measures. For this reason, the previous waste rock characterisation investigations for both Sonoma (Parsons Brinckerhoff, 2006) and Belmore-Pipeline (Collinsville Coal Company, 1999) have direct relevance to the Cows Project.

Analytical data is reproduced in **Appendix 1** for the Sonoma mine and **Appendix 2** for the former Belmore-Pipeline coal mine.

5.0 INVESTIGATION RESULTS

5.1 Sonoma Coal Mine

5.1.1 Acid Generation and Neutralisation Capacity

Laboratory test results indicated that all overburden samples have negative net acid producing potential meaning that the maximum theoretical acid production would be less than the theoretical capacity of the rock to neutralise the produced acid.

Carbonaceous mudstone and layers adjacent to coal seams were noted to contain minor pyrite and/or siderite. These pyritic layers could produce some acid drainage if they are concentrated near the surface of the spoil.

In March 2011, QCoal undertook additional sampling and waste rock characterisation investigations of the expected overburden materials. Waste rock samples from above the B seam (B_R_01 to B_R_06), C seam (C_R_01 & C_R_02) and Q seam (Q_R_01 & Q_R_02) were analysed for acid generation and neutralising potential (**Appendix 1, Tables 3 and 4**). All samples analysed were found to have low total sulphur contents (<0.03%), negative NAPP values and are therefore considered to represent NAF materials suitable for direct disposal into the overburden dumps.

However, it is suggested that layers of coal roof and floor material, and any material that is visually assessed at the time of mining as containing pyrite, should not be concentrated near the surface of the spoil stockpile.

5.1.2 Acidity/Alkalinity, Salinity and Cation Exchange Capacity

Alluvial soils encountered were mainly of low to moderate salinity (EC < 600µS/cm , intermediate pH (< pH 9) value and ESP values less than 15 and are considered suitable for spoil stockpile capping material.

The breakdown products of the weathered Permian rocks are estimated to have intermediate to moderate salinity and sodicity and moderately high pH value. They are considered as suitable for spoil stockpile capping material with moderate erosion potential and moderate growth medium characteristics for re-establishment of vegetation. Spreading of topsoil and re-shaping of spoil stockpiles to reduce potential for concentrated runoff would reduce the erosion potential of these soils.

Fresh Permian age claystone, mudstone, siltstone and labile sandstone encountered to about 70 m depth are considered as less suitable for spoil stockpile capping material than sandstone.

An analysis of the cation exchange capacity (CEC) and sodicity were undertaken to determine the potential environmental risks associated with saline and/or sodic waste rock materials (**Appendix 1, Table 5**).

Sodicity refers to a high proportion of sodium (Na^{+}) ions relative to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in overburden materials, soil or water. Sodicity can degrade soil structure by breaking down clay aggregates, which makes the soil more erodible and less permeable to water, and reduces plant growth (DME, 1995a).

A number of important physical parameters are affected by the proportion of the various cations (calcium, magnesium, sodium, potassium) in the waste material. If the Ca/Mg ratio is low (less than 2) and sodicity or the proportion of sodium (ESP) is high (>12%), then waste rock/soil materials will be more prone to dispersion. Alluvial soils encountered on

Sonoma (PB, 2005)were mainly of low to moderate salinity (EC < 600µS/cm , intermediate pH (< pH 9) value and ESP values less than 15 and are considered suitable for spoil stockpile capping material.

The breakdown products of weathered Moranbah Coal Measures are estimated to have intermediate to moderate salinity and sodicity and moderately high pH value (PB, 2005). They are considered as suitable for spoil stockpile capping material with moderate erosion potential and moderate growth medium characteristics for re-establishment of vegetation. Spreading of topsoil and re-shaping of spoil stockpiles to reduce potential for concentrated runoff would reduce the erosion potential of these soils.

Fresh claystone, mudstone, siltstone and labile sandstone of the Moranbah Coal Measures encountered to about 70 m depth are considered as less suitable for spoil stockpile capping material than sandstone (PB, 2005). It is noted that these particular lithologies represent less than 10 percent of the total volume of overburden (**Table 2**). High alkalinity of rocks from below about 70 m depth is indicating potential for dispersion that was also confirmed by ESP values (PB, 2005).

5.1.3 Trace Element Geochemistry

In March 2011, QCoal undertook additional sampling and waste rock characterisation investigations of the expected overburden materials. These samples were also assayed for total metals content (**Appendix 1**, **Table 6**) and metals leachate content using toxicity characteristic leaching procedure in neutral, pH 9 and pH 11 conditions (**Appendix 1**, **Tables 7, 8 and 9 respectively**). Two of the Sonoma samples (2011 data) recorded elevated Mn (945 & 2730 mg/kg) and V (86 & 80 mg/kg) levels. . All samples returned very low levels of metals leaching into to solution (**Appendix 1, Tables 7, 8 and 9**) and results were well below the ecological investigation levels for soils published by the National Environmental Protection Council (1999a & b). The following summary is representative of data:

- As < 0.1 mg/kg;
- Cd < 0.05 mg/kg;
- Co < 0.2 mg/kg;
- Se < 0.005 mg/kg; and
- Zn < 0.5 mg/kg.

5.1.4 Surface Water Monitoring

An indication of the likely surface water quality at Cows can be achieved by reviewing the Sonoma experience. Surface water quality monitoring in Sonoma's sediment control dams, open-cut pit and borrow pit was undertaken in November 2011, and is ongoing (**Appendix 3, Table 14 and Figure 5**). The majority of analytes tested are below the trigger values for freshwaters (ANZECC, 2000: Table 4.4.1). The exceptions are discussed in more detail below.

A single pit water sample had a dissolved As level of 0.032 µg/L, which is above the trigger value (0.013 µg/L) for freshwaters in slightly to moderately disturbed catchments (ANZECC, 2000: Table 4.4.1 & Table 4.4.2). The pit water also returned a Se value of 0.06 µg/L, which is above the trigger value of 0.011 µg/L. SD4 also recorded an elevated Se value of 0.03 µg/L.

Elevated dissolved copper levels (0.002 µg/L) were recorded in two sediment control dams, SD 3 and SD 4 (**Appendix 3, Table 14**). It should be noted that dissolved copper can be readily removed from solution by precipitation as metallic copper.

5.1.5 Groundwater Monitoring

Hydrogeological investigations have been undertaken for the Sonoma Coal Mine (AGE, 2005), located immediately to the north of the Cows Project and for the Coal Project to the south of Cows (Geoaxiom, 2010). These two studies found the regional groundwater regime to be confined to Cainozoic colluvial/alluvial sediments and deeper confined aquifers within the Moranbah Coal Measures. There are no records of bores in the coal measures being used for stock and domestic purposes and no significant groundwater was encountered during exploration drilling in the Cows lease (Geoaxiom, 2011).

Since the development of the Sonoma Coal Mine in 2007, regular monitoring has been undertaken on a 3 monthly basis. Recent data from this monitoring program has been supplied by QCoal and in presented in **Appendix 3 Table 15** with the bore locations shown in **Appendix 3 Figure 6**. The field data collected at Sonoma confirms the low variability in groundwater levels throughout the area (Geoaxiom, 2011).

The results of laboratory analysis undertaken during the Sonoma Coal Project EIS (AGE 2005) and for the Coal Project to the south of Cows indicate that the groundwater and surface waters have a neutral pH and the groundwater found in alluvial aquifers was relatively fresh. Analysis of water from coal seam monitoring bores to the south of Cows shows this groundwater is unsuitable for domestic or irrigation use due to the high chloride and sodium levels. EC and pH data are given for monitoring bore to the north of Cows in (**Appendix 3, Table 15)**. The concentration of nutrients are reported as being relatively low in both groundwater and surface water samples as were the concentrations of metals. In general groundwater, particularly where available from the alluvial aquifer, is suitable for stock use (Geoaxiom, 2011).

The alluvial aquifer is considered to have a low vulnerability to contamination form mining operations due to the protective cover of black clay soil throughout much of the area. Where the surface clays are removed the alluvial aquifer will have little protection from potential surface contaminants (Geoaxiom, 2011).

Upon cessation of mining groundwater inflow will continue into the pit until a point of equilibrium is reached with the potential development of a pit lake. It is expected that the majority of this inflow will be derived from the alluvial aquifer and surface runoff. Given that average evaporation exceeds rainfall in this region it is expected that the two pit lakes will provide a permanent cone of depression in the surrounding aquifers (Geoaxiom, 2011). Given that the majority of inflow is expected to be derived from the alluvial aquifer and surface runoff it is anticipated that the resultant pit water quality will be slightly brackish and may still be suitable for limited stock use. Given the pit lake will be provide a permanent cone of depression there is very little likelihood of contamination of surrounding aquifers from pit lake water (Geoaxiom, 2011).

5.1.5 Geotechnical Assessment

Particle size distribution was determined on 6 soil samples. Results are shown in **Appendix 1** (**Table 1**) and were used for soil classification and assessment of erosion potential.

Dispersion potential of soils is assessed by Emerson class number test. Classes 1 to 3 are considered dispersive, class 4 indicates the presence of carbonate or gypsum, classes 5 and 6 are considered non-dispersive, and classes 7 and 8 are non-slaking. The Emerson class number test results are tabulated in **Appendix 1** (**Table 2**).

Tertiary/Quaternary age clayey sands and sandy clays and weathered or fresh Permian age siltstones and sandstone are considered suitable as potential road and rail embankment and pavement materials provided selected excavation is possible and practical (Parsons Brinckerhoff, 2006 a & b).

5.2 Belmore Pipeline Coal Mine

5.2.1 Acid Generation and Neutralisation Capacity

At the former Belmore Pipeline Coal Mine the acid-base accounting results show neutral, uniform, non-saline geochemistry throughout the profile with no potential for acid drainage in the short, medium or long term. The results listed in **Appendix 2** (**Tables 10 and 11**) are better demonstrated as scattergrams comparing the value obtained against the depth of overburden **Appendix 2, Figures 1 and 2**. The characteristics of overburden at depth are important to understand as the mining process will mix and tum over the various layers of strata.

In calculating acid base accounting, using an estimate of sulphides to determine total potential acidity is more accurate than using total sulphur content alone. Pyrite is assumed to be the main species of sulfide and has been determined by subtracting the total sulfur from the soluble sulfate values **Appendix 2 (Table 10).** A portion of the 'pyritic sulfur' is organic or unreactive, thereby overestimating the total acid potential (Morin, et al.1997).

Appendix 2, Figure 3 shows values of pyritic sulphur less than 0.016 %. In comparison with acid base accounting conducted on the Collinsville mine overburden samples (Slater, 1991), values of greater than 0.4% pyritic sulphur were an indication of potentially acid producing material, after taking into consideration the neutralising capacity of the material involved. Most values are <0.006% and hence very low sulphur content.

Appendix 2, Figure 4 shows the gross neutralising capacity, which is expressed as kg H_2S0_4 per tonne of spoil. For comparison, the assessment of neutralising capacity of overburden at Collinsville resulted in values generally less than 10 (with one result of 20) (Slater, 1993). **Figure 3, Appendix 2** indicates that there are very low levels of sulphur in the spoil that could potentially react to produce acidic drainage and that the inherent buffering capacity of the spoil far exceeds any requirements for further neutralisation.

The Belmore-Pipeline mine is located in different geological units to that of the Collinsville coal mine. The Belmore-Pipeline overburden materials and the coal seams do not contain pyrite and little sulphur and therefore has no capacity to produce acid drainage. ABA data for each metre of overburden is presented in **Appendix 2, Table 10**. The mean NAG values for the samples are listed in **Appendix 2, Table 11.** When assessed against the ANC values, the materials were classed as strongly non-acid forming. The calculation of the values used in the accounting process contemplates the worst case scenario and does not consider rates of acid production as influenced by oxygen availability, water, temperature, or the size or surface area (reactivity) of the pyrite present.

5.2.2 Acidity/Alkalinity and Salinity

The pH values in **Appendix 2** (**Figure 1**) clearly illustrate the benign nature of the overburden. The elevated alkalinity at depth will not pose a rehabilitation problem, as the material closest to the coal seam will be buried.

The electrical conductivity of a sample gives an indication of the salinity levels of the spoil**. Figure 2, Appendix 2** shows the conductivity levels of the spoil down the profile allowing the spoil to be classified as non-saline.

Even though the Belmore Pipeline overburden material was essentially uniform in lithology and initial characteristic assessment, composite samples were formed from each drill hole and tested further. The second series of analyses included a full assessment of chemical characteristics, cation exchange capacity, water holding capacity, and dispersion potential.

The cation exchange capacity values listed in **Appendix 2 (Table 13)** indicates the ability of the spoil to hold nutrients. Leaching of cations used in plant growth can become a problem in soil with a very low cation exchange capacity e.g. less than 5.

The water holding capacity indicates the extent of available water for vegetation that can be drawn from the spoil. All of these factors indicate that the spoil is not limited in providing a media suitable for vegetative growth.

A list of the relative salt tolerances for a selection of pastures is provided in **Table 3**.

Table 3: Tolerance of Pasture Grasses to Salinity in Irrigation Water

Pasture	Scientific Name	Av. Root Zone EC Threshold (µS/cm)	EC Threshold (µS/cm)		
			Sand	Loam	Soil
Wheatgrass, tall	*Agropyron elongatum*	**7500**	12500	7200	4200
Rhodes grass, Pioneer	*Chloris gayana*	**7000**	12800	7300	4200
Couch grass	*Cynodon dactylon*	**6900**	10800	6100	3600
Buffel grass, Gayndah	*Cenchrus ciliaris var Gayndah*	**5500**	8200	4700	2700
Phalaris	*Phalaris tuberosa (aquatica)*	**4200**	5300	3000	1800
Fescue	*Festuca clatior*	**3900**	7300	4200	2400
Green panic, Petri	*Panicum maximum*	**3000**	5600	3200	1800
Townsville stylo	*Stylosanthes humilis*	**2400**	3700	2100	1200
Clover, Berseem Clover	*Trifolium alexandrinum*	**2000**	3800	2200	1300
Lucerne, Hunter River	*Medicago sativa*	**2000**	4700	2700	1600
Clover, strawberry (Palestine)	*Trifolium fragiferum*	**1600**	3300	1900	1100
Snail medic	*Medicago scutellata*	**1500**	2900	1700	1000

Source: ANZECC Water Quality Guideline (2000), Table 4.2.5

5.2.3 Trace Element Geochemistry

Appendix 2 (Table 11) lists the trace element geochemistry determined per drill hole for the Belmore Pipeline Coal Mine. These results reflect the trace element chemistry recorded at Sonoma, and the data contains no anomalous metal levels apart from Mn and V. Both metals tend to be elevated in weathered or oxidised sediments due to low solubilities in neutral waters.

5.2.4 Geotechnical Assessment

Appendix 2, Table 13 shows the proportions of the various fractions that make up the spoil. Due to the uniform nature of the overburden, the spoil will not be substantially different from the existing profile (CEC, 1999).

6.0 OVERBURDEN MANAGEMENT PRACTICES

There are no specific requirements to design overburden dumps to encapsulate PAF materials, as the Cows-Sonoma-Belmore overburden materials have been shown to be non-acid forming (NAF). However, small quantities of low-grade coal and carbonaceous siltstone/mudstone/shale maybe potentially acid forming, these materials should not be placed on the outer batters of the Cows overburden dumps. The impacts of any acid generation will be negated by the high neutralising capacity of the lithologies to be placed within overburden dumps. Due to the lack of high levels of trace elements in the Belmore waste, it is inferred that the risk of metals leachate and saline (neutral mine drainage) waters from Cows will also be minimal.

For progressive rehabilitation purposes, an operational Overburden Management Plan will be developed for the activity to ensure the conclusions of this report are valid and to ensure there is a detailed geochemical analysis conducted on the overburden inventory for residual calculations (progressive rehabilitation). The Overburden Management Plan may include one or a combination of the standard water treatment practices outlined in **Figure 10** below.

Salinity values for both Sonoma and Belmore overburden and regional groundwater regime have been demonstrated to be low. Specific requirements to manage salinity are outlined water management plan and should include ongoing surface and groundwater quality monitoring for changes in pH, EC and total sulphate levels above the background levels reported in **Appendix 3**.

The GARD Guide (INAP, 2011) provides a generic range of drainage treatment technologies (**Figure 10**) for ARD, NMD and SD issues.

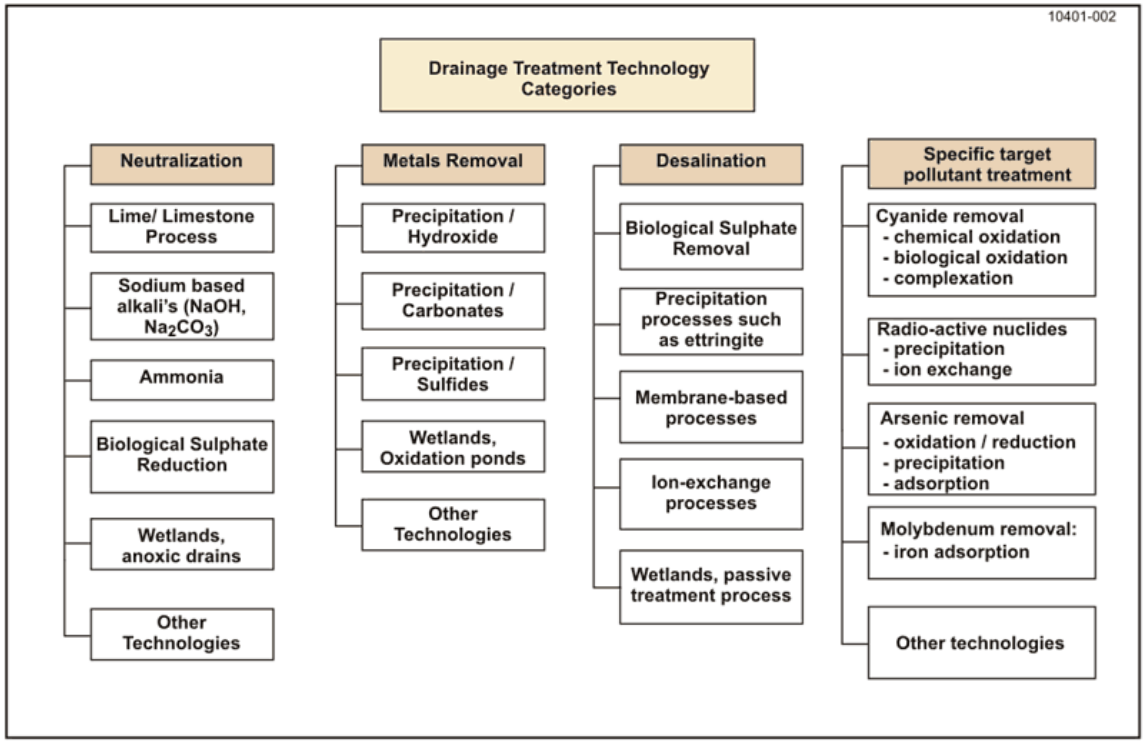


Figure 10: Mine Drainage Treatment Technologies

Site planning and analysis has been completed to identify the natural features for consideration in planning and design of the water management and erosion control structures. Stormwater drainage requirements and constraints have been assessed, including flood control (Q1000 flood limit), the maintenance of natural drainage features and the planning for stormwater management structures and the impact on adjacent sites and receiving waters. Wetlands of environmental significance are not located within the catchment west of the Cows project area.

To minimise disruption to landforms and natural hydrological features, a conceptual plan for the water management structures are being prepared a suitably qualified engineers.

The conceptual plan has been prepared to ensure that there is adequate land area in appropriate locations designated for the purpose of stormwater management.

Wherever practicable, clean runoff entering the site from external areas shall be diverted around disturbed areas in a manner that minimises soil erosion.

During mining activities, measures (such as establishing grass or placement of rock armouring) shall be employed to control flow velocities in such a manner that prevents soil erosion along drainage lines.

Appropriate scheduling of construction and mining activities will minimize the area disturbed, duration of soil exposure and any negative effects of climatic conditions (eg from high rainfall or strong winds). The design, construction and operation of these water management structures will follow stormwater treatment guidelines (DERM, 2008).

The following site management practices will be implemented:

a) All personnel or contractors conducting mining activities on site shall conduct such activities in accordance with the requirements of relevant environmental legislation.

b) Operational schedules for mining activities will aim to minimise the duration that disturbed lands are exposed to the erosive effects of wind and rain.

c) QCoal shall be responsible for ensuring that mining activities are undertaken to minimise erosion and to limit sediment deposition.

d) ensure moderately saline material (11%) is placed inside the pit shell and not placed on the external batters/surface of the in pit overburden dump

e) Any material conducive to disperse (ESP), shall be placed inside the pit shell and buried

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GLOSSARY

ABA	acid base accounting;
AMD	acid & metalliferous drainage;
ARD	acid rock drainage refers to low pH, high metal pollutants typical of sulphidic rocks & commonly mine wastes from the oxidation iron pyrites;
ANC	acid neutralizing capacity (kg/t H_2SO_4);
EC	electrical conductivity;
EIS	environmental impact statement;
MPA	maximum potential acidity (kg/t H_2SO_4);
NAF	non-acid forming;
NAG	net acid generation test or '*single addition NAG test*' (kg/t H_2SO_4);
NAPP	net acid producing potential (NAPP = MPA-ANC) (kg/t H_2SO_4);
PAF	potentially acid forming;
Pyrite	iron sulphide;
SRB	sulphate reducing bacteria;
Static test	procedure for characterizing the physical or chemical status of a geological sample at one point in time;
Total % Stotal sulphur (%);	
UC	uncertain classification.

APPENDICES

Appendix 1

Sonoma Coal Mine

Table 1: Particle Size Distribution Results (Sonoma, 2005)

			AS Sieve Size (mm)										
Hole No.	**Depth (m)**	**Lithology**	**26.5**	**19**	**9.5**	**4.75**	**2.36**	**1.18**	**0.6**	**0.425**	**0.3**	**0.15**	**0.075**
BR204C	3	Silty sandy clay			100	98	96	95	92	91	88	76	63
BR204C	6	Medium grained clayey sand			100	99	94	86	74	67	60	50	46
BR204C	16	Gravelly clayey sand		100	91	84	78	72	65	61	57	47	39
PC138	12	Medium to coarse grained clayey sand		100	99	92	81	73	65	56	49	41	36
BR215	18	Fine grained clayey sand			100	98	96	93	90	87	81	60	47
BR194	14	Sandy clay with gravel		100	98	91	86	93	79	76	73	62	52

Table 2: Emerson Class Number Test Results (Sonoma, 2005)

Bore No.	Depth (m)	Lithology	Emerson Class	Comment
BR204C	3	Silty sandy clay	**5**	Non-dispersive
BR204C	16	Gravelly clayey sand	**6**	Non-dispersive
BR204C	33	Clayey Gravel	**6**	Non-dispersive
BR215	6	Silty clay	**2**	Dispersive
BR194	14	Sandy clay with gravel	**6**	Non-dispersive

Table 3: Acid Generation and Neutralisation Potential Test Results (Sonoma, 2005)

Project	Hole Nos.	Depth (m)	NAPP	pH (Ox)	NAG (kg H_2SO_4/t)	ANC (kg H_2SO_4/t)	Total S	MAP	ANC/MAP
Sonoma	BR194	21	-75.1	11.1	<0.01	75.1	0.01	0.3	245.4
Sonoma	BR194	34	-35.6	10.3	<0.01	39.1	0.11	3.4	11.6
Sonoma	BR194	61	-71.7	9.8	<0.01	73.2	0.05	1.5	47.8
Sonoma	BR194	90	-50.5	10.2	<0.01	51.7	0.04	1.2	42.2
Sonoma	BR194	106	-49.3	10.2	<0.01	50.5	0.04	1.2	41.3
Sonoma	BR194	129	-57	10.8	<0.01	57.6	0.02	0.6	94.1
Sonoma	BR204C	33	-86.8	10.4	<0.01	89.3	0.08	2.4	36.5
Sonoma	BR204C	42	-59.2	10	<0.01	62.6	0.11	3.4	18.6
Sonoma	BR204C	61	-80.6	10.9	<0.01	81.2	0.02	0.6	132.7
Sonoma	BR204C	72	-66.2	10.8	<0.01	67.1	0.03	0.9	73.1
Sonoma	BR204C	100	-69.2	10.6	<0.01	70.1	0.03	0.9	76.4
Sonoma	BR204C	107	-75.8	11.1	<0.01	77.9	0.07	2.1	36.4
Sonoma	BR215	21	-39.8	9.7	<0.01	39.8	0.01	0.3	130.1
Sonoma	BR215	33	-45.4	9.9	<0.01	47.2	0.06	1.8	25.7
Sonoma	PC138	25	-104	10.9	<0.01	105	0.02	0.6	171.6
Sonoma	PC138	34	-112	10.8	<0.01	113	0.03	0.9	123.1
Sonoma	PC138	49	-57.6	10.8	<0.01	59.1	0.05	1.5	38.6
Sonoma	PC138	59	-58.8	8.2	<0.01	61.2	0.08	2.4	25.0

Table 4: Acid Generation and Neutralisation Potential Test Results (Sonoma, 2011)

Formation	Lithology	Sample	RL (m)	NAPP (kg H_2SO_4/t)	pH (Ox)	NAG (kg H_2SO_4/t)	ANC (kg H_2SO_4/t)	Total S	MAP	ANC/MAP	PAF/NAF
MCC[1]	Carbonaceous shale	B_R_01	80 - 87	-5.9	3.2	17.7	7.4	0.005	0.153	48.4	NAF
MCC[1]	Interbedded carbonaceous siltstone & sandstone	B_R_02	87 - 105	-5.5	3.2	6.5	6.4	0.003	0.0918	69.7	NAF
MCC[1]	Massive sandstone	B_R_03	105 - 120	-68.6	9.2	0.1	68.6	0.01	0.306	224.2	NAF
MCC[1]	Coarse-grained sandstone	B_R_04	120 - 130	-104	8.5	0.1	105	0.01	0.306	343.1	NAF
MCC[1]	Siltstone	B_R_05	130 - 137	-103	8.3	0.1	103	0.01	0.306	336.6	NAF
MCC[1]	TBA	B_R_06		-13.2	8.5	0.1	14.2	0.03	0.918	15.5	NAF
MCC[1]	Massive sandstone	C_R_01	154 – 165	-69.9	8.3	0.1	69.9	0.01	0.306	228.4	NAF
MCC[1]	Alluvium	Q_R_01	169 – 175	-148	8.8	0.1	148	0.01	0.306	483.7	NAF

Note 1: Moranbah Coal Measures (MCC)

Table 5: Acidity, EC, CEC and ESP Values (Sonoma, 2005)

Project	Sample ID	Depth	pH	EC (µS/cm)	CEC (meq/100g)	ESP* (%)
Sonoma	BR194	14	8.3	299	49.6	2
Sonoma	BR194	21	8.4	296	27	4
Sonoma	BR194	34	8.6	238	27.8	4
Sonoma	BR194	61	8.6	405	28.8	12
Sonoma	BR194	90	9.2	567	18.8	34
Sonoma	BR194	106	9.2	564	21.4	34
Sonoma	BR194	129	9	296	29	8
Sonoma	BR204C	3	8	380	51.4	4
Sonoma	BR204C	6	8	613	46.2	4
Sonoma	BR204C	16	7.8	595	39.4	4
Sonoma	BR204C	33	7.7	434	31.7	3
Sonoma	BR204C	42	8	360	24.1	7
Sonoma	BR204C	61	8.8	477	35	15
Sonoma	BR204C	72	9.2	604	30.7	22
Sonoma	BR204C	100	8.4	675	29.4	20
Sonoma	BR204C	107	9.1	397	26.6	14
Sonoma	BR215	6	8.6	924	53.8	18
Sonoma	BR215	18	8.3	511	42.6	9
Sonoma	BR215	21	8.1	343	28.8	6

Project	Sample ID	Depth	pH	EC (µS/cm)	CEC (meq/100g)	ESP* (%)
Sonoma	BR215	33	7.8	488	31.2	3
Sonoma	PC138	12	8.4	574	42.9	7
Sonoma	PC138	25	8	511	34.4	5
Sonoma	PC138	34	8.1	461	31.3	7
Sonoma	PC138	49	8.9	383	25.1	14
Sonoma	PC138	59	8.1	408	21	13

Calculated from CEC results

Note: Shaded results represent samples that are either excessively alkaline (pH> 9.0), contain excessive amount of dissolved solids (ie. salts, EC > 600 µS/cm) or are considered having high potential for dispersivity (ESP >15).

Table 6: Total Metals Analyses (Sonoma, 2011)

Formation	Sample	As[1]	Ba[1]	Be[1]	Cd[1]	Co[1]	Cr[1]	Cu[1]	Pb[1]	Mn[1]	Ni[1]	Se[1]	V[1]	Zn[1]	Hg[2]
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MCC[3]	B_R_01	<5	200	<1	<1	<2	<2	28	16	<5	3	<5	<5	72	<0.1
MCC[3]	B_R_02	<5	290	1	<1	9	3	30	28	253	14	<5	10	74	<0.1
MCC[3]	B_R_03	<5	320	<1	<1	3	<2	20	27	132	8	<5	<5	53	<0.1
MCC[3]	B_R_04	<5	140	<1	<1	19	7	15	<5	945	5	<5	86	31	<0.1
MCC[3]	B_R_05	<5	140	<1	<1	10	6	19	7	645	21	<5	21	50	<0.1
MCC[3]	B_R_06	6	260	2	<1	25	5	33	20	2730	27	<5	40	86	<0.1
MCC[3]	C_R_01	<5	400	<1	<1	31	4	22	14	733	30	<5	22	76	<0.1
MCC[3]	Q_R_01	<5	130	<1	<1	19	32	39	5	584	26	<5	80	63	<0.1
Background values(soils) – range or average[4]		6	1	<40	<1000	<100	<200	850	<500		<500	<300			
Ecological investigation values Soils[4]			3			100	600	500	60		50	200			

Note 1: Analytical procedure - ICP-AES; Note 2: Analytical procedure – FIMS; Note 3: Moranbah Coal Measures - MCC

Note 4:.. NEPC(1999)

Table 7: TCLP Neutral Leachate Analysis (Sonoma, 2011)

Formation	Sample ID	As[1]	Ba[1]	Be[1]	Cd[1]	Co[1]	Cr[1]	Cu[1]	Pb[1]	Mn[1]	Ni[1]	Se[1]	V[1]	Zn[1]	Hg[2]
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
MCC[3]	B_R_01	<0.1	2.2	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.05	<0.1	<0.1	<0.001
MCC[3]	B_R_02	<0.1	3.8	<0.05	<0.05	<0.1	<0.1	<0.1	0.2	0.4	<0.1	<0.05	<0.1	<0.1	<0.001
MCC[3]	B_R_03	<0.1	7.3	<0.05	<0.05	<0.1	<0.1	<0.1	0.1	2.9	0.1	<0.05	<0.1	0.2	<0.001
MCC[3]	B_R_04	<0.1	2.2	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	12.9	<0.1	<0.05	<0.1	0.5	<0.001
MCC[3]	B_R_05	<0.1	3.5	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	4	<0.1	<0.05	<0.1	0.1	<0.001
MCC[3]	B_R_06	<0.1	3.1	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	1.7	<0.1	<0.05	<0.1	<0.1	<0.001
MCC[3]	C_R_01	<0.1	11.5	<0.05	<0.05	0.2	<0.1	<0.1	<0.1	3.7	0.2	<0.05	<0.1	0.3	<0.001
MCC[3]	Q_R_01	<0.1	0.9	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	0.4	<0.1	<0.05	<0.1	<0.1	<0.001

Note 1: Analytical procedure - ICP-AES; Note 2: Analytical procedure – FIMS; Note 3: Moranbah Coal Measures - MCC

Table 8: TCLP Leachate Analysis pH 9 (Sonoma, 2011)

Formation	Sample ID	As[1]	Ba[1]	Be[1]	Cd[1]	Co[1]	Cr[1]	Cu[1]	Pb[1]	Mn[1]	Ni[1]	*Se[1]*	*V[1]*	*Zn[1]*	*Hg[2]*
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	*mg/L*	*mg/L*	*mg/L*	*mg/L*
MCC[3]	B_R_01	<0.1	**3.2**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*0.001*
		<0.1	**3.4**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	B_R_02	<0.1	**3.6**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	B_R_03	<0.1	**4.7**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	**0.1**	*<0.05*	<0.1	<0.1	*<0.001*
		<0.1	**3.4**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	B_R_04	<0.1	**0.8**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
		<0.1	**1.3**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	B_R_05	<0.1	**2.6**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
		<0.1	**2.1**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	B_R_06	<0.1	**2.4**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
		<0.1	**3.4**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	C_R_01	<0.1	**9.1**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	Q_R_01	<0.1	**0.6**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	**0.2**	*<0.05*	<0.1	<0.1	*<0.001*
		<0.1	**0.5**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*

Note 1: Analytical procedure - ICP-AES; Note 2: Analytical procedure – FIMS; Note 3: Moranbah Coal Measures - MCC

Table 9: TCLP Leachate Analysis pH 11 (Sonoma, 2011)

Formation	Sample ID	As[1]	Ba[1]	Be[1]	Cd[1]	Co[1]	Cr[1]	Cu[1]	Pb[1]	Mn[1]	Ni[1]	*Se[1]*	*V[1]*	*Zn[1]*	*Hg[2]*
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	*mg/L*	*mg/L*	*mg/L*	*mg/L*
MCC[3]	B_R_01	<0.1	**1.9**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*0.001*
MCC[3]	B_R_02	<0.1	**3.0**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	B_R_03	**0.1**	**2.8**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1		*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	B_R_04	<0.1	**1.0**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	B_R_05	<0.1	**1.4**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	B_R_06	<0.1	**2.1**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	C_R_01	<0.1	**6.2**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*
MCC[3]	Q_R_01	<0.1	**0.6**	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*<0.05*	<0.1	<0.1	*<0.001*

Note 1: Analytical procedure - ICP-AES; Note 2: Analytical procedure – FIMS; Note 3: Moranbah Coal Measures - MCC

APPENDIX 2

Former Belmore-Pipeline Coal Mine

Table 10: Analysis Results of Combined Drill Hole Overburden Samples for each metre below Ground Level

ID	Location	Hole Nos	Depth (m)	EC (Av.)	pH (Av.)	Gross ANC (Av.)	Total Sulphur (Av.)	MAP (Av.)	MAP/ANC (Av.)
B1	Belmore/Pipeline	**R1025**	1	180.3	7.6	32.2	0.0018	0.1	584.6
B2	Belmore/Pipeline	**R1026**	1						
B3	Belmore/Pipeline	**R1030**	1						
B4	Belmore/Pipeline	**R1031**	1						
B5	Belmore/Pipeline	**R1033**	1						
B6	Belmore/Pipeline	**R1041**	1						
B7	Belmore/Pipeline	**R1044**	1						
B8	Belmore/Pipeline	**R1025**	2	196.6	8.69	74.62	0.0016	0.049	1524.1
B9	Belmore/Pipeline	**R1026**	2						
B10	Belmore/Pipeline	**R1030**	2						
B11	Belmore/Pipeline	**R1031**	2						
B12	Belmore/Pipeline	**R1033**	2						
B13	Belmore/Pipeline	**R1041**	2						
B14	Belmore/Pipeline	**R1044**	2						

ID	Location	Hole Nos	Depth (m)	EC (Av.)	pH (Av.)	Gross ANC (Av.)	Total Sulphur (Av.)	MAP (Av.)	MAP/ANC (Av.)
B15	Belmore/Pipeline	**R1025**	3	187	8.74	73.64	0.0029	0.089	829.8
B16	Belmore/Pipeline	**R1026**	3						
B17	Belmore/Pipeline	**R1030**	3						
B18	Belmore/Pipeline	**R1031**	3						
B19	Belmore/Pipeline	**R1033**	3						
B20	Belmore/Pipeline	**R1041**	3						
B21	Belmore/Pipeline	**R1044**	3						
B22	Belmore/Pipeline	**R1025**	4	174.3	8.73	69.16	0.0026	0.080	869.3
B23	Belmore/Pipeline	**R1026**	4						
B24	Belmore/Pipeline	**R1030**	4						
B25	Belmore/Pipeline	**R1031**	4						
B26	Belmore/Pipeline	**R1033**	4						
B27	Belmore/Pipeline	**R1041**	4						
B28	Belmore/Pipeline	**R1044**	4						
B29	Belmore/Pipeline	**R1025**	5	167.9	8.74	79.24	0.0048	0.1	539.5
B30	Belmore/Pipeline	**R1026**	5						
B31	Belmore/Pipeline	**R1030**	5						
B32	Belmore/Pipeline	**R1031**	5						
B33	Belmore/Pipeline	**R1033**	5						

ID	Location	Hole Nos	Depth (m)	EC (Av.)	pH (Av.)	Gross ANC (Av.)	Total Sulphur (Av.)	MAP (Av.)	MAP/ANC (Av.)
B34	Belmore/Pipeline	**R1041**	5						
B35	Belmore/Pipeline	**R1044**	5						
B36	Belmore/Pipeline	**R1025**	6						
B37	Belmore/Pipeline	**R1026**	6						
B38	Belmore/Pipeline	**R1030**	6						
B39	Belmore/Pipeline	**R1031**	6	160.6	8.77	73.36	0.0044	0.1	544.9
B40	Belmore/Pipeline	**R1033**	6						
B41	Belmore/Pipeline	**R1041**	6						
B42	Belmore/Pipeline	**R1044**	6						
B43	Belmore/Pipeline	**R1025**	7						
B44	Belmore/Pipeline	**R1026**	7						
B45	Belmore/Pipeline	**R1030**	7						
B46	Belmore/Pipeline	**R1031**	7	155.6	8.73	65.66	0.0036	0.1102	596.0
B47	Belmore/Pipeline	**R1033**	7						
B48	Belmore/Pipeline	**R1041**	7						
B49	Belmore/Pipeline	**R1044**	7						
B50	Belmore/Pipeline	**R1025**	8						
B51	Belmore/Pipeline	**R1026**	8	155.3	8.7	72.66	0.0056	0.1714	424.0
B52	Belmore/Pipeline	**R1030**	8						

ID	Location	Hole Nos	Depth (m)	EC (Av.)	pH (Av.)	Gross ANC (Av.)	Total Sulphur (Av.)	MAP (Av.)	MAP/ANC (Av.)
B53	Belmore/Pipeline	**R1031**	8						
B54	Belmore/Pipeline	**R1033**	8						
B55	Belmore/Pipeline	**R1041**	8						
B56	Belmore/Pipeline	**R1044**	8						
B57	Belmore/Pipeline	**R1025**	9	143.5	8.83	75.63	0.006	0.2	411.9
B58	Belmore/Pipeline	**R1026**	9						
B59	Belmore/Pipeline	**R1030**	9						
B60	Belmore/Pipeline	**R1031**	9						
B61	Belmore/Pipeline	**R1033**	9						
B62	Belmore/Pipeline	**R1041**	9						
B63	Belmore/Pipeline	**R1025**	10	143.5	8.85	75.78	0.0059	0.2	419.7
B64	Belmore/Pipeline	**R1026**	10						
B65	Belmore/Pipeline	**R1030**	10						
B66	Belmore/Pipeline	**R1031**	10						
B67	Belmore/Pipeline	**R1033**	10						
B68	Belmore/Pipeline	**R1041**	10						
B69	Belmore/Pipeline	**R1026**	11	141.5	8.8	71.5	0.0046	0.1	508.0
B70	Belmore/Pipeline	**R1030**	11						
B71	Belmore/Pipeline	**R1031**	11						

ID	Location	Hole Nos	Depth (m)	EC (Av.)	pH (Av.)	Gross ANC (Av.)	Total Sulphur (Av.)	MAP (Av.)	MAP/ANC (Av.)
B72	Belmore/Pipeline	**R1041**	11						
B73	Belmore/Pipeline	**R1026**	12	138.0	8.80	80.60	0.005	0.15	526.8
B74	Belmore/Pipeline	**R1030**	12						
B75	Belmore/Pipeline	**R1031**	12						
B76	Belmore/Pipeline	**R1041**	12						
B77	Belmore/Pipeline	**R1026**	13	135.3	8.9	76.19	0.0044	0.13	565.9
B78	Belmore/Pipeline	**R1030**	13						
B79	Belmore/Pipeline	**R1031**	13						
B80	Belmore/Pipeline	**R1041**	13						
B81	Belmore/Pipeline	**R1026**	14	131.5	9.0	78.4	0.0042	0.13	610.0
B82	Belmore/Pipeline	**R1030**	14						
B83	Belmore/Pipeline	**R1031**	14						
B84	Belmore/Pipeline	**R1041**	14						
B85	Belmore/Pipeline	**R1026**	15	130	8.9	74.97	0.0044	0.13	556.8
B86	Belmore/Pipeline	**R1030**	15						
B87	Belmore/Pipeline	**R1031**	15						
B88	Belmore/Pipeline	**R1041**	15						
B89	Belmore/Pipeline	**R1026**	16	131.8	8.98	76.93	0.0056	0.2	448.9
B90	Belmore/Pipeline	**R1030**	16						

ID	Location	Hole Nos	Depth (m)	EC (Av.)	pH (Av.)	Gross ANC (Av.)	Total Sulphur (Av.)	MAP (Av.)	MAP/ANC (Av.)
B91	Belmore/Pipeline	**R1031**	16						
B92	Belmore/Pipeline	**R1041**	16						
B93	Belmore/Pipeline	**R1026**	17	128	9.05	73.26	0.0053	0.2	451.7
B94	Belmore/Pipeline	**R1030**	17						
B95	Belmore/Pipeline	**R1031**	17						
B96	Belmore/Pipeline	**R1041**	17						
B97	Belmore/Pipeline	**R1026**	18	136.5	8.78	76.19	0.0097	0.3	256.7
B98	Belmore/Pipeline	**R1030**	18						
B99	Belmore/Pipeline	**R1031**	18						
B100	Belmore/Pipeline	**R1041**	18						
B101	Belmore/Pipeline	**R1026**	19	126.3	9	80.68	0.0077	0.2	342.4
B102	Belmore/Pipeline	**R1030**	19						
B103	Belmore/Pipeline	**R1031**	19						
B104	Belmore/Pipeline	**R1031**	20	154	9.3	86.24	0.007	0.2	402.6
B105	Belmore/Pipeline	**R1031**	21	151	9.4	83.3	0.007	0.2	388.9
B106	Belmore/Pipeline	**R1031**	22	154	9.3	87.22	0.007	0.2	407.2
B107	Belmore/Pipeline	**R1031**	23	155	9.2	84.28	0.007	0.2	393.5
B108	Belmore/Pipeline	**R1031**	24	168	9.3	87.22	0.007	0.2	407.2
B109	Belmore/Pipeline	**R1031**	25	176	9.5	91.14	0.01	0.3	297.8

ID	Location	Hole Nos	Depth (m)	EC (Av.)	pH (Av.)	Gross ANC (Av.)	Total Sulphur (Av.)	MAP (Av.)	MAP/ANC (Av.)
B110	Belmore/Pipeline	**R1031**	26	210	9.3	68.6	0.018	0.6	124.5

Table 11: Acid Base Accounting of Overburden Samples (Belmore-Pipeline)

Depth	Net Acid Production							
	R1025	**R1026**	**R1030**	**R1031**	**R1033**	**R1041**	**R1044**	**Average**
1	12.7	38.1	18.6	16.6	43.1	19.6	76.4	32.2
2	91.1	36.2	76.4	85.2	89.1	64.7	79.4	74.6
3	91.1	54.9	88.2	90.1	85.2	59.6	46.1	73.6
4	91.1	49	65.6	87.2	89.1	62.7	39.2	69.1
5	91.1	67.6	70.5	90.1	90.9	67.6	76.4	79.2
6	91.1	63.7	79.3	83.2	75.3	54.9	65.6	73.3
7	91.1	52.9	54.9	86.2	80.3	65.6	28.4	65.6
8	91.1	80.3	70.3	82.2	71.5	57.8	54.8	72.6
9	91.1	65.6	82.3	87.1	71.4	55.8		75.6
10	82.3	64.6	81.3	86.1	80.2	59.7		75.7
11		86.2	55.8	85.2		56.8		71
12		88.1	75.7	84.2		74.5		80.6
13		62.7	82.2	87.1		72.5		76.2
14		89.2	60.7	83.2		80.4		78.4
15		74.4	64.6	84.2		76.4		74.9
16		86.2	76.4	85.2		59.7		76.9
17		75.4	70.5	85.2		61.7		73.2
18		90.1	62.7	89.1		62.3		76

Depth	Net Acid Production							
	R1025	**R1026**	**R1030**	**R1031**	**R1033**	**R1041**	**R1044**	**Average**
19		85.2	69.5	87.1				80.6
20				86.2				
21				83.2				
22				87.2				
23				84.2				
24				87.2				
25				91.1				
26				68.4				

Table 12: Chemical Analysis of Composite Drill Hole Samples

			Al	Br	Ca	Cl	Cr	Cu	F	Fe	Mg
			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Composite sample	Belmore/Pipeline	**R1025**	25200	<0.5	69500	4.8	8.6	46	3.9	35800	13100
Composite sample	Belmore/Pipeline	**R1026**	23200	<0.5	35600	0.65	42	35	1.4	42400	15500
Composite sample	Belmore/Pipeline	**R1030**	26700	<0.5	28200	1.5	39	39	5.1	45500	17200
Composite sample	Belmore/Pipeline	**R1031**	23000	<0.5	39800	18	36	36	1.4	16400	13900
Composite sample	Belmore/Pipeline	**R1033**	27000	<0.5	37100	53	36	35	3.6	51000	13900
Composite sample	Belmore/Pipeline	**R1041**	26300	<0.5	36700	<2.5	40	41	1.6	47400	14200
Composite sample	Belmore/Pipeline	**R1044**	26700	<0.5	35800	<2.5	29	42	5.5	45300	8950
	Background						0.5-110	1-190			
							50	60			

			Mn	Mo	Ni	NO_3	NO_2	P	K	Si	Na
			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Composite sample	Belmore/Pipeline	**R1025**	650	<10	5.6	<0.5	<0.5	600	770	54	270
Composite sample	Belmore/Pipeline	**R1026**	1000	<10	23	<0.5	<0.5	950	1020	96	230
Composite sample	Belmore/Pipeline	**R1030**	770	<10	25	<0.5	<0.5	930	900	76	320
Composite sample	Belmore/Pipeline	**R1031**	1150	<10	22	<0.5	<0.5	900	950	71	260
Composite sample	Belmore/Pipeline	**R1033**	950	<10	31	<0.5	<0.5	800	860	100	320
Composite sample	Belmore/Pipeline	**R1041**	980	<10	24	<0.5	<0.5	880	1030	80	155
Composite sample	Belmore/Pipeline	**R1044**	890	<10	17	<0.5	<0.5	870	770	56	230
	Background		4-12600	<1-20	2-400						
			500		60						

			SO_4	S	V	Zn
			mg/kg	mg/kg	mg/kg	mg/kg
Composite sample	Belmore/Pipeline	**R1025**	<2.5	78	94	83
Composite sample	Belmore/Pipeline	**R1026**	14	110	115	79
Composite sample	Belmore/Pipeline	**R1030**	24	110	110	90
Composite sample	Belmore/Pipeline	**R1031**	59	300	89	80
Composite sample	Belmore/Pipeline	**R1033**	42	170	120	135
Composite sample	Belmore/Pipeline	**R1041**	17	100	105	82
Composite sample	Belmore/Pipeline	**R1044**	3.7	36	100	75
	Background		35-1000			2-180

Table 13: Particle Size Analysis, Water Holding Capacity and Cation Exchange Capacity

Particle Size	R1025	R1026	R1030	R1031	R1033	R1041	R1044	Average
Gravel (>2 mm)	0.83	0.7	<0.01	<0.01	0.16	3.7	<0.01	0.68
Sand (50 µm – 2 mm)	80	88	94	91	88	83	94	88.3
Silt (2 µm – 50 µm)	16	11	5.7	8	11	13	6.1	10.1
Clay (< 2 µm)	1	0.3	0.2	0.2	0.4	0.4	0.2	0.4
Water holding capacity (%)	61	31	44	38	39	39	50	43.1
Cation exchange capacity (meq/100g)	3.9	1.4	5.1	1.4	3.6	1.6	5.5	3.2

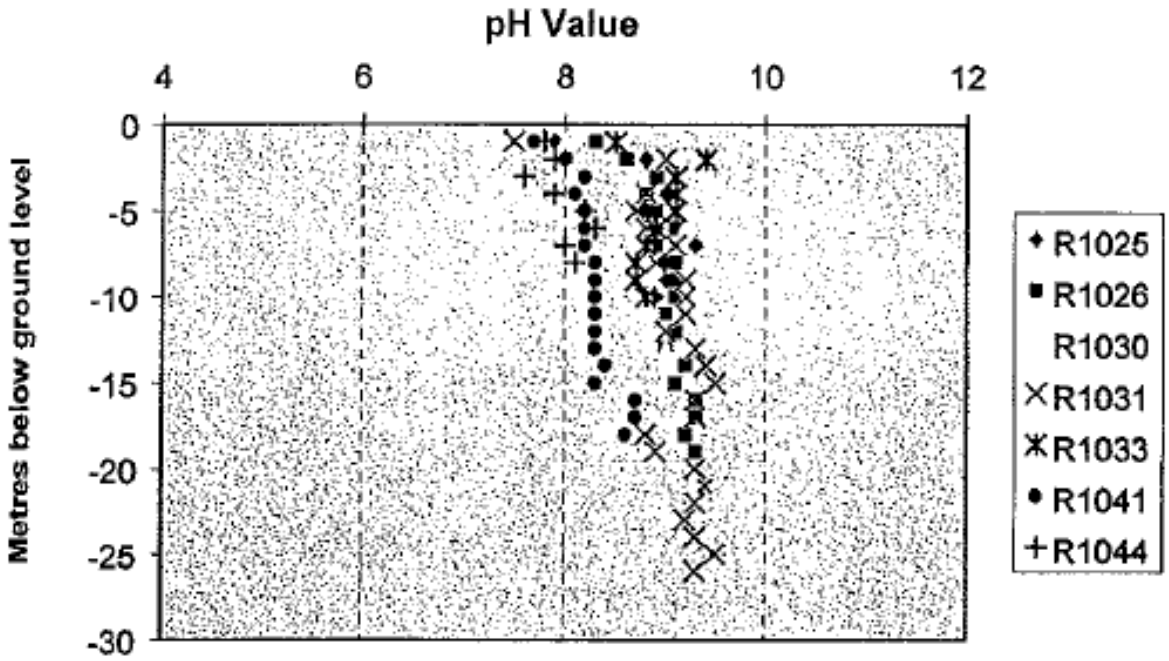


Figure 1: Scattergram of pH levels against depth of overburden

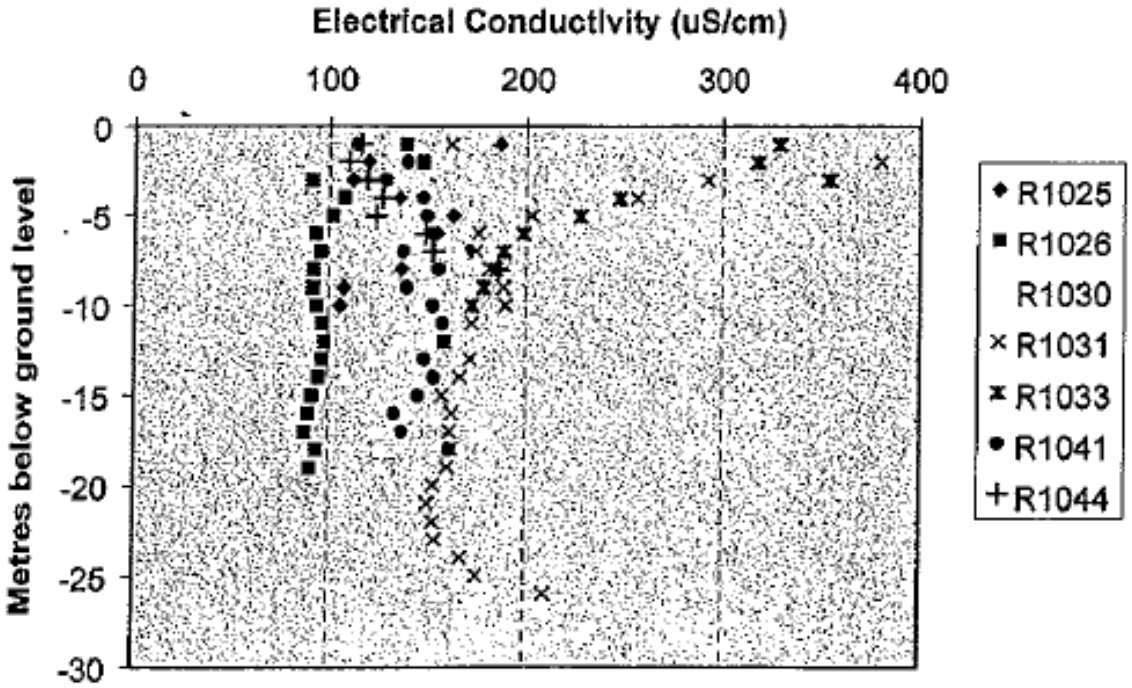


Figure 2: Scattergram of Electrical Conductivity levels against depth of overburden

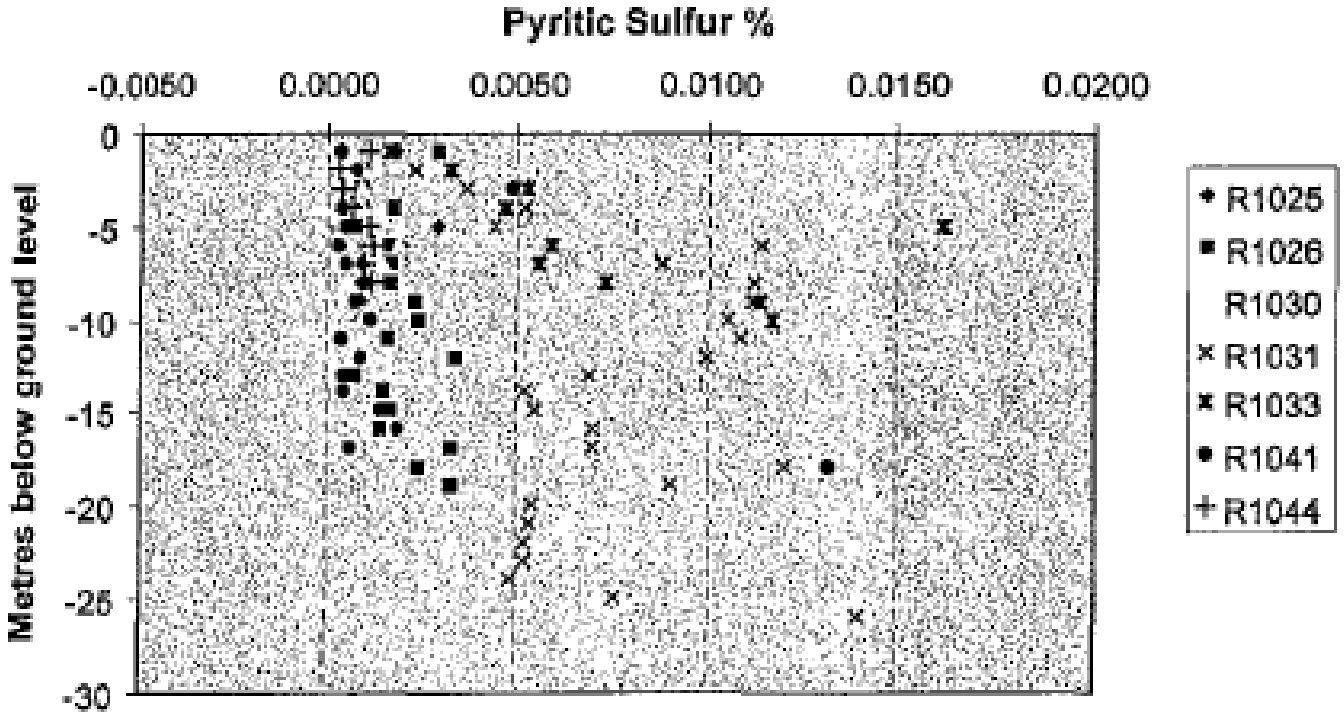


Figure 3: Scattergram of Pyritic Sulfur levels against depth of overburden

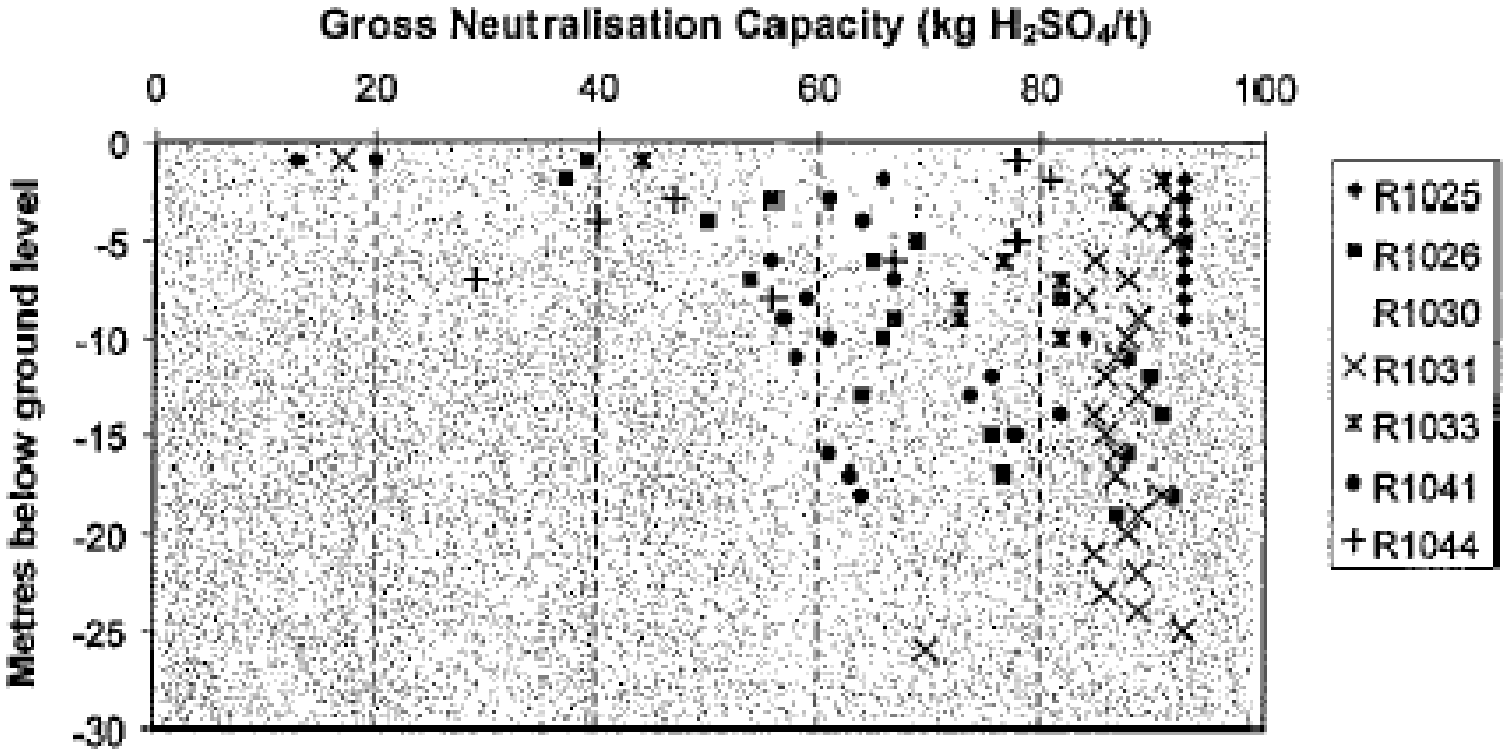


Figure 4: Scattergram of Gross Neutralising Capacity values against depth of overburden

Appendix 3

Sonoma Coal Mine

Table 14: Surface Water Monitoring Data

		Sample ID		ANZECC 2000 (mg/L)	SD3	SD4	Pit	SD8	Raw Water	SD5	Decant	Borrow Pit	SD7
		Date Sampled			17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010
Analyte	**CAS #**	**Units**	**LOR**		Water	Water	Water	Water	Water	Water	Water	Water	Water
pH Value		pH Unit	0.01		8.41	8.24	8.67	9.1	8.13	8.28	8	8.52	7.38
Electrical Conductivity @ 25°C		µS/cm	1		403	223	1170	1160	1600	1580	1800	304	1180
Suspended Solids (SS)		mg/L	5		210	2480	21	12	39	21	6	21	31
Turbidity		NTU	0.1		270	3860	71.9	13.9	23.3	11.3	3.2	21.3	30.3
Sulfate as SO4 - Turbidimetric	14808-79-8	mg/L	1		13	1	271	125	622	636	697	14	524
Calcium	7440-70-2	mg/L	1		16	2	10	9	148	152	192	13	80
Magnesium	7439-95-4	mg/L	1		10	1	5	16	83	90	106	4	55
Dissolved Metals by ICP-MS													
Aluminium	7429-90-5	mg/L	0.01	0.055	<0.01	0.12	<0.01	0.02	<0.01	<0.01	<0.01	0.03	<0.01
Arsenic	7440-38-2	mg/L	0.001	0.024 – 0.013	0.004	0.018	0.032	0.005	0.002	0.001	0.002	<0.001	0.006
Cadmium	7440-43-9	mg/L	0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	mg/L	0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

		Sample ID		ANZECC 2000 (mg/L)	SD3	SD4	Pit	SD8	Raw Water	SD5	Decant	Borrow Pit	SD7
		Date Sampled			17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010
Cobalt	7440-48-4	mg/L	0.001	ID	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Copper	7440-50-8	mg/L	0.001	0.0014	0.002	0.002	0.001	<0.001	0.001	0.001	0.001	<0.001	<0.001
Lead	7439-92-1	mg/L	0.001	0.0034	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	mg/L	0.001	1.9	<0.001	0.001	0.001	<0.001	0.042	<0.001	0.167	<0.001	0.136
Molybdenum	7439-98-7	mg/L	0.001	ID	0.003	0.031	0.06	0.051	0.029	0.023	0.026	0.009	0.061
Nickel	7440-02-0	mg/L	0.001	0.011	0.001	0.002	0.002	<0.001	0.001	<0.001	0.001	<0.001	0.002
Selenium	7782-49-2	mg/L	0.01	0.011	<0.01	0.03	0.06	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	mg/L	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	mg/L	0.001	ID	<0.001	<0.001	0.002	0.002	0.003	0.003	0.003	<0.001	0.001
Vanadium	7440-62-2	mg/L	0.01	ID	0.02	0.04	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	mg/L	0.005	0.008	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	7440-42-8	mg/L	0.05	0.370	0.07	0.07	0.06	0.08	<0.05	<0.05	<0.05	<0.05	0.15
Iron	7439-89-6	mg/L	0.05	ID	<0.05	0.08	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Metals by ICP-MS													
Aluminium	7429-90-5	mg/L	0.01		11	45.9	3.55	0.63	1.01	0.24	0.11	1.22	0.43
Arsenic	7440-38-2	mg/L	0.001		0.006	0.004	0.041	0.006	0.002	0.002	0.001	<0.001	0.007
Cadmium	7440-43-9	mg/L	0.0001		<0.0001	0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	mg/L	0.001		0.021	0.096	0.004	0.001	0.002	<0.001	<0.001	0.001	<0.001
Cobalt	7440-48-4	mg/L	0.001		0.01	0.04	0.003	<0.001	0.001	<0.001	0.001	<0.001	0.002

		Sample ID		ANZECC 2000 (mg/L)	SD3	SD4	Pit	SD8	Raw Water	SD5	Decant	Borrow Pit	SD7
		Date Sampled			17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010
Copper	7440-50-8	mg/L	0.001		0.023	0.12	0.009	0.003	0.006	0.004	0.003	0.002	0.006
Lead	7439-92-1	mg/L	0.001		0.005	0.033	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Manganese	7439-96-5	mg/L	0.001		0.356	0.537	0.018	0.009	0.097	0.009	0.219	0.021	0.181
Molybdenum	7439-98-7	mg/L	0.001		<0.001	<0.001	0.099	0.068	0.029	0.023	0.029	<0.001	0.086
Nickel	7440-02-0	mg/L	0.001		0.025	0.138	0.01	0.002	0.003	0.002	0.002	0.002	0.003
Selenium	7782-49-2	mg/L	0.01		<0.01	<0.01	0.07	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	mg/L	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	mg/L	0.001		<0.001	0.002	0.003	0.003	0.003	0.003	0.004	<0.001	0.001
Vanadium	7440-62-2	mg/L	0.01		0.06	0.22	0.02	0.02	0.01	<0.01	<0.01	0.01	<0.01
Zinc	7440-66-6	mg/L	0.005		0.041	0.224	0.011	<0.005	0.008	0.006	<0.005	0.006	0.016
Boron	7440-42-8	mg/L	0.05		0.07	0.05	0.07	0.07	<0.05	<0.05	<0.05	<0.05	0.15
Iron	7439-89-6	mg/L	0.05		14.4	57.2	1.3	0.64	0.72	0.21	<0.05	0.86	0.33
Dissolved Mercury by FIMS													
Mercury	7439-97-6	mg/L	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Other WQ Parameters													
Fluoride	16984-48-8	mg/L	0.1		0.6	0.6	0.6	0.5	0.4	0.4	0.5	0.7	0.4
Ammonia as N	7664-41-7	mg/L	0.01		0.03	0.21	0.06	0.01	0.27	0.02	0.61	2.05	0.02

		Sample ID		ANZECC 2000 (mg/L)	SD3	SD4	Pit	SD8	Raw Water	SD5	Decant	Borrow Pit	SD7
		Date Sampled			17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010	17/11/2010
Nitrite as N		mg/L	0.01		<0.01	0.06	1.64	0.14	0.25	0.07	0.18	0.51	<0.01
Nitrate as N	14797-55-8	mg/L	0.01		<0.01	0.17	23	4.9	1.59	0.26	0.81	18.6	<0.01
Nitrite + Nitrate as N		mg/L	0.01		<0.01	0.24	24.7	5.04	1.84	0.33	0.98	19.1	<0.01
Dissolved Oxygen		mg/L	0.1		7.6	7.9	9.4	8.3	8.5	10.1	9.9	9.6	8.1
C6 - C9 Fraction		µg/L	20		<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction		µg/L	50		<50	<50	<50	<50	<50	<50	<50	<50	400
C15 - C28 Fraction		µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	660
C29 - C36 Fraction		µg/L	50		<50	<50	<50	<50	<50	<50	<50	<50	60
C10 - C36 Fraction (sum)		µg/L	50		<50	<50	<50	<50	<50	<50	<50	<50	1120
1.2-Dichloroethane-D4	17060-07-0	%	surrogate		114	115	112	118	120	117	115	104	109
Toluene-D8	2037-26-5	%	surrogate		96.7	94.5	96.7	96.2	95.8	95.2	96.5	94.1	99.3
4-Bromofluorobenzene	460-00-4	%	surrogate		93.4	92.4	90.6	93	92.8	93.1	94.5	89	89.9

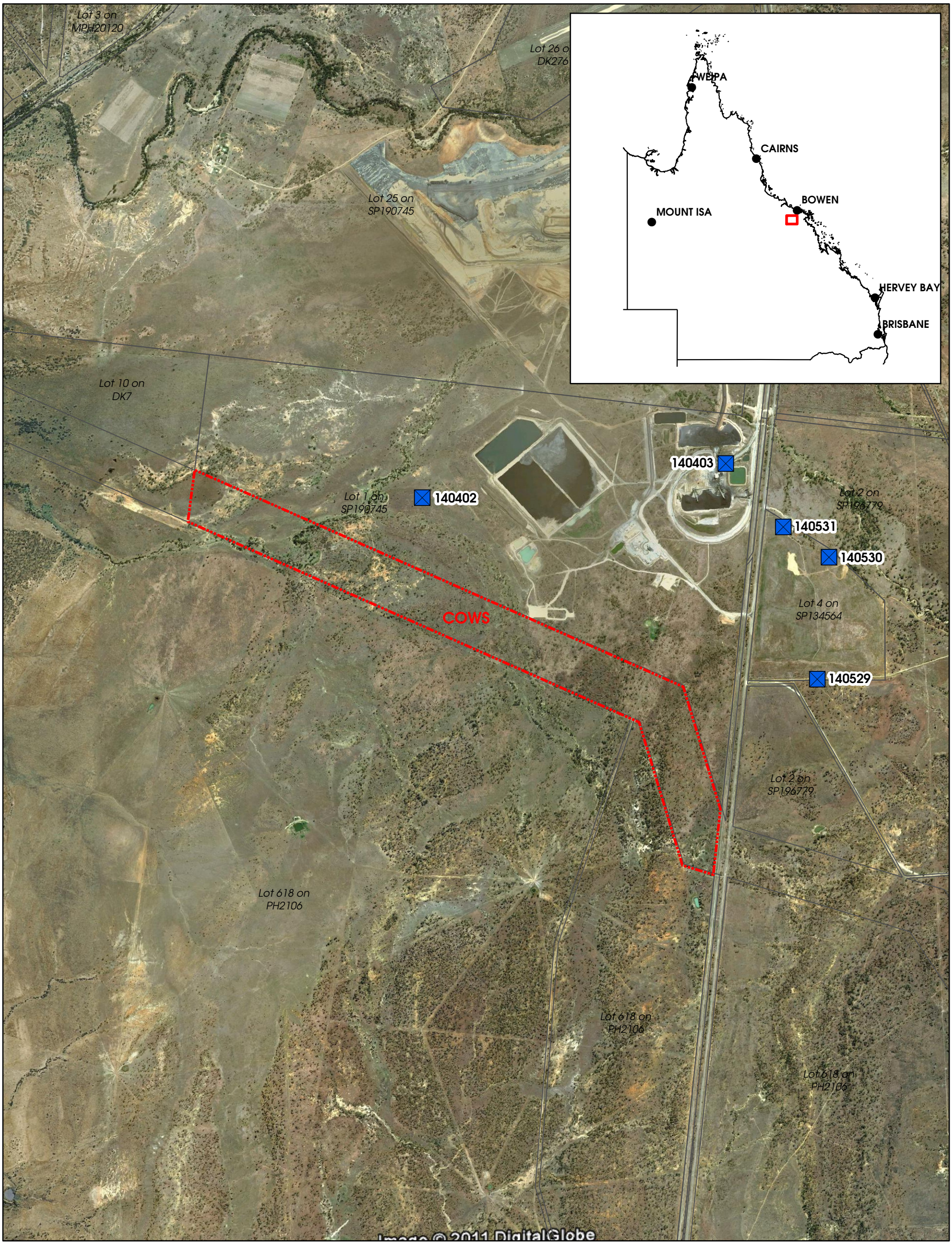
SD – Sediment Dam



Figure 5: Surface Water Sampling Points

Table 15: Groundwater Monitoring Data

Bore	RN	12 March 2010			16 June 2010			8 October 2010		
		SWL (m)	pH	EC	SWL (m)	pH	EC	SWL (m)	pH	EC
1	**140400**	12.31	7.13	884	12.21	7.07	972	12.49	7.08	884
2	**140401**	15.67	7.36	1188	15.88	6.95	1389	15.61	6.96	1593
3	**140402**	11.62	6.69	2874	11.0	6.42	3006	10.44	6.73	3231
4	**140403**	Dry			Dry			Dry		
5	**140404**	14.48	7.17	1471	13.57	6.67	1521	13.13	6.92	1535
6	**140405**	12.0	7.06	1353	12.0	7.17	1410	11.54	6.98	1450
7	**140406**	Dry			Dry			Dry		
8	**140407**	11.5	7.19	1260	11.2	6.95	1191	11.42	7.08	1189
9	**140408**	10.09	7.41	1635	Dry			10.15	7.51	1627



QCOAL PTY LTD

0 0.3 0.6 0.9 1.2 1.5
Kilometres

Scale: 1:25,000 @ A3

Projection: UTM Zone 55
Datum: GDA 1994

N W E S

Legend

- Registered Bores
- Cows Coal Project
- DCDB

COWS COAL PROJECT (ML 10345)

REGISTERED GROUNDWATER MONITORING BORES

Date: 11 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM & DEEDI

Drake Coal Pty Ltd

Environmental Impact Statement

Excavated Waste Characterisation Report

February 2013

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Appendices

Appendix A –Geochemical sample descriptions

Appendix B – ALS laboratory results

Appendix C – Whole rock metals and global abundance index results

Appendix D – Leachate results

Appendix E – Dispersivity results

List of Abbreviations

Term	Definition
ABA	Acid base account
ABCC	Acid buffering capacity curve
ALS	Australian Laboratory Services
AMD	Acid and metalliferous drainage
ANC	Acid neutralising capacity (kgH_2SO_4/tonne)
ARD	Acid rock drainage
CEC	Cation exchange capacity
CHPP	Coal handling and preparation plant
CRS	Chromium reducible sulfur
EC	Electrical conductivity
EIS	Environmental impact statement
EPC	Exploration permit coal
ESP	Exchangeable sodium percent
GAI	Global abundance index
ha	Hectares
ICP-MS	Inductively coupled plasma mass spectrometry
ICP-OES	Inductively coupled optical emission spectroscopy
kg	Kilogram
M	Million
Mt	Million tonnes
Mtpa	Million tonnes per annum
m	Metre
mbgs	Metres below ground surface
MPA	Maximum potential acidity calculated assuming that all sulfur is present as pyrite (kgH_2SO_4/tonne)
NAF	Non-acid forming - a classification in regard to potential for rock to be acid forming
NAG	Net acid generation (kgH_2SO_4/tonne)
NAPP	Net acid producing potential (kgH_2SO_4/tonne)
NMD	Neutral mine drainage
NPR	Net Potential Ratio
PAF	Potentially acid forming - a classification in regard to potential for rock to be acid forming
PAF-LC	Potentially acid forming and of low capacity to produce acid
pH	Negative logarithm of the concentration of hydrogen ions
ROM	Run of mine
SD	Saline drainage
t	Tonnes
TDS	Total dissolved salts
TIC	Total inorganic carbon
TOC	Total organic carbon

Term	Definition
tpa	Tonnes per annum
UC	Uncertain – a classification in regard to potential for rock to be acid forming

Executive Summary

The proposed Drake Coal Mine (the Project), located approximately 17 km south of Collinsville, Queensland, is being developed by Drake Coal Pty Ltd (Drake Coal; the Proponent); a wholly owned subsidiary of QCoal Pty Ltd (QCoal).

This excavated waste characterisation report was completed to ascertain the risk for over and interburden units proposed for disturbance at the Project to generate acid, neutral or alkaline drainage (AMD) as stated in the Drake Coal Mine Environmental Impact Statement (EIS) Terms of Reference (ToR).

Due to ongoing site access constraints at Drake, the Proponent had been unable to enter the proposed mine site area to undertake intrusive geochemical sampling for subsequent analysis to inform the excavated waste section of the Drake EIS. Therefore, the Proponent submitted a desktop excavated waste assessment in the Drake EIS submitted for Project approval in May 2012. Within that desktop report, the Proponent committed to completing additional sampling and analysis to further characterise the excavated waste material on site, to better inform the forward risk of handling and storing the excavated waste rock on site.

This report therefore, forms a stand-alone technical report within the Drake Coal Mine Supplementary Environmental Impact Statement (SEIS) to add to the desktop excavated waste assessment in the Drake EIS submitted for Project approval.

Drake Coal are seeking approval to mine up to 10 million tonnes per annum (Mtpa) of run of mine (ROM) coal over the anticipated 30 year mine life, netting approximately 6 Mtpa of product export coal. There are 10 open cut pits proposed at Drake, with the two main pits West 1 and West 2, accounting for approximately 75% of the estimated 1,190 million bank cubic metres, or 2,708 million tonnes, of over and interburden on site. Additionally, Drake Coal propose to build a coal handling and preparation plant (CHPP) on site, which will generate coarse reject and tailings streams. To geochemically characterise the excavated waste and assess the risk of acid, neutral or alkaline, in addition to assessing the suitability of the respective waste units for use during progressive rehabilitation of waste rock dumps at Drake, a drilling and sampling program was completed in October and November 2012. Sixteen boreholes were drilled during this program with 329 geochemical samples collected.

Based on the data reviewed herein, the key findings of the excavated waste geochemical characterisation were:

- That all seven lithological waste groups, in addition to the tailings results, were classified as non-acid forming (NAF) using data from 284 sample analyses;
- That all seven lithological waste groups, in addition to the tailings results, had no mean individual total metal value elevated above a global abundance index of 3, using data from 292 sample analyses;
- That all seven lithological waste groups, in addition to the tailings results, had some leachable metal concentrations, above the adopted trigger values, from the 92 samples that underwent ASLP tests. The elements most commonly present in leachate above the trigger values, from the excavated waste, were aluminium, arsenic, lead, zinc and selenium; and
- Based on data from 295 sample analyses across the seven lithological waste groups and the tailings samples; the carbonaceous material, coaly material, mudstone and tailings

showed a high dispersivity risk. The siltstone showed a medium dispersivity risk, while the sandstone and intrusive lithological waste groups showed low to medium dispersivity risk. The soil unit showed a low dispersivity risk.

Therefore, based on the data reviewed herein, the soil, then weathered sandstone, then fresh sandstone appear to be the most appropriate lithological waste groups to use on site in progressive capping of out of pit waste rock dumps. Higher-risk, potentially dispersive materials that should be managed through on-site burial / encapsulation include the carbonaceous material, the coaly material, the mudstone and the tailings; particularly the fresh component of each of those four lithological waste groups.

Based on the data reviewed herein, the intrusive unit is also appropriate for beneficial use, although has very high leachate pH values that exceed stock watering guidelines; therefore, any drainage must be contained and managed appropriately. Additionally, the intrusive unit may be useful as a neutralising agent for any marginal acid producing tailings through co-disposal in engineered tailings structures on site.

Considering the above, and based on the data assessed herein, it may be concluded that there is a low risk of acid drainage at Drake. There is a risk of metalliferous drainage at neutral to alkaline drainage pH values given the results of the 92 ASLP leachate samples analysed; however, it should be noted that considering mean leachate pH values for the same 92 samples of 8.0; that the elements of concern being aluminium, arsenic, lead, zinc and selenium will be sparingly soluble and have limited environmental ecotoxicological risk at such a drainage pH value. This observation is in addition to the existing surface water drainage controls being the proposed engineered environmental dams and dirty water drainage on site; both of which will also reduce risk. The surface water drainage mitigation and management strategies outlined in the Drake Water Management Plan in the 2012 EIS are appropriate to manage this risk.

Additional to the surface water drainage mitigation and management strategies as outlined in the Drake Water Management Plan, would be the excavated waste handling and long term storage by lithological waste group based on geochemical risk. This would include storage of the carbonaceous material, the coaly material, the mudstone and the tailings, particularly the fresh component of each of those four lithological waste groups, in in-pit facilities. Additionally, these materials should not be used as waste rock storage facility capping materials during progressive site rehabilitation activities.

The above notwithstanding, it would appear that there is a very low risk of acid drainage being generated from the excavated waste at Drake. This conclusion is consistent with the low risk in coal mines adjacent to Drake in the northern Bowen Basin, including Sonoma and Belmore-Pipeline for example, where alkaline conditions prevail (QCoal 2011).

1. Introduction

1.1 Background and Context

1.1.1 The Proponent and Project Location

Drake Coal Pty Ltd (the Proponent); a wholly owned subsidiary of QCoal Pty Ltd (QCoal), is developing the proposed Drake Coal Mine (the Project), located approximately 17 kilometres (km) south of Collinsville, Queensland (Figure 1).

1.1.2 Environmental Approvals Context

On 1 April 2010, the Proponent made an application to the (then) Queensland Department of Environment and Resource Management (DERM) (now Queensland Department of Environment and Heritage Protection (DEHP)) to prepare a voluntary Environmental Impact Statement (EIS) under sections 70 and 71 of the *Queensland Environmental Protection Act 1994*.

Subsequent to the Proponent's submission, DERM approved the application to prepare a voluntary EIS on 9 April 2010. The draft EIS Terms of Reference (ToR) were released for public and advisory agency comment between 30 August 2010 and 8 October 2010. The final EIS ToR, which considered public submissions received during the comment period, were issued to the Proponent in December 2010. The Proponent subsequently compiled an EIS which went on public display in May and June 2012.

Due to ongoing site access constraints at Drake, the Proponent has been unable to enter the proposed mine site area to undertake intrusive geochemical sampling for subsequent analysis to inform the excavated waste section of the ToRs (Section 3.6.2 – Excavated Waste). As such, the Proponent compiled a desktop assessment to meet the excavated waste ToR requirements using geochemical data from mine sites proximal with Drake (GHD 2012c). Within the desktop mine waste report, the Proponent committed to completing additional sampling and analysis to further characterise the excavated waste material on site, to better inform the forward risk of handling and storing the excavated waste rock on site.

This report therefore, forms a stand-alone technical appendix within the Drake Coal Mine Supplementary Environmental Impact Statement (SEIS) which will be assessed by DEHP for Project approval under the *Queensland Environmental Protection Act 1994*.

As noted above, the contents of this report aim to address specific requirements within the Project's final ToR; and in particular, Section 3.6.2 – Excavated Waste. The report may also inform other ToR requirements, potentially including:

- Section 3.6.3 – Tailings or Fine Rejects;
- Section 3.7 – Rehabilitation and Decommissioning;
- Section 4.4 – Waste;
- Section 4.5 – Water; and/or
- Section 5 – Environmental Management Plan.



LEGEND

- Town
- Major Town
- River
- Major Road
- Railway
- Project Area
- Local Government Area

Based on or contains data provided by the State of QLD (DERM) [2010]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:1,250,000 (at A4)

0 10 20 30 40 50

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

N

CLIENTS | PEOPLE | PERFORMANCE

Drake Coal Pty Ltd
Drake Coal EIS

Job Number 41-25138
Revision A
Date 31 Jan 2013

Project Location Plan

Figure 1

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Data source: QCOAL: Study Area (2010); GA: 250K V3 Topo/2009; DERM: Local Government Area. Created by: TH, WW

Finally, it remains important for overall holistic Project environmental assessment and management, that the contents of this report are considered in conjunction with information reported in other EIS technical reports, including, though potentially not limited to:

- Soil and Land Suitability Assessment (GHD 2012a, Volume 2a, Appendix C);
- Groundwater Report (GHD 2012b, Volume 2b, Appendix J);
- Waste Rock Characterisation Report (GHD 2012c, Volume 2a, Appendix G);
- Environmental Management Plan (GHD 2012d, Volume 3, Appendix A); and
- Water Management Plan (GHD 2012e, Volume 3, Appendix B).

1.2 Report Aims, Scope and Structure

1.2.1 Report Aim and Method

The primary aim of this report is to assess the potential for excavated mineral waste at the Project site to generate acid, neutral or alkaline drainage. Accordingly, and as noted in Section 1.1.2, the report intends to address specific requirements of the EIS ToR; in particular, Section 3.6.2 – Excavated Waste. Content from Section 3.6.2 of the ToRs is provided in Table 1 for ease of reference.

Table 1: Excavated waste terms of reference

Section	Activity / Impact	Description
3.6.2	Excavated Waste	Describe the materials to be excavated as waste. Also, describe and illustrate the location, design and methods for constructing dumps for waste rock and any subsoil that will not be replaced in rehabilitation. Estimate the tonnage and volume of waste rock and subsoil to be excavated during the various stages of operation. Estimates will be made for each separate rock and soil type. Describe the chemical and physical properties of the waste rock and subsoil, and assess the properties that affect their erosion and leaching potential. Discuss the potential for acid, neutral or alkaline drainage from waste dumps. Characterise the potential quality of leachate from the mined waste under field conditions, including contaminants such as sulfate, pH, chloride, iron, major cations and anions, and any chemical species in sufficient quantity that is likely to cause environmental harm including nuisance. Use the estimated amounts and characteristics of excavated waste to develop appropriate measures for dealing with that waste, including designs for waste dumps, and alternatives for excavated waste disposal such as in-filling of voids, off-site options and treatment of contaminated soil.

The method utilised herein to assess the primary report aims was to undertake a geochemical sampling and analysis program, and assessing the results against appropriate industry guidelines within the context of the proposed Drake mine plan. The geochemical results were then used to inform future materials handling, storage and rehabilitation of the excavated waste.

1.3 Information and Data Sources

GHD did not undertake any primary data generation by intrusive site investigations and/or sample collection and analysis for this report. All data used within this report, therefore, was generated by the Proponent. In that regard, GHD was reliant on the quality assurance processes of third parties with respect to data integrity during sample collection, transport, and analysis.

Information for use in this report was sourced from:

- A draft waste rock report supplied by Drake Coal (Drake Coal, 2011);
- Other electronic and hard copy reports (complete and incomplete) provided by QCoal for the Project site;
- Meetings, telephone conversations and emails with Drake Coal staff involved in the Drake Project between April 2011 and January 2013;
- Geochemical data generated by ALS as provided to GHD by the Proponent;
- Publically available information including books, theses, journal articles, and Government Department websites; and/or
- Drake Coal Project EIS chapters and/or technical reports, including the initial desktop waste rock characterisation report (GHD 2012c).

Technical guidelines considered when scoping and completing the contents of this report included:

- ACARP (2008). *Development of ARD assessment for coal process wastes*. Project C15034. Undertaken by Miller S. and Levay and Co Environmental Services;
- AMIRA (2002). *ARD Test Handbook*. Project P387A Prediction and kinetic control of acid mine drainage;
- Commonwealth Government - Department of Industry, Tourism and Resources (2007). *Leading Practice Sustainable Development Program for the Mining Industry: Managing Acid and Metalliferous Drainage*. Canberra;
- INAP (The International Network for Acid Prevention) (2009). *Global Acid Rock Drainage Guide*. Available at www.gardguide.com;
- Queensland Department of Mines and Energy (1995). *Assessment and Management of Acid Drainage*. Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland;
- Queensland Department of Mines and Energy (1995a). *Assessment and Management of Saline and Sodic Wastes.* Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland; and
- Queensland Department of Mines and Energy (1995b). *Tailings Management*. Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland.

1.4 Limitations

This report has been prepared by GHD for Drake Coal Pty Ltd and may only be used and relied on by Drake Coal Pty Ltd for the purpose agreed between GHD and the Drake Coal Pty Ltd as set out in Section 1.2.1 of this report. GHD otherwise disclaims responsibility to any person other than Drake Coal Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report. The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on information provided in the inputs to this report (refer Section 1.3). GHD disclaims liability arising from any of the information being incorrect.

GHD has prepared this report utilising geochemical data provided by Drake Coal Pty Ltd which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

1.5 Report Structure

The report is structured as follows:

- Section 1: Introduction;
- Section 2: Project Description and Excavated Waste Volumes;
- Section 3: Boreholes, Sampling and Analysis;
- Section 4: Results and Discussion;
- Section 5: Summary and Conclusions;
- Section 6: References; and
- Appendices.

2. Project Description and Excavated Waste Volumes

The Project description remains consistent with that provided in the Drake EIS (QCoal 2012). A brief summary is provided below for ease of reference and application for this excavated waste report.

2.1 Project Overview and Location

As noted in Section 1.1, the Proponent is developing the Project, which located approximately 17 kms south of Collinsville in Queensland (Figure 1).

Exploration by the Proponent on the Drake site over recent years has resulted in the discovery of a new, shallow coal resource of over 200 million tonnes (Mt), over which the Proponent presently has three mining lease applications (MLAs).

Given the surficial proximity of the mineable reserves, ranging from 20 m to 140 m below surface, the Proponent proposes to establish a 10 pit, open-cut operation, using conventional on-site excavators and truck fleets. Primary mining activities will include:

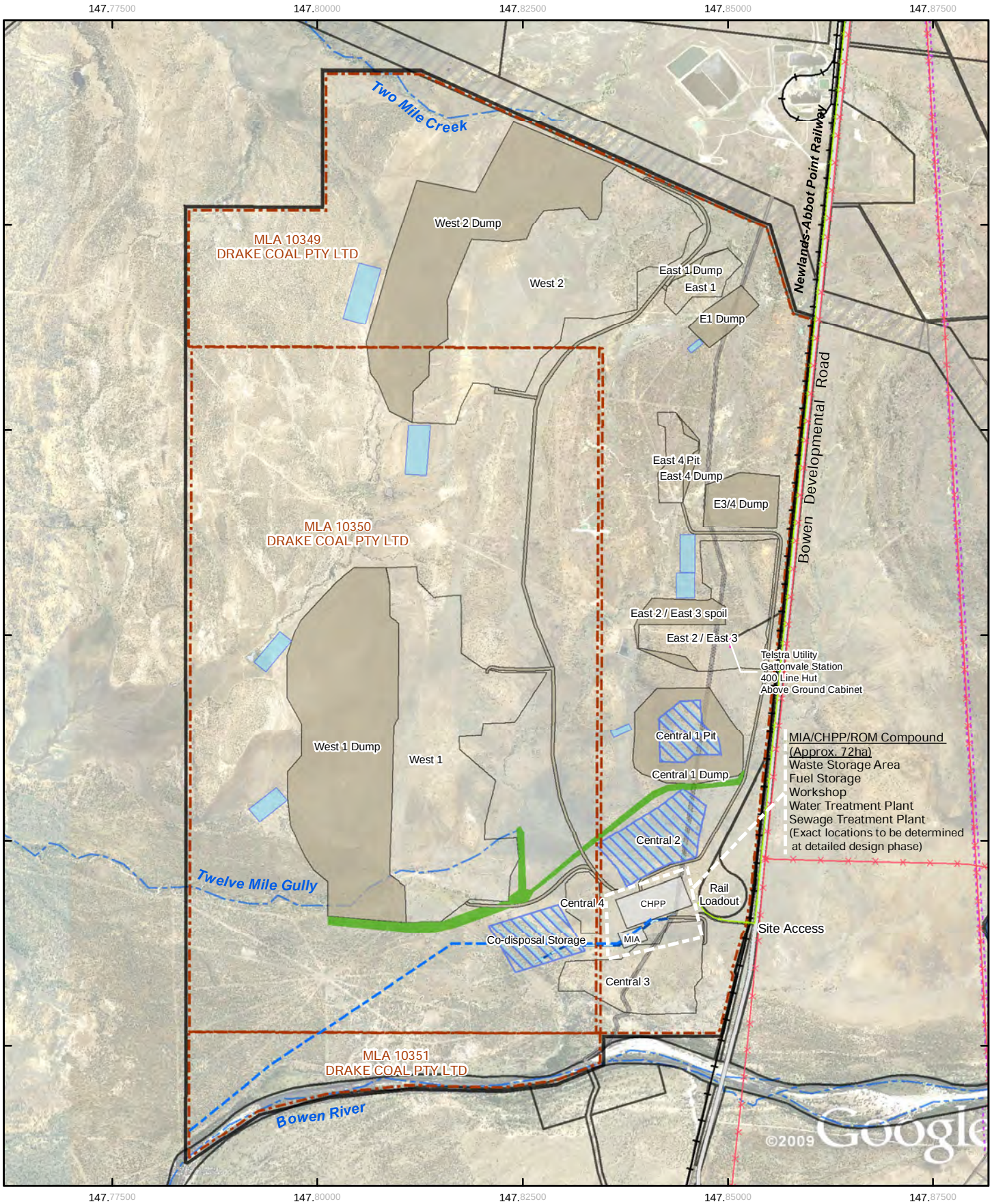
- Clearing vegetation;
- Stripping topsoil as appropriate;
- Removing over and interburden to out of pit, and later, in-pit dumps;
- Coal mining;
- Coal improvement through a coal handling and preparation plant (CHPP) as required; and
- Progressive rehabilitation.

The Project will seek approval to mine up to 10 million tonnes per annum (Mtpa) of run of mine (ROM) coal over the anticipated 30 year mine life, netting approximately 6 Mtpa of product export coal. The Project will produce both coking and thermal coal products, which will be railed to Abbot Point via load out by a yet to be constructed on-site rail loop.

The Proponent anticipates that a total area of approximately 3,442 hectares (ha) will be disturbed over the mine life.

Key elements relevant to this excavated waste assessment include (Figure 2):

- The development of 10 open-cut pits on-site;
- Out of pit over- and interburden dumps to the west of each pit. It is proposed that once sufficient air space has been created in each void, pits will be progressively backfilled with over- and interburden during on-going mining operations;
- A water management system will be constructed that diverts clean water run-on, and captures and manages both dirty water runoff and pit water for beneficial reuse; and
- A CHPP is to be constructed on-site with a designed throughput of 1,400 tonnes per hour (tph). The presence of a CHPP will generate two mine waste streams, being;
  - Coarse rejects; and
  - Coal wash fines, or tailings.



LEGEND

- Major Road
- Existing Railway
- Contour (5m interval)
- Powerline
  - Proposed
  - Existing
- Water Supply Pipeline (Indicative)
- Slurry Pipeline (Indicative)
- Telstra Utility
- Project Area
- Mining Lease Application Boundary
- Mine Process Plant
- Out of Pit Spoil Area
- Haulage Road
- Co-disposal Storage
- Sediment Basin
- Pit
- Diversion Channel
- Proposed Rail

1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Project Layout Plan

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Revision B
Date 11 Feb 2013

Figure 2

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Data source: QCOAL: Mine Layout (2013), Pipeline (2012), Ergon Transmission Line (2012); DME: Mining Lease (2011); GA: 250K V3 Topo (2009). Telstra DBYD (12042012); GE: Imagery (06062011). Created by: TH

The two CHPP waste streams are to be managed by transferring the material into to be constructed, on-site co-disposal facilities (Figure 2).

Pending approval for the Project, it is anticipated that construction will commence in mid-2013, with commissioning and first coal production scheduled for late 2014.

2.2 Target geology

A detailed description of the regional and local geology for the northern Bowen Basin and the Drake site respectively were presented in GHD (2012c). Therefore, only a brief summary is provided below.

The target coal seams for the Project are located within the Permian aged Moranbah Coal Measures within the Blackwater Group (Table 2).

Table 2: Northern Bowen Basin Coal Group Nomenclature

Age	Million years before present[2] (approx.)		Group	Geological Units (Northern Bowen Basin)	Tectonic formative event[1]
Late Permian	258-253	IV	Blackwater Group	Rangal Coal Measures Fort Cooper Coal Measures[3]	Flexural loading phase
	263-258	III		Moranbah Coal Measures	
Early Permian	284-270	II	Back Creek Group	Blenheim Subgroup Collinsville Coal Measures	Thermal sag phase
	325-284	I	Lizzie Creek Volcanics Reids Dome Beds		Rift Phase

1: Michaelson (2000, 2000a)
2: Fielding *et al*. (2000)
3: Included as Group III A by Mallet *et al*. (1995).

The full sequence of coal seams present within the Moranbah Coal Measures, from the A to the Q seam inclusive, are present at Drake and are planned for exploitation. The target seams are presented schematically in Figure 3. Note that not all seams are present in all pits on site due to localised faulting, in addition to a stratigraphic dip of approximately 5-7º ESE.

As seen on Figure 3, regionally adopted Moranbah Coal Measure nomenclature has the coal seams at the Project site alphabetised from the stratigraphically oldest 'A Seam' to the youngest 'Q or Upper Goonyella' Seam. The overlying R and S Seams present on adjacent mining tenures will not be disturbed at the Project site as they are either not present, or are not economically viable. They have been included herein for stratigraphical completeness. The inter- and overburden units shown in Figure 3 have been demarcated by the author based on the existing coal seam nomenclature for simplicity.

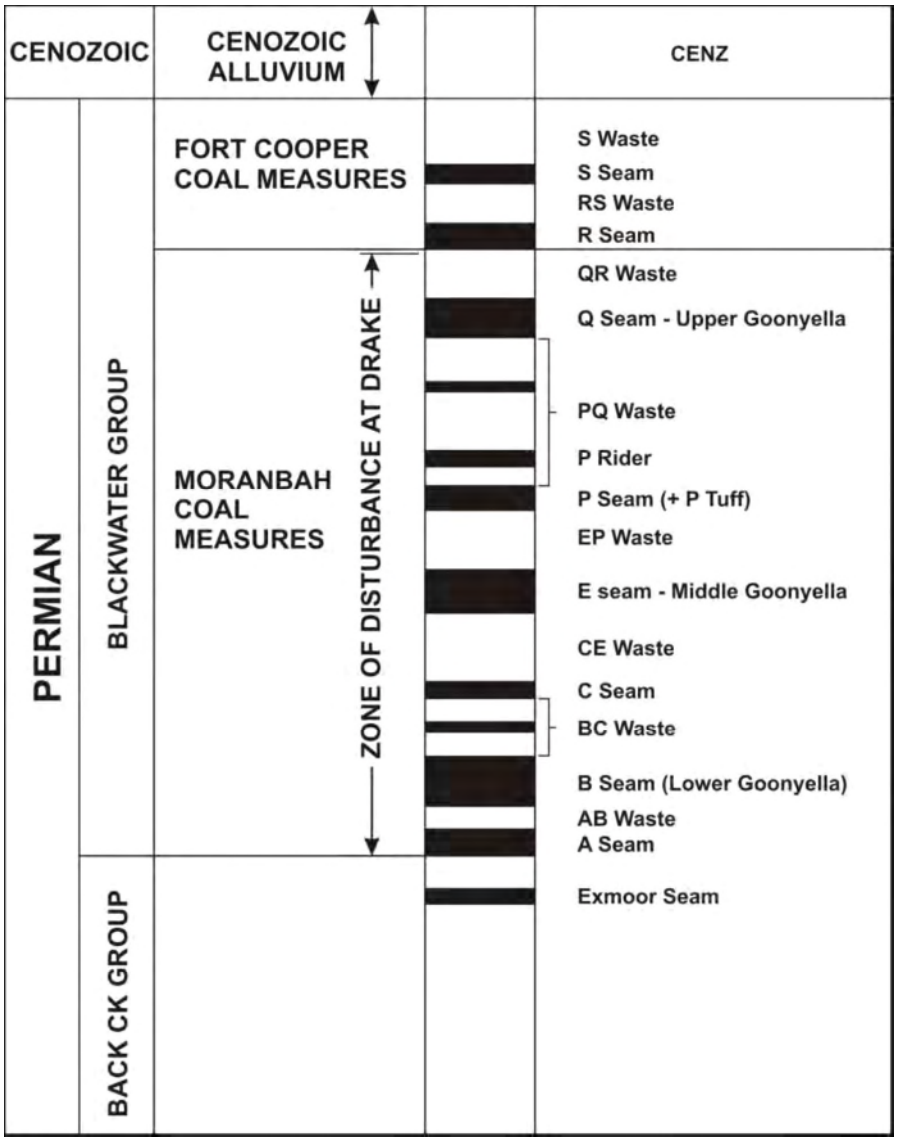
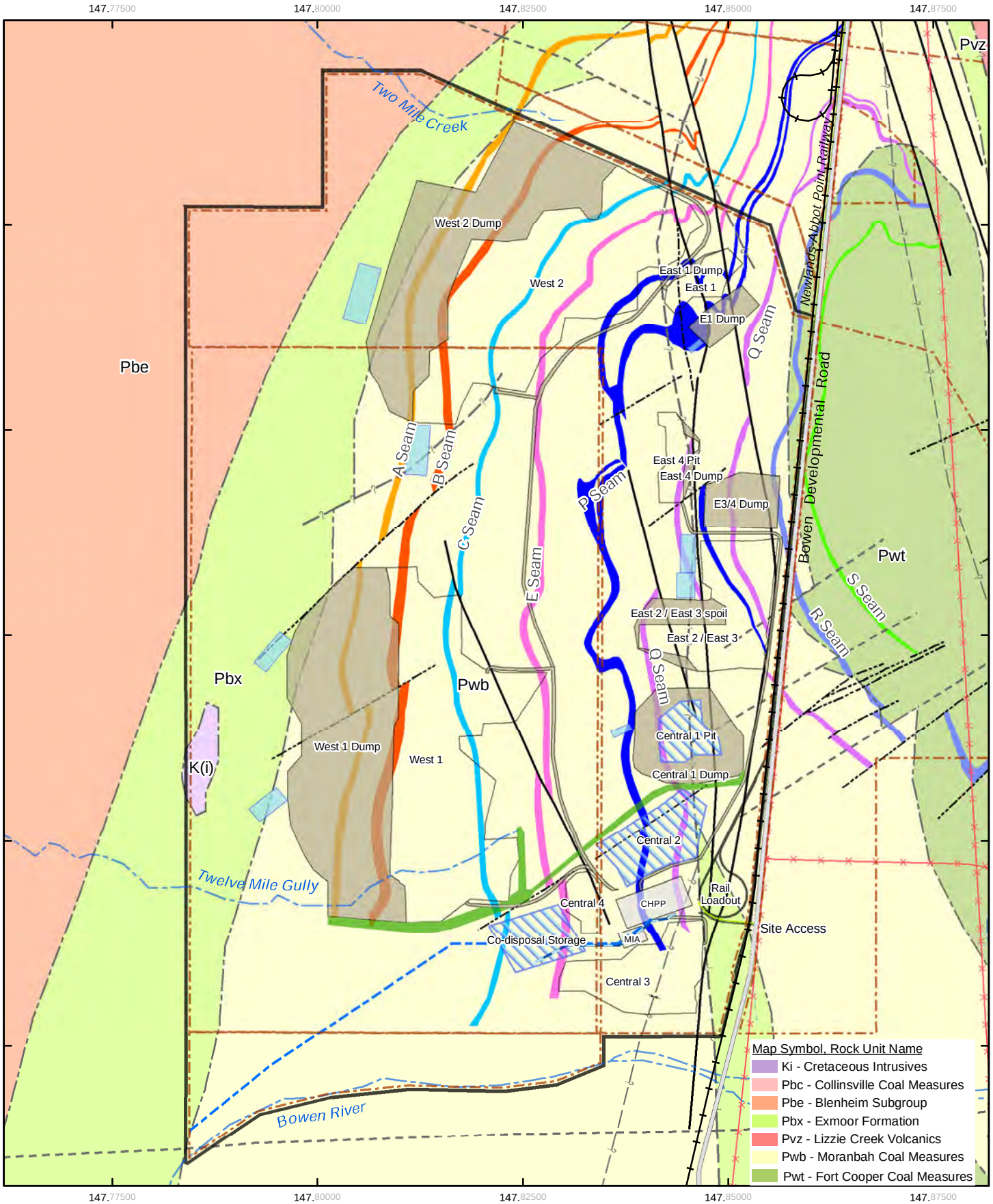


Figure 3: Schematic of the Targeted Drake Stratigraphy

Note: Seams A to Q inclusive to be mined at Drake at various locations.
Dip of coal seams normalised to zero for illustrative purposes.

The surface geological expression as represented by the outcropping of individual coal seams as they relate to the proposed mine pits on the Project site are shown on Figure 4.

Two schematic cross sections constructed from site exploration drilling depicting the target coal seams within the western (West 1 and West 2 pits) side of the Drake lease are shown in Figure 5 and Figure 6 respectively.



LEGEND

- Major Road
- Existing Railway
- Drainage Feature
- Water Supply Pipeline (Indicative)
- Slurry Pipeline (Indicative)
- Powerline (Proposed)
- Powerline (Existing)
- Project Area
- Mining Lease Application Boundary
- Mine Process Plant
- Out of Pit Spoil Area
- Haulage Road
- Co-disposal Storage
- Sediment Basin
- Pit
- Diversion Channel
- Proposed Rail

Geological Structure

- Fault Approximate
- Fault Inferred
- Geological Boundary Approximate
- Geological Boundary Inferred
- Syncline Approximate

1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Project Layout Plan and Geology

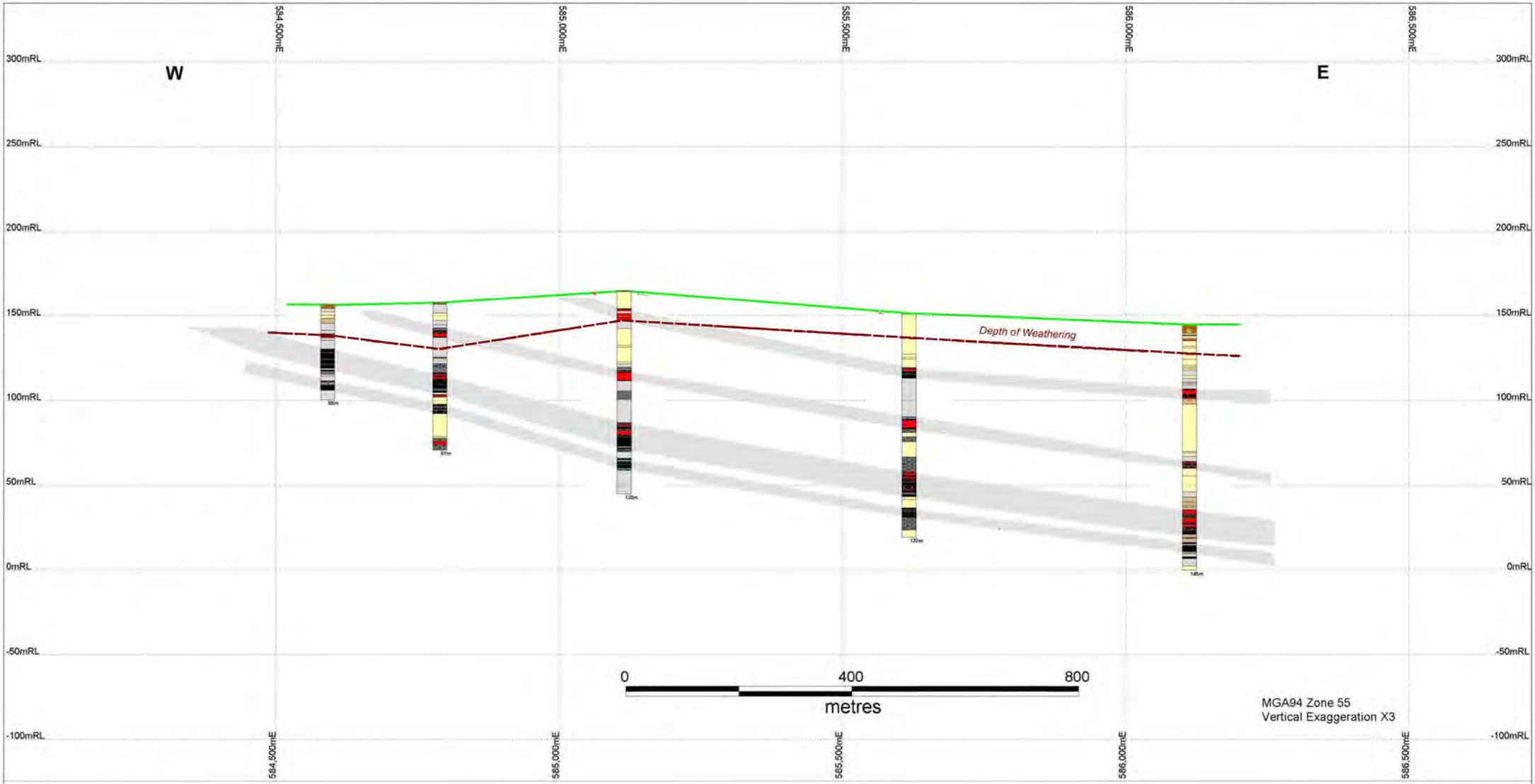
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Figure 4

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Data source: QCOAL: Mine Layout (2013); DME: Mining Lease (2011); GA: 250K V3 Topo (2009). GE: Imagery (06062011). Created by: TH



LITHOLOGY LEGEND

SO	Soil	CG	Conglomerate	CW	Weathered Coal	BA	Basalt
CL	Clay	SC	Calcareous Sandstone	CO	Coal	IN	Igneous Intrusion
SA	Sand	SS	Sandstone	CD	Cindered Coal	GR	Granite
AL	Alluvium	SH	Shale	HC	Heat-affected Coal	IG	Igneous Rock
GV	Gravel	SL	Siltstone	XM	Carbonaceous Mudstone	MT	Metasediment
BW	Weathered Basalt	MS	Mudstone	ZM	Coaly Mudstone	TF	Tuff
		CS	Claystone	XS	Carbonaceous Sandstone	TM	Tuffaceous Mudstone
		LS	Limestone	XL	Carbonaceous Siltstone		

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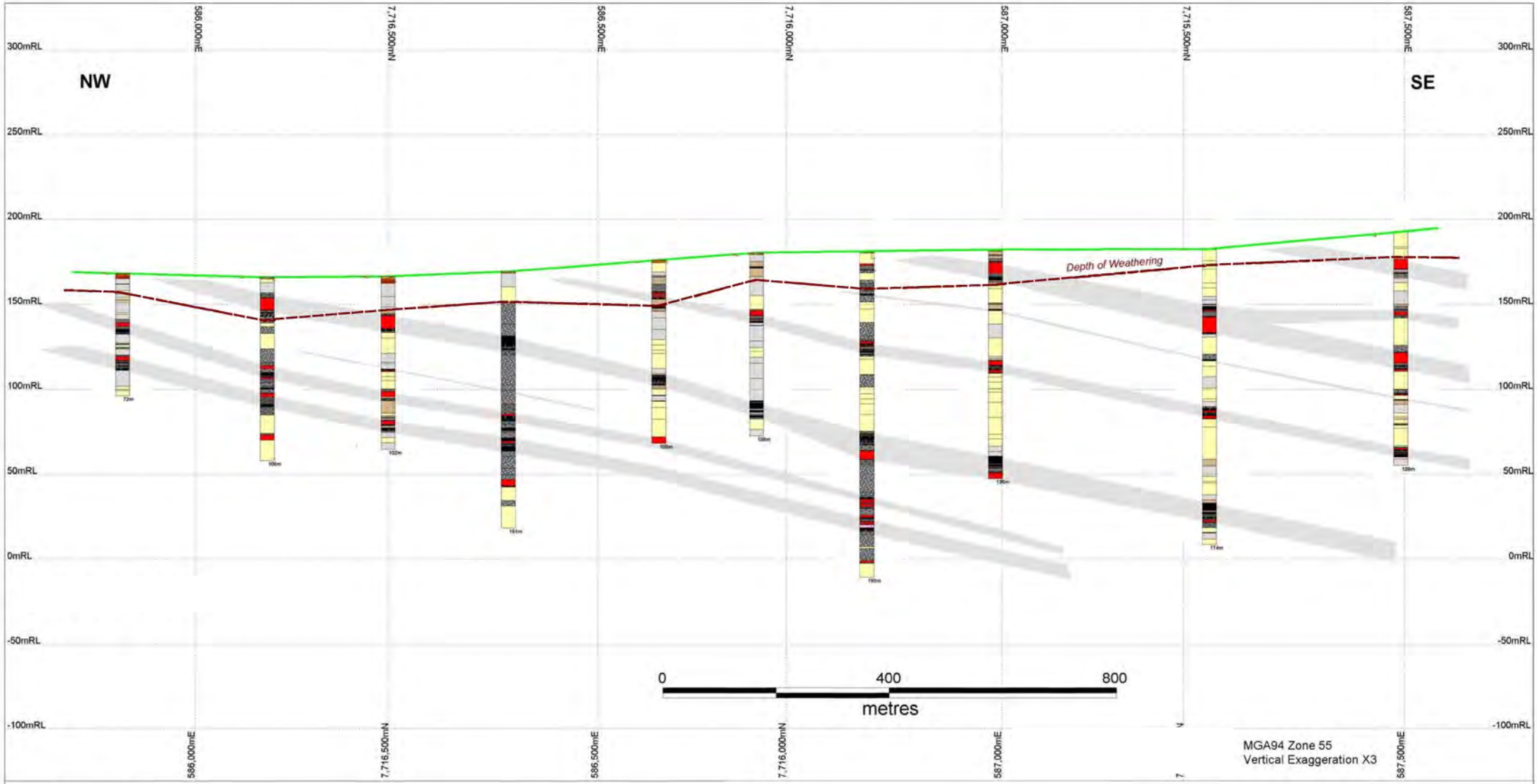
W-E x-section through West Pit 1

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Figure 5

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Data source: QCOAL: Mine Layout (2011). Created by: JB



LITHOLOGY LEGEND

SO	Soil	CG	Conglomerate	CW	Weathered Coal	BA	Basalt
CL	Clay	SC	Calcareous Sandstone	CO	Coal	IN	Igneous Intrusion
SA	Sand	SS	Sandstone	CD	Cindered Coal	GR	Granite
AL	Alluvium	SH	Shale	HC	Heat-affected Coal	IG	Igneous Rock
GV	Gravel	SL	Siltstone	XM	Carbonaceous Mudstone	MT	Metasediment
BW	Weathered Basalt	MS	Mudstone	ZM	Coaly Mudstone	TF	Tuff
		CS	Claystone	XS	Carbonaceous Sandstone	TM	Tuffaceous Mudstone
		LS	Limestone	XL	Carbonaceous Siltstone		

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W-E x-section through
West Pit 2

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Date 08 Mar 2012

Figure 6

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Data source: QCOAL: Mine Layout (2011). Created by: JB

2.3 Mine Plans

2.3.1 Pits and Mining Method

The proposed site plan for the Project was presented in Figure 2 and Figure 4; which show two main pits (West 1 and West 2), with eight proposed satellite pits (East 1 – 4 and Central 1 to 4 inclusive).

Target seams, run-of-mine (ROM) coal, waste volume and approximate disturbance area for each of the 10 proposed pits are shown in Table 3.

Table 3: Drake Pit Information

Pit	Target Seams	ROM Coal (mt)	Waste Volume[1] (million bcm)
Central 1	P3, Q3	3.3	11.2
Central 2	P Rider, P3, C, E3, B Plies	7.1	78.2
Central 3	C and E3	8.4	69.0
Central 4	C and E3	1.3	8.0
West 1	P Rider, P3, C, E3, B Plies, A2	80.9	342.7
West 2	Q3, P Rider, P3, C, E3, B Plies, A2	83.6	543.7
East 1	P Rider, P	2.6	11.9
East 2	E3, Q3, P Rider, P3	1.4	16.2
East 3	Q3, P Rider, P3, C, E3, B Plies	11.5	100.1
East 4	Q3, P Rider, P3	1.7	10.1
Total	A, B, C, E, P, Q	201.8	1,191.1

1: Bank cubic metres refer to the *in situ* volume of waste material. Appropriate bulk densities have been applied to convert bank cubic metres to tonnages in Table 4.

The Proponent proposes to extract the ROM coal using hydraulic excavators and rear dump trucks in a series of traditional strip mines. Mining is scheduled to commence in the north western corner of pit West 1, in addition to Central 1; the latter being prepared as a co-disposal location for CHPP waste materials. Refer to Section 3.4.4 of GHD (2012) for additional detail on mine sequencing.

Mining would proceed by initially stripping surface vegetation, ahead of topsoil removal and stockpiling for reuse during progressive rehabilitation. Over- and interburden material above the limit of oxidation (LOX); reported as between approximately 12 to 25 m below surface from exploration borelogs, would be free-dug using a hydraulic excavator. Any non-weathered interburden below the LOX line would be blasted prior to removal. Initially, the Proponent proposes to haul the excavated waste material to out of pit spoil areas (Figure 4), prior to placing all subsequent mine waste in-pit as soon as practicable given mine scheduling.

The coal seams themselves would be free-dug using hydraulic excavators, or wheel loaders, with coal either being transported by dump truck to the ROM stockpile, or dumped directly into the ROM crusher facility depending on processing capacity at the time.

Multiple mining blocks would be active within a given mining strip, and at times, multiple active strips would be exploited over the life of mine to manage production rates against the technical challenges of mining the multiple plies within many of the Drake coal seams. Multiple mining blocks and mining strips would also allow for managing production dips due to the presence of igneous intrusions in the lower seams.

2.3.2 Waste Rock

Classification of the excavated waste material at Drake as reported herein is by:

- Stratigraphic inter- and overburden waste unit as delineated in Figure 3 (e.g. BC Waste); and
- Major lithological grouping as determined by drilling metres in the 2012 drilling program as reported by Drake Coal (e.g. carbonaceous material).

Table 4 provides a summary of estimated mine waste tonnages by waste unit for the Project.

Table 4: Summary of Total Mine Waste Volumes and Tonnages by Unit at Drake

Stratigraphically younger →	Excavated Waste Unit[1]	Estimated Life of Mine Waste Volumes (million bcm)	Estimated Life of Mine Tonnes[2] (mt)	Percentage (%) by Weight
	CENZ[5]	299.1	478.5	25.1
	QR Waste	12.6	31.5	1.6
	PQ Waste	21.7	54.3	1.8
	EP Waste	96.5	241.3	8.1
	CE Waste	137.2	343.1	11.5
	BC Waste	491.8	1,229.6	41.3
	AB Waste	131.9	329.7	11.1
	Total[3]	1,190.8[4]	2,708.0	100.5[4]

1: Refer to Figure 3. 2: Bulk densities used for conversion and relative percent geologic units were estimated using exploration drilling data from Drake Coal at Drake in 2008 and 2012. Bulk densities used for volume to mass conversion for fresh material was sandstone 2.45, siltstone, mudstone including carbonaceous material 2.6. Remaining units were coal and igneous. Mean bulk density for approximate conversion used across all units was 2.5. Bulk density of 1.6 used for CENZ / soil / weathered waste units. 3: Excludes igneous intrusive waste rock. Approximately 7% of total waste tonnage estimated to be igneous distributed across units as determined by drilling data. 4. Variance from total in Table 3 and 100% due to rounding errors. 5. Note that CENZ as referred to herein refers to all topsoil and weathered material, including weathered Permian material. Whilst not technically correct, it was initially defined by a previous QCoal geological consultant and has been retained herein for continuity.

2.3.3 CHPP Waste

In addition to the over- and interburden waste for the Project described in Section 2.3.2, mine waste will be generated from a proposed 1,400 tonnes per hour (tph) Coal Handling and

Preparation Plant (CHPP) on-site. The CHPP will generate two discrete waste streams; those being:

- Coarse rejects; and
- Tailings.

It is important to consider the potential for AMD generation from these waste streams as the Proponent proposes to store the coarse rejects and tailings in three dedicated, on-site co-disposal facilities (Figure 2 and Figure 4); being:

1. Initial co-disposal storage located west of Central 3 Pit;
2. Subsequent storage into Central 1 Pit; and
3. Additional storage into Central 2 Pit.

If any pyrite is present in the coal seams themselves, the beneficiation process utilised in the CHPP will have the effect of concentrating the sulphidic content prior to on-site disposal. It is therefore important to understand the geochemistry of the CHPP waste streams to determine AMD potential. Table 5 details the approximate tonnages of CHPP waste (coarse rejects and tailings) from each of the 10 pits.

Table 5: Approximate CHPP Waste Volumes by Pit at Drake

Pit[1]	Coarse Rejects (million tonnes)	Tailings (million tonnes)	Total CHPP Waste (million tonnes)
Central 1	0.74	0.25	0.99
Central 2	1.79	0.60	2.39
Central 3	2.29	0.76	3.05
Central 4	0.35	0.17	0.52
West 1	24.05	8.02	32.07
West 2	24.12	8.04	32.16
East 1	0.67	0.22	0.89
East 2	0.29	0.10	0.39
East 3	2.95	0.98	3.93
East 4	0.44	0.15	0.59
Total	57.69	19.29	76.98

1: Refer to Figures 2 and 4 for pit locations.

The Initial Co-Disposal storage will be built at the start of the mine operations and will be ready to receive the first co-disposal material from the CHPP. After year 2, Central 1 Pit becomes available; whereby all co-disposal material will be stored therein. The next available storage will be Central 2 Pit, which will be taken into production at the start of mine year 3, and is planned to

be exhausted by the end of mine year 5. Additional co-disposal storage capacity is likely to be required at the beginning of year 11, whereby West 1 Pit is proposed for utilisation.

2.3.4 Summary of Mine Waste Streams at Drake

Based on the site geology, proposed mine plans, and site coal processing technology; an estimate of mine waste volumes generated at the Project over the life of mine are summarised in Table 6.

Table 6: Summary of Life-of-Mine Waste Mass

Waste Stream	Million Tonnes	Percentage (%) Total Waste by Weight
Waste Rock		
CENZ	478.5	25.1
QR Waste	31.5	1.6
PQ Waste	54.3	1.8
EP Waste	241.3	8.1
CE Waste	343.1	11.5
BC Waste	1,229.6	41.3
AB Waste	329.7	11.1
Total Waste Rock	2,708	97.2
CHPP Waste		
Coarse Rejects	57.7	2.1
Tailings	19.3	0.7
Total CHPP Waste	77.0	2.5
Total Waste	2,785.0	100.0

3. Boreholes, Sampling and Analysis

3.1 Borehole locations

For the stated purposes of geochemically characterising the geological material on-site and assessing any subsequent AMD potential, a mine waste sampling and analysis plan was developed and approved by DEHP in mid-2012. Initially, 14 new boreholes were proposed, with 16 actually drilled. The drilling and sampling program completed in October and November 2012, therefore, drilled 16 boreholes (Figure 7) for a cumulative total depth of 1,583 m.

The sampling and analysis plan aimed to achieve an appropriate distribution of boreholes across the project site, such that the geochemical samples collected would be broadly representative of the geological makeup of the excavated waste, such that the AMD risk could be informed. It was also based on:

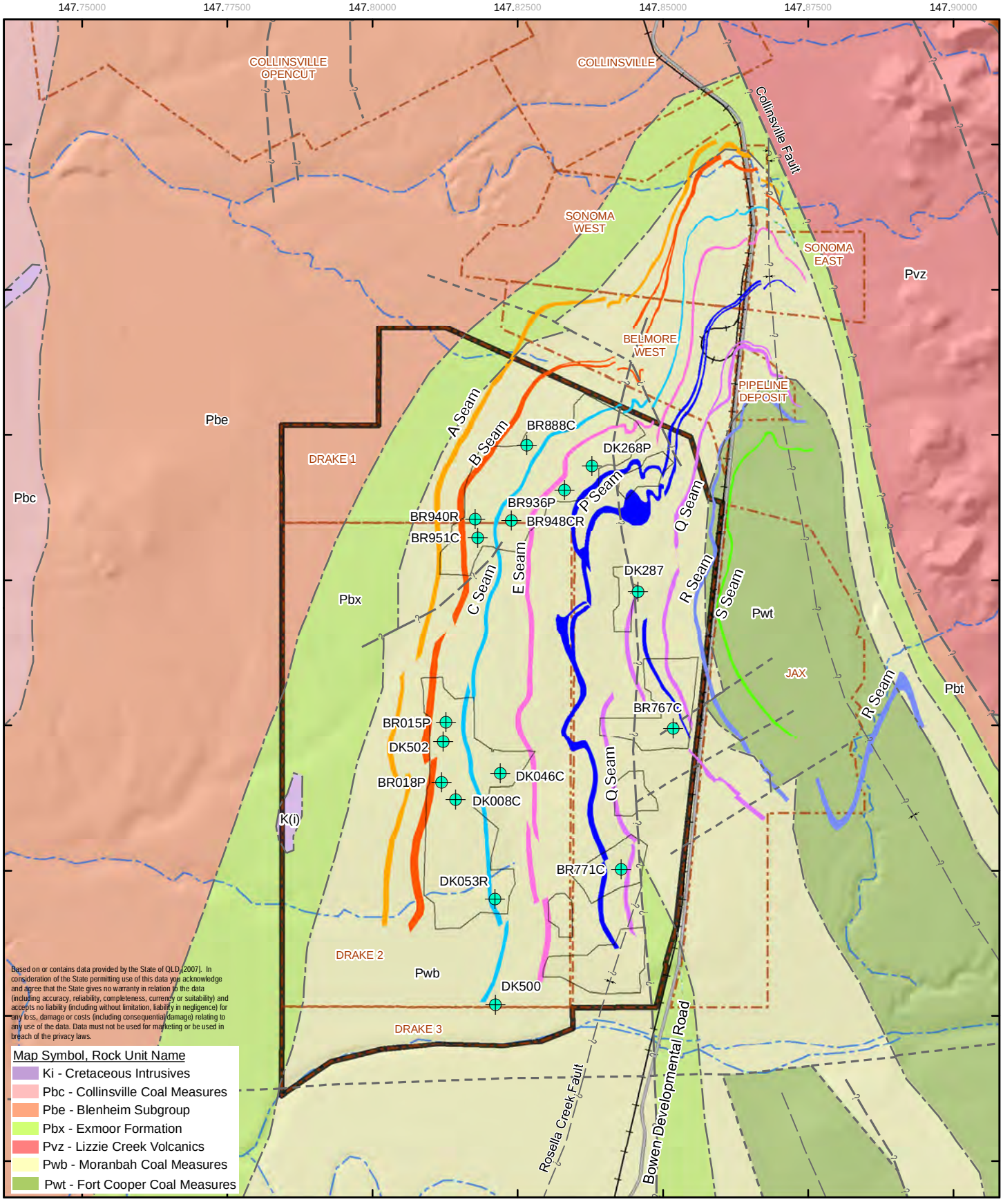
- The proposed location of the 10 pits at Drake;
- The location of the lithological units present that would contribute to excavated waste; and
- Drilling, sampling and analysis costs.

The holes were drilled by Global Drilling Pty Ltd and Focus Drilling Pty Ltd, with both contractors utilising variants of the Mayhew 1000 style rotary drilling rig along with a combination of drilling bits. In general, PCD (poly crystalline diamond) bits were used for both coring and chipping operations due to the hardness of the interburden rocks and intrusion within coal seams. In areas where downhole rock hardness was less, and coal seams were largely un-intruded, conventional tungsten carbide drill bits were used. The chip drill bits have an external diameter of 125 mm, while the core bits produce 100 mm (4 inch) drill core.

At Drake, all drill holes were lithologically logged by a geologist and rock types sampled with the assistance of a field technician. Geophysical logs were obtained from the holes in order to assist in the interpretation of parameters including rock density, clay composition, and coal quality.

In chipped holes, and chipped sections of holes, drill cuttings returned to the surface were collected and placed on the ground at 1m depth intervals (the average weight per meter per pile was in the order of 2 kg). Once lithologically logged by the geologist the chip piles were sub-sampled by hand based on rock type and observable physical/compositional variance. Based on the nature of the sedimentary sequence, this invariably resulted in sampling densities of approximately one sample per 1-3 m. In thicker more homogenous rock units, i.e. some sandstone units, the sampling density was decreased marginally but generally did not exceed a 5 m interval. The average sample weight throughout the program was in the order of 1-1.5 kg. The samples were placed in sealable plastic bags and stored in a cool, dark environment prior to transport to ALS in Brisbane.

The sampling of drill core involved the continuous quartering of the core by way of a hammer and chisel. As with the chip sampling, the endeavour of the core sampling was to gather representative samples of various rock types at a sufficient enough sampling density to ensure a statistically relevant result. Core sample intervals were similar to those of the chip program, but due to the greater specific gravity of the core sample, weights were significantly higher (up to 3 kg per metre sub-sampled). As with the chip sampling, the core samples were sealed in plastic bags and stored in a cool dark environment prior to transportation to ALS in Brisbane for analysis.



LEGEND

- Geochemical Borehole Locations
- Drainage Feature
- Mining Lease Application Boundary
- Project Area
- Pit

Geological Structure

- Fault Approximate
- Fault Inferred
- Geological Boundary Approximate
- Geological Boundary Inferred
- Syncline Approximate
- Syncline Approximate Showing Dip and Plunge

1:100,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

N

CLIENTS | PEOPLE | PERFORMANCE

Drake Coal Pty Ltd
Drake Coal EIS

Geochemical Borehole Locations

Job Number 41-25138
Revision B
Date 11 Feb 2013

Figure 7

G:\41\25138\GIS\Maps\Deliverables\08_WasteRock\41-25138-131_rev_b.mxd
Level 4, 201 Charlotte St Brisbane QLD 4000 Australia T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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Data source: QCOAL: Project Area (2013), Site Layout (2011); DERM: GeologyRivers, DEM (2007), GA: 250K Topography - ©Commonwealth of Australia,
GHD: Waste Rock Samples (2012). Created by: TH/IH

A list of sample numbers collected from each of the 16 boreholes is shown in Table 7. Lithological descriptives as provided by QCoal for the 329 geochemical samples are provided in Appendix A. The number of geochemical samples by lithological group is discussed below.

Table 7: Geochemical sample numbers by borehole

Borehole	Sample number	Borehole	Sample number
BR015P	9	BR951C	21
BR018P	11	DK008C	5
BR767C	23	DK046C	20
BR771C	25	DK053R	32
BR888C	22	DK268P	36
BR936P	34	DK287	16
BR940R	22	DK500	18
BR948CR	25	DK502	10
		Total	329

3.2 Lithological units sampled

Eight (including coal) broad lithological groups were identified from the 329 geochemical samples collected during the October and November 2012 field program; including coal (Table 8). The coal group was assessed separately herein as a surrogate for CHPP tailings.

As noted above in Section 3.1, samples were collected to be broadly representative of the volumes of each respective stratigraphic and lithological waste unit being excavated under the Proponent's current mine plans. Each stratigraphic waste unit itself comprises several lithological waste groups as determined using the drill core metres and geologists' notes from the October and November 2012 drilling program (Appendix A).

Table 8 presents the lithological waste groups, the length of drill core logged (and relative percentage of total length drilled), the number of fresh and weathered samples selected for each group (and relative percent of lithological samples by group).

Broadly, geochemical sample numbers correlated with the respective volume of excavated waste by lithological unit, as determined by drilled metres. The carbonaceous materials were purposely over represented as previous experience has determined that they are often amongst the higher risk lithologies with respect to the potential for AMD generation. This phenomenon is due to sulfide minerals forming through sulfate reduction during coal formation. As a result, there remains the potential for material in and adjacent to coal seams to have higher sulphidic material present than the overlying bedrock, and therefore, a higher AMD risk. Note that the coal lithological unit has been reported upon separately in this report as a surrogate for CHPP tailings (refer Sections 4.6 to 4.9 respectively).

Table 8: Geochemical samples by lithological group

Lithological group	Sum of 2012 drillhole length	% by drillhole length	No. of fresh samples	No. of weathered samples[3]	Total samples	% by total samples
Soil	30.2	1.9	0	19	19	5.8
Siltstone	217.1	13.7	36	18	54	16.4
Sandstone	441.5	27.9	77	33	110	33.4
Mudstone	175.5	11.1	37	14	51	15.5
Intrusion	112.6	7.1	25	7	32	9.7
Coaly material	14.7	0.9	7	1	8	2.4
Carbonaceous material	117.8	7.4	51	4	55	16.7
Coal	473.1	29.9	NA[2]	NA[2]	NA[2]	NA[2]
Total	1,582.5	99.9[1]	233	96	329	100

1: Variance from total in Table 3 and 100% due to rounding errors.

2: NA – not applicable. Coal samples were collected and analysed as surrogates for CHPP generated coal tailings. Refer to Sections 4.6 to 4.9 respectively.

3: Weathered samples are representative of the CENZ waste group (Tables 4 and 6) which accounts for approximately 25.1% of the excavated waste at Drake. 96 of the 329 samples analysed were weathered representing approximately 29.2% of the samples collected.

3.3 Geochemical Analysis

Geochemical analyses as shown in Table 9 were undertaken on the samples collected from Drake, and are reported herein. The data in Table 9 excludes the six coal seam composite samples analysed as surrogates for CHPP tailings (refer Sections 4.6 to 4.9 respectively).

ALS Environmental, Brisbane, conducted all geochemistry analysis and coordinated all sub-contracted testing. Metals analysis was completed by ALS Minerals in Brisbane through an internal ALS sub-consultancy. Laboratory results and QA/QC are presented in Appendix B. Individual detailed laboratory methods are available from ALS at http://test.alsglobal.com.

Table 9: Geochemical analysis

Analysis	Samples analysed	Method
Analysis on solid samples		
Slurry pH and EC	329	Soil / Water 1:5 (APHA 21st ed. 4500H+)
Total sulphur	284	LECO at 1350 deg C.
Sulphate sulphur	284	HCl digestion then ICP-AES
Sulphide sulphur	284	By calculation
Acid neutralising capacity (ANC)	284	USEPA 600/2-78-054 / Modified Sobek
Maximum potential acidity (MPA)	284	By calculation
Net acid production potential (NAPP)	284	By calculation
Oxidation pH and single addition net acid generation (NAG)	284	AMIRA (2002) / Miller (1996)
Chloride	280	Chloride discrete analyser
Exchangeable cations and cation exchange capacity (CEC)	295	Rayment and Higginson (1992). Method 15A2. Ammonium chloride contact and then ICP-AES.
Exchangeable sodium percentage (ESP)	295	By calculation
35 element metals analysis on solids	292	35 elements by aqua-regia acid digestion and ICP-AES.
Australian Standard Leaching Procedure (ASLP)	92	AS 4439.2
Leachate pH and EC	92	APHA 21st edition Procedure 4500 H+ B and APHA 2510 B.
Leachate alkalinity and acidity	92	APHA 21st edition Procedure 2320B and 2310B respectively.
Leachate sulphate and chloride	92	ICP-AES and chloride discrete analyser
Leachate metals	92	ICP-AES

4. Results and Discussion

4.1 Introduction

The following section presents the analytical results and discusses any implications from those results with respect to AMD risk. The results are presented as follows:

1. Excavated waste results:
    a. Geochemistry;
    b. Metals;
    c. Leachate; and
    d. Dispersivity.
2. CHPP waste / tailings results:
    a. Geochemistry;
    b. Metals;
    c. Leachate; and
    d. Dispersivity.

Sample results are initially assessed by lithological waste group (e.g. sandstone), with subsequent correlation and discussion relative to excavated waste stratigraphic units for selected pits (e.g. AB waste in West 1 pit).

4.2 Excavated waste: Geochemistry

4.2.1 Slurry pH, EC and chloride

Slurry pH, electrical conductivity (EC) and chloride parameters provide a relatively cheap and rapid indication of the acidity and salinity of a sample at the time of testing. The degree of weathering the material has undergone, in addition to the availability of readily soluble salts may be inferred from these parameters.

The method used herein was a 1:5 solid to water ratio, which is an alternative to the AMIRA (20012) 1:2 method as approved under Queensland Government guidelines (DME 1995).

An acidic slurry paste pH ($pH_{1:5}$) value of less than approximately 5 may indicate the presence of stored acidity, or stored sulphide oxidation products within a sample, and subsequent potential for acid generating conditions. Conversely, alkaline slurry $pH_{1:5}$ values may indicate the presence of reactive neutralising minerals in a sample.

Slurry electrical conductivity ($EC_{1:5}$) may provide an indication of soluble salt loads associated with the sample. If the sample originates from a naturally saline environment, elevated slurry $EC_{1:5}$ values may indicate salinity. This is unlikely to be the case at Drake based on the depositional palaeoenvironment (see GHD 2012c for example). However, where natural salinity is low, elevated slurry $EC_{1:5}$ values would likely indicate the presence of salt from sulphide mineral oxidation.

Slurry chloride values are an alternative method of measuring the accumulation of water soluble salts in the soil sample, or the salinity of the sample. It most commonly measures chloride dissolved from sodium salts, although can also measure chloride dissolved from potassium and/or calcium salts.

Acidic slurry $pH_{1:5}$ values, and/or elevated slurry $EC_{1:5}$ and/or chloride values may be indicative of the potential of a sample to negatively impact the quality of drainage water emanating from waste stockpiles following dissolution of minerals following rainfall.

Sample classification for slurry $pH_{1:5}$, $EC_{1:5}$ and chloride values against indicative classification values (DME 1995) are presented below. DME (1995) classification guidelines are reproduced in Table 10 for ease of reference.

Table 10: Slurry pH, EC and chloride classification

Test	Unit	Very low	Low	Med.	High	Very high
pH (1:5)	pH unit	<4.5	4.5 – 5.5	5.5 – 7.0	7.0 – 9.0	>9.0
EC (1:5)	µS/cm	150	150 - 450	450 - 900	900 – 2,000	>2,000
Chloride (1:5)	ppm	<100	100 - 300	300 - 600	600 – 2,000	>2,000

Slurry $pH_{1:5}$ values

Slurry $pH_{1:5}$ values are shown by fresh and weathered lithological waste groups in Table 11. Classification using the mean value as it compares to data in Table 10 is also provided.

The data presented in Table 11 indicates that the lithological waste groups at Drake are alkaline. All lithological waste groups; both fresh and weathered, are classified as having a 'very high' $pH_{1:5}$ value (mean $pH_{1:5}$ value in excess of 9.0 pH units), with the exception of the weathered soil and weathered carbonaceous material lithological waste groups, which were classified as 'high' (mean $pH_{1:5}$ values between 7.0 and 9.0).

The excavated waste is highly unlikely to produce acidic drainage in the short term. This is based on the results of 329 Drake excavated waste samples returning a mean slurry $pH_{1:5}$ classification of 'very high'; which suggests the presence of reactive neutralising minerals within the lithology. Note that the static geochemical testing used herein can only be used in predicting short term outcomes, with longer term material responses being predicted using kinetic geochemical testing. However, the static geochemical results are considered appropriate for the stated purpose of providing an indication of AMD risk for the excavated waste. Given the consistency of the dataset, in addition to consideration of the additional geochemical results provided in Section 4 of this report, longer term kinetic leaching would appear redundant in determining acid generation for the Drake samples.

Table 11: Excavated waste slurry $pH_{1:5}$ values by lithological waste group

	Count	Mean	Median	Max.	Min.	St. Dev.	Classification[1]
Waste group	No.	←|	$pH_{1:5}$ units		|→|	
Soil - fresh	0	NA	NA	NA	NA	NA	NA
Soil - weathered	19	8.5	8.4	9.7	7.4	0.6	High
Soil - all	19	8.5	8.4	9.7	7.4	0.6	High
Siltstone - fresh	36	9.5	9.6	9.9	8.5	0.3	Very high
Siltstone - weathered	18	9.3	9.3	9.8	8.8	0.3	Very high
Siltstone - all	54	9.4	9.5	9.9	8.5	0.3	Very high
Sandstone - fresh	77	9.4	9.5	9.9	8.3	0.3	Very high
Sandstone – weathered	33	9.2	9.2	9.7	8.2	0.3	Very high
Sandstone - all	110	9.4	9.4	9.9	8.2	0.3	Very high
Mudstone - fresh	37	9.5	9.5	9.9	8.5	0.3	Very high
Mudstone - weathered	14	9.1	9.1	9.5	8.2	0.4	Very high
Mudstone - all	51	9.3	9.4	9.9	8.2	0.4	Very high
Intrusion - fresh	25	9.7	9.6	10.1	9.1	0.3	Very high
Intrusion – weathered	7	9.1	9.0	9.8	8.8	0.4	Very high
Intrusion - all	32	9.5	9.5	10.1	8.6	0.4	Very high
Coaly material - fresh	7	9.2	9.1	9.7	8.8	0.3	Very high
Coaly material - weathered	1	9.8	9.8	9.8	9.8	0	Very high
Coaly material - all	8	9.3	9.2	9.8	8.8	0.4	Very high
Carb. material - fresh	51	9.4	9.4	10.0	8.2	0.4	Very high
Carb. material - weathered	4	8.8	8.7	9.4	8.4	0.4	High
Carb. material - all	55	9.3	9.4	10.0	8.2	0.4	Very high
Total - fresh	233	9.5	9.5	10.1	8.2	0.3	Very high
Total – weathered	96	9.0	9.1	9.8	7.4	0.5	Very high
Total – all	329	9.3	9.4	10.1	7.4	0.4	Very high

1: Classification as determined from Table 1 (DME 1995) – refer Table 10. NA: Not applicable as no samples in this category.

Slurry $EC_{1:5}$

Slurry $EC_{1:5}$ values are shown by fresh and weathered lithological waste groups in Table 12. Classification using the mean value as it compares to data in Table 10 is also provided.

The data presented in Table 12 indicates that the lithology at Drake is non-saline. All lithological units; both fresh and weathered, are classified as having a 'low' $EC_{1:5}$ value (mean $EC_{1:5}$ value between 150 and 450 µS/cm), with the exception of the weathered mudstone and weathered coaly units which were both classified as 'medium' (mean $EC_{1:5}$ values between 450 and 900 µS/cm).

Table 12: Excavated waste slurry $EC_{1:5}$ values by lithological waste group

	Count	Mean	Median	Max.	Min.	St. Dev.	Classification[1]
Waste group	No.	←		µS/cm		→	
Soil - fresh	0	NA	NA	NA	NA	NA	NA
Soil - weathered	19	234	191	593	93	151	Low
Soil - all	19	234	191	593	93	151	Low
Siltstone - fresh	36	215	193	403	80	91	Low
Siltstone - weathered	18	348	293	862	109	190	Low
Siltstone - all	54	259	213	862	80	145	Low
Sandstone - fresh	77	200	175	485	64	87	Low
Sandstone – weathered	33	332	303	763	93	192	Low
Sandstone - all	110	251	189	763	64	144	Low
Mudstone - fresh	37	210	189	416	46	86	Low
Mudstone - weathered	14	459	454	840	199	214	Medium
Mudstone - all	51	278	232	840	46	173	Low
Intrusion - fresh	25	253	246	556	113	112	Low
Intrusion – weathered	7	290	239	594	167	153	Low
Intrusion - all	32	261	243	594	113	121	Low
Coaly material - fresh	7	140	131	197	91	44	Very low
Coaly material - weathered	1	544	544	544	544	0	Medium
Coaly material - all	8	190	147	544	91	149	Low
Carb. material - fresh	51	198	185	402	57	86	Low
Carb. material - weathered	4	150	137	196	129	31	Low

	Count	Mean	Median	Max.	Min.	St. Dev.	Classification[1]
Carb. material - all	55	195	182	402	57	84	Low
Total - fresh	233	207	184	556	46	91	Low
Total – weathered	96	326	267	862	93	193	Low
Total – all	329	245	198	862	46	141	Low

1: Classification as determined from Table 1 (DME 1995) – refer Table 10. NA: Not applicable as no samples in this category.

Additionally, the fresh coaly material was classified as 'very low' having mean slurry $EC_{1:5}$ values of 140 µS/cm.

The overall slurry $EC_{1:5}$ classification for the 329 Drake excavated waste samples as 'low' suggests that the lithology is non-saline, and would imply that the excavated waste is highly unlikely to produce saline drainage in the short term. These findings are consistent with weathering characteristics of lithologies deposited in deltaic and fluvial, rather than marine environments within the Bowen Basin in the late Permian (Hunt 1987).

Chloride

Slurry chloride values are shown by fresh and weathered lithological units in Table 13. Classification using the mean value as it compares to data in Table 10 is also provided.

The data presented in Table 13 broadly supports the $EC_{1:5}$ data and indicates that the lithology at Drake is generally non-saline. All lithological units; both fresh and weathered are classified as having either a 'very low' or 'low' chloride value (mean chloride value below 100 ppm and between 100 and 300 ppm respectively), with the exception of the weathered mudstone unit which was classified as 'medium' (mean chloride values between 300 and 600 ppm). This finding is broadly consistent with the $EC_{1:5}$ data, presented above.

As may be expected, mean chloride concentrations in all lithological groups was higher in the weathered samples relative to the fresh samples, likely due to an increase secondary salts as the geology weathers.

The overall slurry chloride classification for the Drake excavated waste samples as 'very low' further suggests that the lithology is non-saline, and would imply that the excavated waste is highly unlikely to produce saline drainage in the short term. As with the $EC_{1:5}$ data presented above, these findings are consistent with weathering characteristics of lithologies deposited in deltaic and fluvial, rather than marine environments within the Bowen Basin in the late Permian (Hunt 1987).

Table 13: Excavated waste chloride values by lithological waste group

	Count	Mean	Median	Max.	Min[2].	St. Dev.	Classification[1]
Waste group	No.	←|		mg/kg		→|	
Soil - fresh	0	NA	NA	NA	NA	NA	NA
Soil - weathered	11	121	60	500	5	167	Low
Soil - all	11	121	60	500	5	167	Low
Siltstone - fresh	36	38	30	290	5	54	Very low
Siltstone - weathered	9	242	100	660	10	277	Low
Siltstone - all	45	79	30	660	5	152	Very low
Sandstone - fresh	76	35	30	220	5	31	Very low
Sandstone – weathered	17	260	170	890	5	262	Low
Sandstone - all	93	76	30	890	5	143	Very low
Mudstone - fresh	37	35	20	160	5	32	Very low
Mudstone - weathered	8	504	490	1,110	5	413	Medium
Mudstone - all	45	118	30	1,110	5	247	Low
Intrusion - fresh	23	62	20	820	5	166	Very low
Intrusion – weathered	4	225	55	750	40	350	Low
Intrusion - all	27	86	20	820	5	203	Very low
Coaly material - fresh	7	11	10	20	5	7	Very low
Coaly material - weathered	1	300	300	300	300	0	Low
Coaly material - all	8	47	10	300	5	102	Very low
Carb. material - fresh	49	34	30	120	5	24	Very low
Carb. material - weathered	2	120	120	200	40	113	Low
Carb. material - all	51	37	30	200	5	33	Very low
Total - fresh	228	37	30	820	5	62	Very low
Total – weathered	52	238	135	1,110	5	289	Low
Total – all	280	78	30	1,110	5	161	Very low

1: Classification as determined from Table 1 (DME 1995) – refer Table 10.

2: Laboratory detection limit was 10 ppm; a value of 50% of this limit was used for statistical purposes, i.e. 5 ppm.

NA: Not applicable as no samples in this category.

4.2.2 Acid base accounting

Acid base accounting is a term that incorporates a range of static geochemical tests to determine the theoretical maximum potential acidity (MPA) of a sample through the oxidation of sulphide minerals, the theoretical maximum acid neutralising capacity (ANC) of a sample through the dissolution of alkaline carbonates, the displacement of exchangeable bases, and the weathering of silicates, and therefore, the net acid producing potential (NAPP) of a sample (AMIRA 2002). These static geochemical techniques are defined by AMIRA (2002) as initial screening tools. The results are the used to classify the samples and identify any uncertain samples whereby additional, more detailed testing may be required.

In order to determine the MPA of a sample, the total sulphur percent must first be determined. At Drake, 284 geochemical samples underwent total sulphur and sulphate sulphur analysis, with the net of total sulphur minus sulphate sulphur being defined as the reactive (or sulphide) sulphur content of the sample. This procedure assumes that all remaining sulphur is 'pyritic' or reactive, and available to form acid upon oxidation; an assumption that does not always hold true with coal waste samples (ACARP 2008) due to the presence of organic, non-acid producing sulfur. The procedure may therefore overestimate the acid potential of a sample, and is therefore deemed to be a somewhat conservative approach for the purposes of this study and was undertaken in lieu of more detailed sulphur speciation in the interests of budgetary considerations (Stewart *et al*. 2005; ACARP 2008).

Sample classification using acid base accounting was undertaken using the ANC/MPA ratio (or net potential ratio - NPR) whereby as a general rule, a NPR ratio of approximately 2 or greater signifies that there is a high probability that the material will remain near neutral, and should not be problematic with respect to AMD; all other factors being equal (AMIRA 2002).

The above methodology may also overestimate the acid neutralising potential of a sample due to assumptions related to the type of carbonate present; i.e. that it is all present as neutralising calcite (Skousen *et al.* 1997; Weber *et al*. 2004). This is in addition to potentially overestimating the MPA of a sample as noted above despite the adjustment for sulphate sulphur. This is as non-acid forming sulphur species may be present in the samples; for example, organic sulphur.

The above consideration notwithstanding, the acid base accounting results provide a useful first pass screening tool for assessing the likely acid risk from the Drake samples upon oxidation, and are therefore deemed appropriate for the stated aims of this study.

The summary acid base accounting results by lithological waste group are presented in Table 14, with NPR classification by lithology then plotted in Figure 8 to Figure 15 respectively. Note that the total sulphur value on the 'x axis' in Figure 8 to Figure 15 inclusive is an adjusted reactive sulphur (or sulphide sulphur) value, calculated as total sulphur minus sulphate sulphur; i.e. the reactive sulphur values in Table 14.

Table 14: Waste Rock Acid Base Accounting Geochemical Results by Lithological Waste Group

Waste Unit	Stat.	Total S	Sulphate S	Reactive S[3]	MPA[1]	ANC	NAPP	NPR[2]
		%	mg/kg	%	←	kg H_2SO_4 tonne	→	ratio
Carbonaceous material	Count	52	52	52	52	52	52	50[5]
	Mean	0.07	128	0.06	1.8	32.2	-30.4	49.0
	S.D.	0.08	126	0.08	2.3	23.5	23.3	NA[6]
	Range	0.01-0.50	50-910	0.0[4]-0.5	0.0-15.1	6.6-124.0	-120.5 to -3.7	2.2 – 323.5
Coaly material	Count	8	8	8	8	8	8	7
	Mean	0.09	86	0.08	2.4	27.1	-24.7	10.4
	S.D.	0.05	51	0.05	1.5	22.8	23.1	NA
	Range	0.005-0.15	50-170	0.0-0.15	0.0-4.5	6.1-60.1	-58.1 to -2.9	**1.9**-30.2
Intrusion	Count	29	29	29	29	29	29	26
	Mean	0.06	83	0.06	1.7	89.5	-87.8	125.5
	S.D.	0.08	59	0.08	2.5	54.5	54.2	NA
	Range	0.005-0.38	50-240	0-0-0.36	0.0-10.9	16.3-315.0	-315.0 to -14.9	10.2-644.4
Mudstone	Count	45	45	45	45	45	45	36
	Mean	0.05	152	0.04	1.2	36.8	-35.6	79.8
	S.D.	0.05	126	0.05	1.5	23.5	23.7	NA
	Range	0.005-0.29	50-630	0.0-0.28	0.0-8.5	9.5-116.0	-115.9 to -8.4	3.9-1,263.6
Sandstone	Count	95	95	95	95	95	95	78
	Mean	0.03	132	0.02	0.6	68.9	-68.3	225.5
	S.D.	0.02	86	0.02	0.7	59.4	59.5	NA
	Range	0.005-0.11	50-450	0.0-0.1	0.0-2.9	4.7-426.0	-425.7 to -3.6	4.4-2,120.9
Siltstone	Count	45	45	45	45	45	45	36
	Mean	0.04	139	0.03	0.8	40.3	-39.5	73.3
	S.D.	0.04	108	0.04	1.2	25.2	25.4	NA
	Range	0.005-0.26	50-620	0.0-0.24	0.0-7.3	5.9-114.0	-114.0 to -4.6	4.6-530.1
Soil	Count	10	10	10	10	10	10	1

Waste Unit	Stat.	Total S	Sulphate S	Reactive S[3]	MPA[1]	ANC	NAPP	NPR[2]
		%	mg/kg	%	← kg H_2SO_4 tonne		→	ratio
	Mean	0.01	225	0.001	0.02	42.8	-42.8	110.0
	S.D.	0.005	148	0.002	0.05	31.5	31.5	NA
	Range	0.005-0.2	50-510	0.0-0.005	0.0-0.15	9.4-85.2	-85.2 to -9.4	110.0-110.0
Weathered samples	Count	52	52	52	52	52	52	13
	Mean	0.01	120	0.006	0.2	63.3	-63.1	129.8
	S.D.	0.02	131	0.01	0.5	64.0	64.0	NA
	Range	0.005-0.11	50-630	0.0-0.075	0.0-0.295	7.9-360.0	-7.4 to -360.0	6.3-530.0
Fresh samples	Count	232	232	232	232	232	232	221
	Mean	0.06	127	0.04	1.3	50.2	-48.9	124
	S.D.	0.06	99	0.06	1.8	41.7	41.8	NA
	Range	0.005-0.5	50-910	0.0-0.5	0.0-15.1	4.7-426.0	-425.7 to -2.9	**1.9**-2,120.9
All samples	Count	284	284	284	284	284	284	234
	Mean	0.048	132	0.04	1.1	52.6	-51.5	123.9
	S.D.	0.056	107	0.05	1.65	46.7	46.8	NA
	Range	0.005-0.5	50-910	0.0-0.5	0.0-15.1	4.7-426.0	-425.7 to -2.9	**1.9**-2,120.9

1: Stoichiometrically calculated from results. Adjusted to consider sulphate sulphur results, and is therefore an adjusted value. When total S was <lab PQL of 0.01 mg/kg, a value of 0.005 was used. When sulphate sulphur was <lab PQL of 100 mg/kg, a value of 50 mg/kg was used. MPA (kg H_2SO_4 per tonne) = (total S – sulphate S) * 30.6.
2: Calculated from results. Generally, an ANC/MPA ratio of greater than 2 indicates a suitable excess of inherent acid buffering capacity in the waste material (AMIRA 2002).
3: Total S – sulphate S.
4: Where the sulphate concentration exceeded the total S concentration, within the allowable laboratory error, resulting in a negative reactive S value, a value of 0 was used.
5: Count may be different due to Note 4, above, in which case the MPA becomes zero and a NPR cannot be calculated due to a return of 'not divisible by zero'. The NPR is effectively a redundant measure in this instance as there is 0.0% reactive S in the sample.
6: NA = not applicable as the NPR is a ratio rather than an absolute number for statistical purposes.

The data in Table 14 indicates overall that there appears to be little risk of AMD generating from either the fresh or weathered samples in all lithological waste groups at Drake in the short term. Indeed, only one sample returned an NPR value less than 2; a sample of coaly material which returned a NPR of 1.9. The total sulphur values within all lithologies, including the coaly material and the carbonaceous material; generally regarded as higher AMD risk, had a maximum value of 0.5%. This is consistent with the broader literature on the late Permian coal measures of the Bowen Basin (Hunt 1987).

As a consequence of the low total sulphur values, the adjusted 'sulphide sulphur' values mean that all lithological waste units retain a very low potential to generate acid upon oxidation of the sulphidic material, with a maximum value of 15.2 kg H_2SO_4 / tonne for a sample of carbonaceous material.

Despite a single MPA reading of 15.2 kg H_2SO_4 / tonne for a sample of carbonaceous material, the carbonaceous material lithological waste group as a whole (52 samples) had a mean MPA value of 1.8 kg H_2SO_4 / tonne, and a mean NPR of 49, thereby indicating a surfeit of acid neutralising capacity relative to the unit's ability to generate acid upon sulphide oxidation (refer Table 14). The data for the carbonaceous material provides increased confidence that the unit is not an AMD risk, notwithstanding the dearth of carbon speciation data (i.e. total, organic, carbonate etc).

Evidence of the likely presence of reactive carbonate minerals in the carbonaceous material lithological group was a mean 'fizz rating' of 1.3 (not reported; refer laboratory results in Appendix B). A 'fizz rating' is determined prior to undertaking net acid generation (NAG) tests whereby a few drops of hydrochloric acid are added to the sample and the visible reaction observed. The 'fizz rating' is measures on a scale of 0 to 5, where 0 is no reaction and 5 is lime, or pure calcite ($CaCO_3$). A mean rating of 1.3 indicates a 'fizz rating' of between slight and moderate; indicative of the presence of reactive carbonate minerals.

The most reactive samples in the 'fizz test' were the intrusive material (a mean value of 2.2) followed by sandstone (a mean value of 1.9). The intrusive material reacting to acid with a moderate to strong response, is consistent with its mean NAPP value of -87.8 kg H_2SO_4 / tonne; almost an acid consuming result. This is consistent with potentially acid consuming mineralogy of the intrusives in the northern Bowen Basin as described by Mallet *et al*. (1995) which includes trachyte, latite, quartz diorite (or andesite), feldspar porphyry and subordinate diorite. The presence of alkali feldspar, biotite and even olivine in such rocks may add to the potential acid neutralising capacity of the intrusive lithology.

The sandstone unit had a mean NAPP value of -68.3 kg H_2SO_4 / tonne, and notwithstanding a lack of carbon speciation data, appears to have the potential to be a suitable capping material for waste rock dumps, should the material not be dispersive. Mean adjusted MPA values of 1.7 and 0.6 kg H_2SO_4 / tonne for the intrusive and the sandstone lithological group respectively (refer Table 14) indicates a very low potential for both units to generate acid upon oxidation; and would further suggest that there is an excess of neutralising minerals in the two lithologies relative to any residual sulphidic material. Note that total sulphur on the 'x-axis' in Figure 8 to Figure 15 respectively is a visual surrogate for MPA.

The weathered material returned a lower adjusted mean MPA value of 0.2 kg H_2SO_4 / tonne than the fresh samples (1.3 kg H_2SO_4 / tonne); likely indicative of less residual, unoxidised sulphidic minerals in the weathered units relative to the fresh units.

The acid base accounting data plotted on Figure 8 to Figure 15 inclusive is simply a visual representation of the information summarised in Table 14. The data shows that all bar one sample has a NPR of greater than 2, indicating that all lithological groups likely have sufficient buffering capacity to offset any acid generated through sulphide oxidation, on the basis of the analytical data assessed. The one sample with an NPR below 2 was a fresh coaly material sample as noted above and shown in Figure 9.

The propensity for the weathered material to have a lower mean MPA value than the fresh samples as the bulk of the sulphidic minerals present have oxidised (as noted above) is visually represented by the bulk of the lighter blue squares plotting proximal to the 'y axis' on Figure 8 to Figure 15 inclusive. Figure 15 has a logarithmic 'y axis' to highlight this point. This is important as the CENZ waste unit is represented by the soil lithological group, in addition to all other excavated weathered material above the limit of oxidation at Drake; in total approximately 480 million tonnes, or 25 percent of the excavated waste. It is therefore important that the weathered material is adequately assessed such that any AMD risk is understood, in addition to subsequently understanding its potential for beneficial reuse in progressive site rehabilitation.

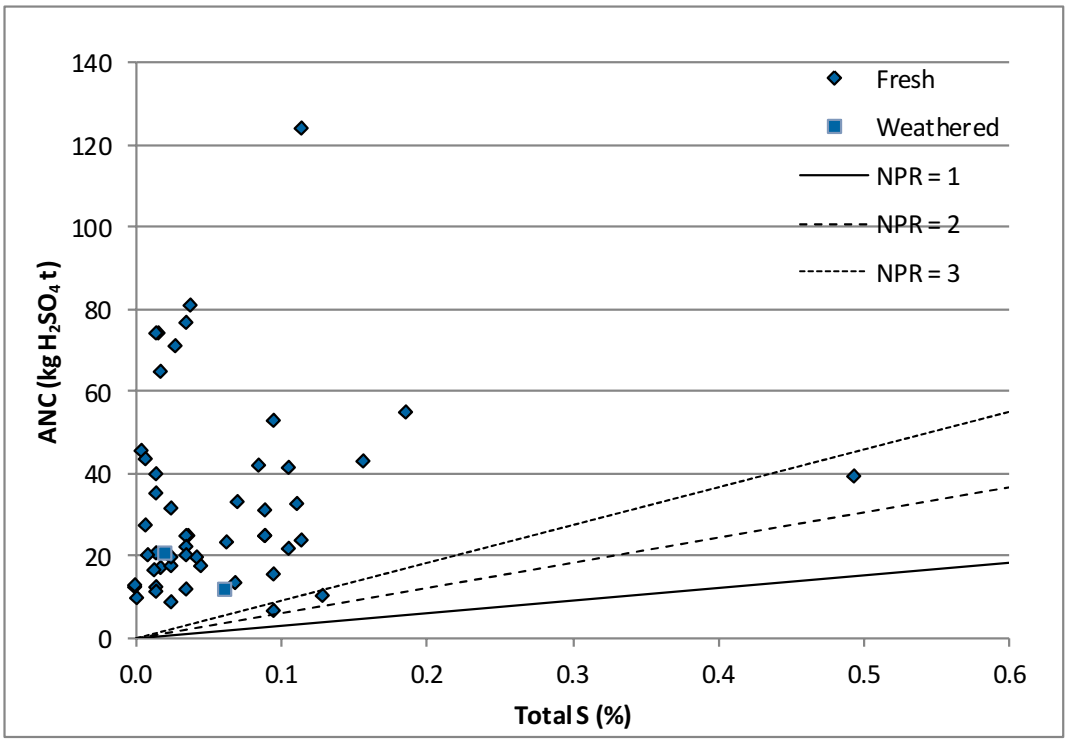


Figure 8: Carbonaceous material acid base account plot

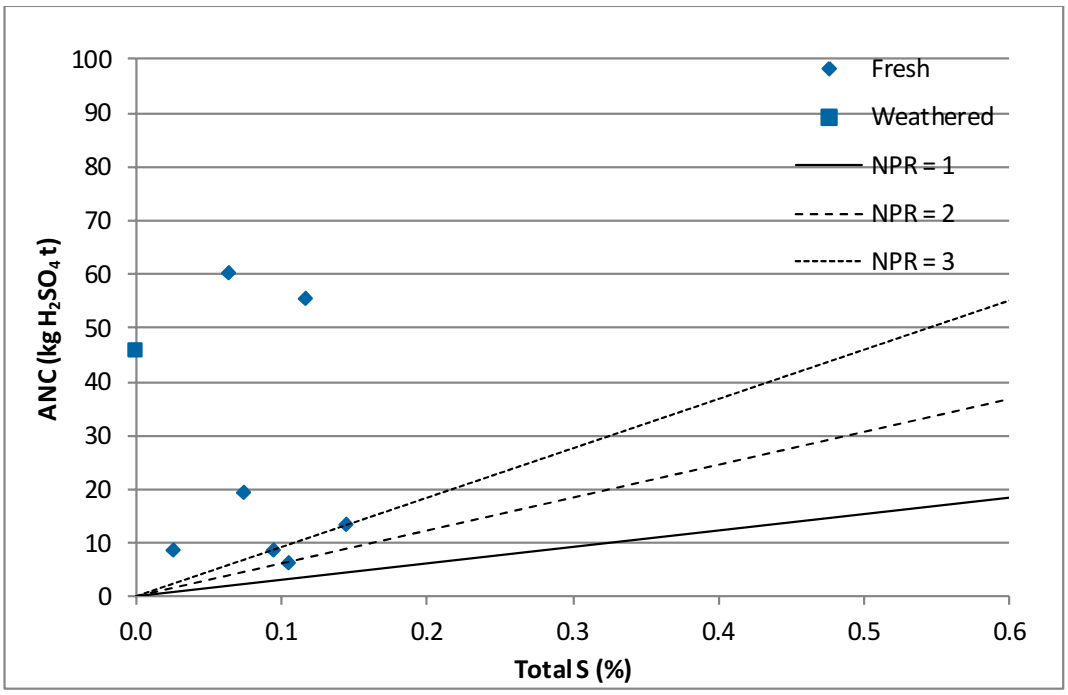


Figure 9: Coaly material acid base account plot

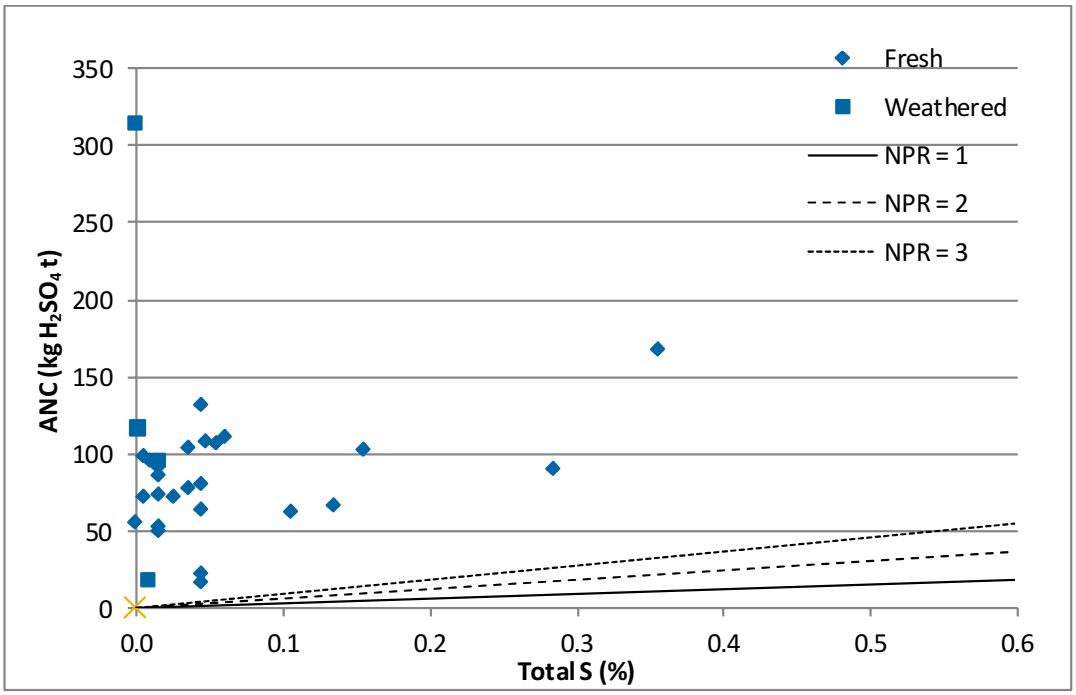


Figure 10: Intrusive material acid base account plot

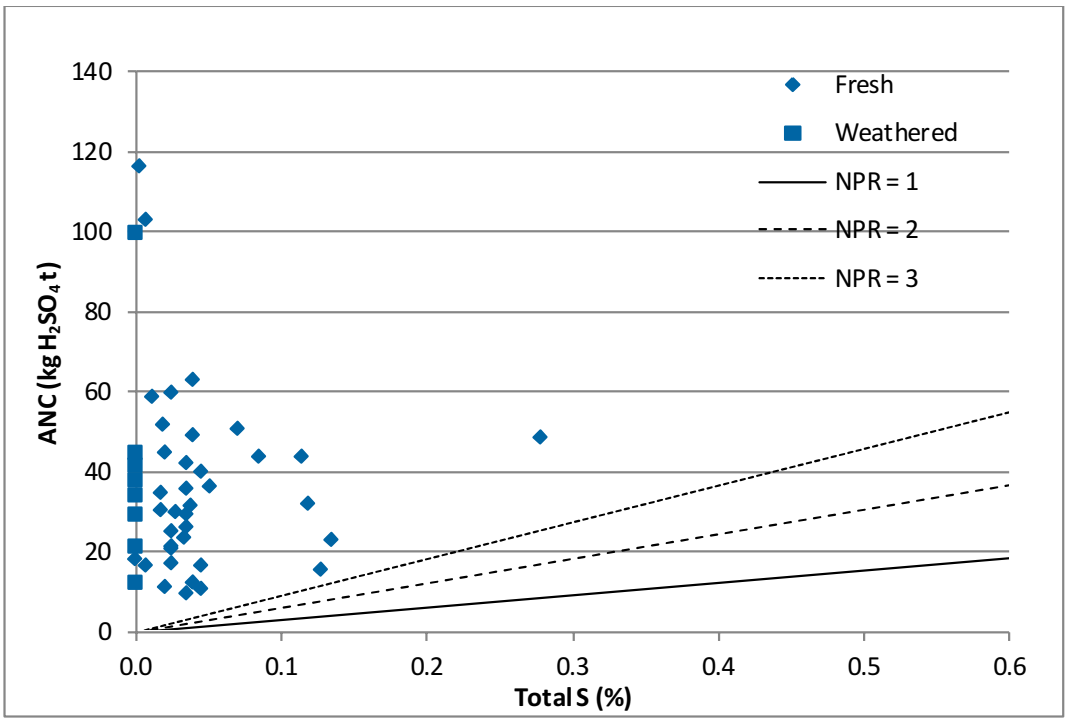


Figure 11: Mudstone acid base account plot

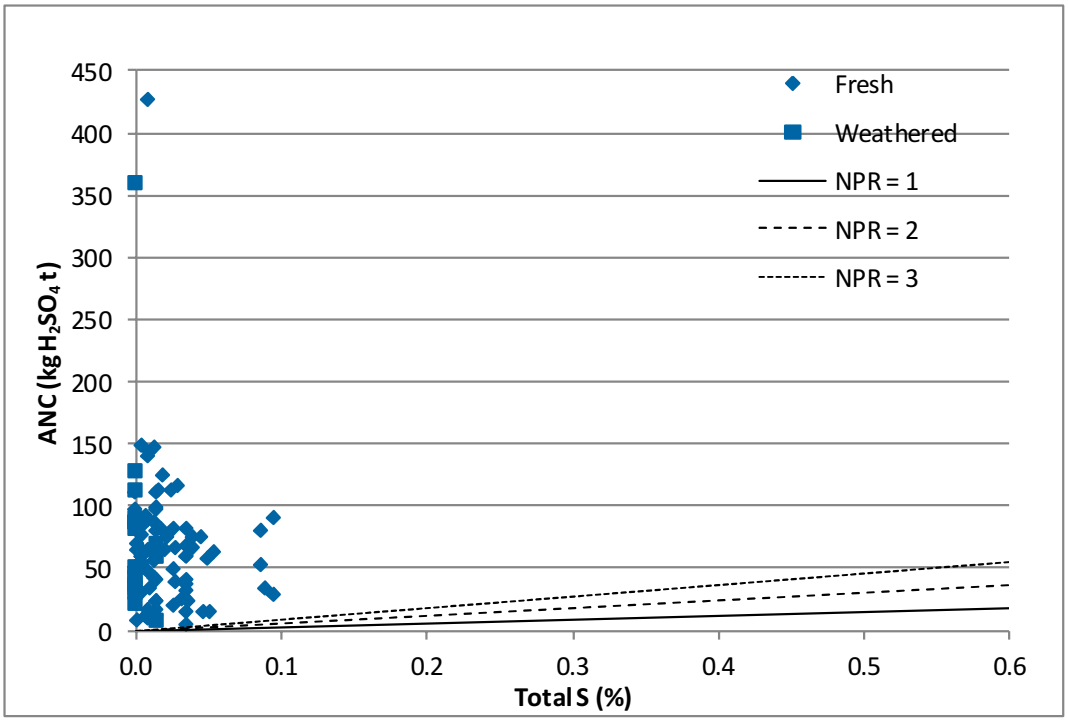


Figure 12: Sandstone acid base account plot

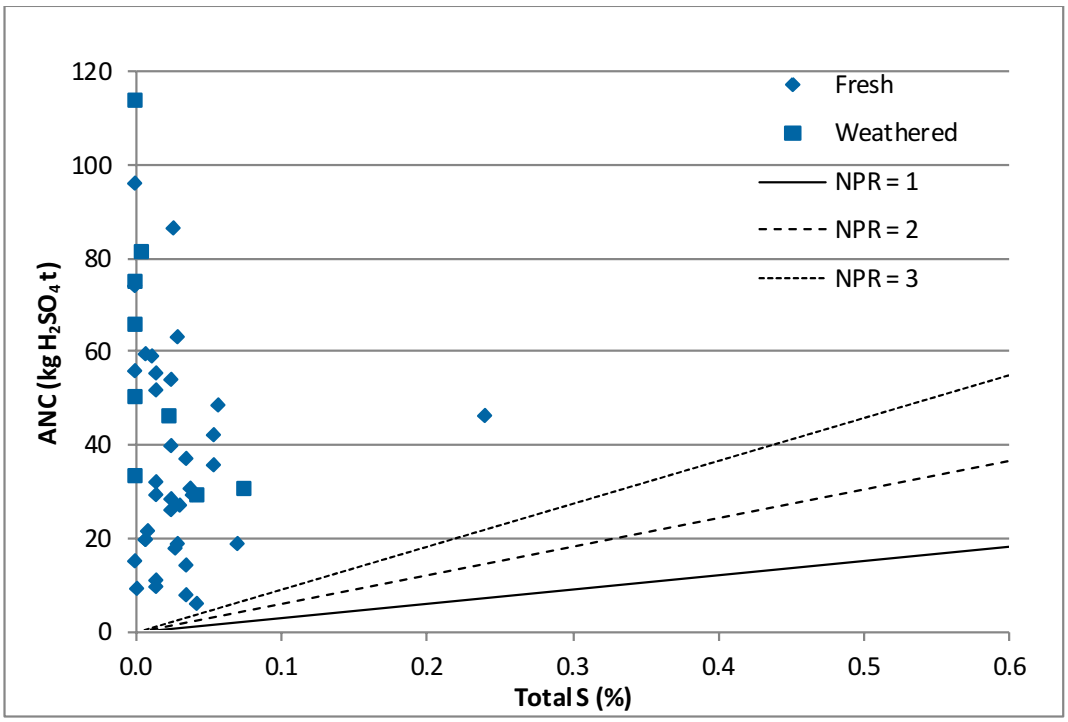


Figure 13: Siltstone acid base account plot

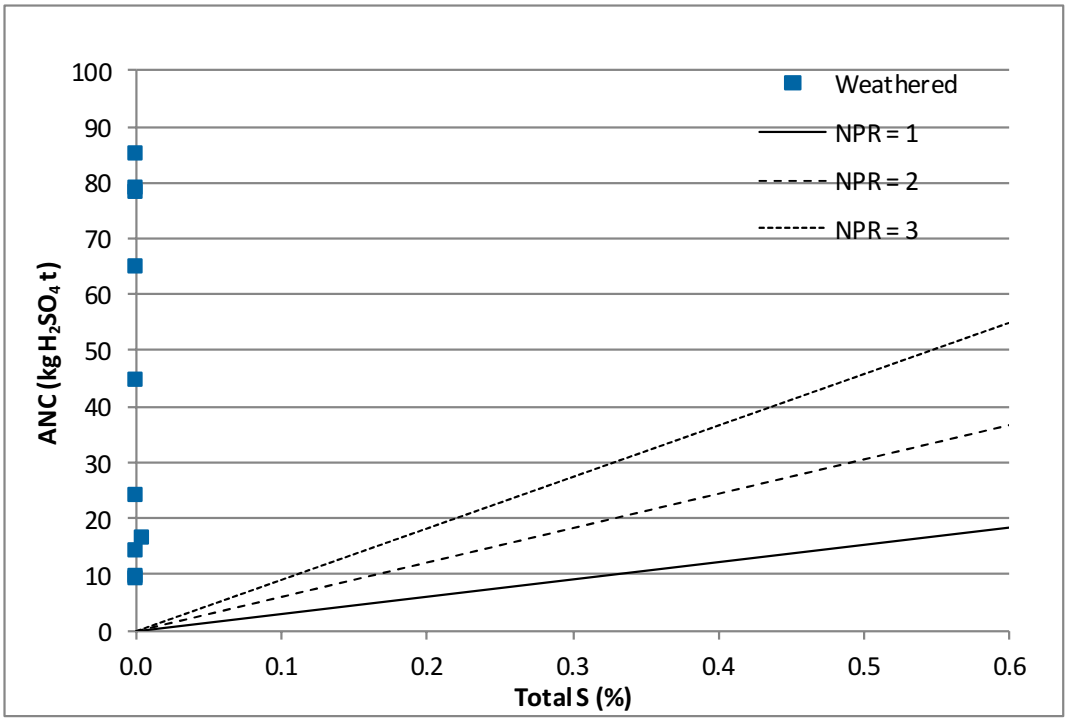


Figure 14: Soil acid base account plot

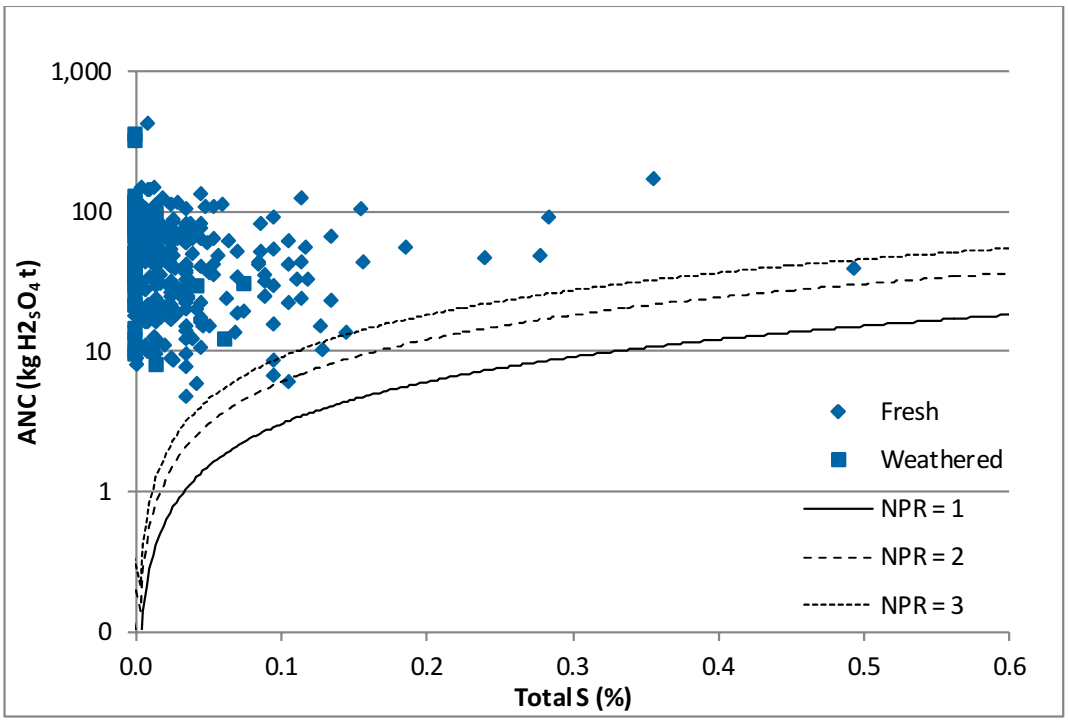


Figure 15: All lithologies acid base account plot

4.2.3 Net acid generation

The single addition net acid generation (NAG) test is used in association with the NAPP value to classify the acid generating potential of a sample. The NAG test involves reaction of a sample with hydrogen peroxide to rapidly oxidise any sulphide minerals contained within a sample. During the NAG test, acid generation and acid neutralisation reactions can occur simultaneously. Therefore, the end result represents a direct measurement of the net amount of acid generated by the sample. This value is commonly referred to as the NAG capacity, and is expressed in the same units as NAPP; i.e. kg H_2SO_4 / tonne (AMIRA 2002).

The single addition NAG test involves adding a known volume of a known concentration of hydrogen peroxide to a known mass of a sample. The peroxide is allowed to react with the sample overnight, with the sample being gently heated the following day to accelerate the oxidation of any remaining sulphides. The sample is then vigorously boiled for several minutes to decompose any residual hydrogen peroxide. When cool, the pH (NAGpH, or pH(OX) as reported by ALS in the results provided in Appendix B) and acidity of the NAG liquor are measured. The acidity of the liquor is then used to estimate the net amount of acid produced per unit weight of sample by titration against a base (hydrogen peroxide) (AMIRA 2002).

Titration to pH 4.5 generally accounts for acidity attributable to free acid (H_2SO_4), and/or acid from soluble ferric iron and aluminium generated during the oxidation of sulphide minerals that has subsequently been neutralised by any contained neutralising capacity at the same pH range. Titration from pH 4.5 to pH 7 then generally accounts for acidity associated with metallic ions, such as copper for example, that are mostly soluble at pH 4.5, though precipitate as hydroxides at pH values between 4.5 and 7.0.

Past research has shown that the single addition NAG test completely oxidises the pyritic, or reactive, sulphide in samples with a 'reactive sulphur' (total sulphur minus sulphate sulphur) value of less than approximately 1% (AMIRA 2002). It was therefore applicable for use on the Drake samples. However, subsequent research (ACARP 2008) has indicated that the single addition NAG test may be unsuitable for samples with elevated organic carbon contents of greater than approximately 5 to 7%. This is as reaction of the hydrogen peroxide with any organic matter tends to produce organic acids; thereby artificially elevating the NAG capacity results, and providing a false (positive) measure of the sulphidic acid potential. This is especially so in samples with sulphidic sulphur concentrations below approximately 1%. Alternative tests including sequential NAG and/or kinetic NAG tests, or alternatively, the chromium reducible sulphur test, may be more appropriate in those circumstances (ACARP 2008). Alternatively, carbon speciation through the use of total carbon, total organic carbon, total inorganic carbon and/or carbonate carbon tests may provide more accurate acid neutralising capacity results; as may use of the acid buffering characteristics curve (ABCC).

The above notwithstanding, and due to budgetary and schedule constraints, single addition NAG tests were completed on 284 Drake samples. The single addition NAG testing undertaken was considered an appropriate first pass indicator of acid risk for the stated purposes of this study; with any addition testing recommended at the appropriate juncture in the text. Summary results are provided in Table 15. The samples have been further classified using the mean NAPP data shown in Table 14 and the mean NAGpH (Table 15) as per the classification scheme developed from Miller (1996) and presented in AMIRA (2002) and ACARP (2008) for example. The classification scheme is shown in Table 16.

The summary data in Table 15 indicates that the excavated waste at Drake has a very low potential to generate acid upon oxidation, as demonstrated by none of the 284 NAG (pH 4.5) results returning a reading over the laboratory level of reporting (LOR) of <0.1 kg H_2SO_4 / tonne.

In addition, only 6 of 284 samples returned a NAG (pH 7.0) result above the laboratory level of reporting of <0.1 kg H_2SO_4 / tonne, being;

- one fresh carbonaceous material sample that returned a value of 3 kg H_2SO_4 / tonne;
- two coaly material samples that returned values of 7 and 11 kg H_2SO_4 / tonne;
- one fresh sandstone sample that returned a value of 0.6 kg H_2SO_4 / tonne;
- one fresh siltstone sample that returned a value of 0.2 kg H_2SO_4 / tonne; and
- one weathered soil sample that returned a value of 0.4 kg H_2SO_4 / tonne.

Table 15: NAG geochemical results

Waste Group	Stat.	pH (ox)	NAG (pH 4.5)	NAG (pH 7.0)	Classification
		pH units	← kg H_2SO_4 / tonne →		(Table 16)
Carbonaceous material	Count	52	52	52	
	Mean	8.8	<0.1[1]	0.11	NAF
	S.D.	1.1	<0.1	0.41	
	Range	5.2-10.6	<0.1	0.05-3.0	
Coaly material	Count	8	8	8	
	Mean	7.6	<0.1	0.1	NAF
	S.D.	1.8	<0.1	4.2	
	Range	4.6-9.4	<0.1	<0.01-11.0	
Intrusion	Count	29	29	29	
	Mean	10.0	<0.1	<0.1	NAF
	S.D.	0.8	<0.1	<0.1	
	Range	8.4-11.2	<0.1	<0.1	
Mudstone	Count	45	45	45	
	Mean	9.1	<0.1	<0.1	NAF
	S.D.	0.9	<0.1	<0.1	
	Range	7.4-10.7	<0.1	<0.1	
Sandstone	Count	95	95	95	
	Mean	9.7	<0.1	0.06	NAF
	S.D.	0.9	<0.1	0.06	
	Range	6.6-11.3	<0.1	0.05-0.6	
Siltstone	Count	45	45	45	
	Mean	9.1	<0.1	0.05	NAF
	S.D.	0.9	<0.1	0.02	
	Range	6.8-10.6	<0.1	0.05-0.2	
Soil	Count	10	10	10	
	Mean	8.7	<0.1	0.09	NAF
	S.D.	1.0	<0.1	0.11	
	Range	6.9-10.2	<0.1	0.05-0.4	
Weathered samples	Count	52	52	52	
	Mean	9.2	<0.1	0.06	NAF
	S.D.	0.8	<0.1	0.05	
	Range	6.9-11.2	<0.1	0.05-0.4	
Fresh samples	Count	232	232	232	
	Mean	9.3	<0.1	0.14	NAF
	S.D.	1.1	<0.1	0.87	
	Range	4.6-11.3	<0.1	0.05-11.0	

Waste Group	Stat.	pH (ox)	NAG (pH 4.5)	NAG (pH 7.0)	Classification
		pH units	← kg H_2SO_4 / tonne →		(Table 16)
All samples	Count	284	284	284	
	Mean	9.3	<0.1	0.13	NAF
	S.D.	1.1	<0.1	0.79	
	Range	4.6-11.3	<0.1	0.05-11.0	

1: The laboratory detection limit was <0.1. Where a non-detect was returned, a value of 50% of the laboratory detection limit was used for statistical analysis purposes.

Table 16: NAG / NAPP Geochemical Classification Scheme

Primary Geochemical Material Type	NAPP[1] (kgH_2SO_4/tonne)	NAG pH[1] (pH units)
Potentially Acid Forming (PAF)	> 10	<4.5
Potentially Acid Forming – Low Capacity (PAF–LC)	0 – 10[2]	<4.5
Non-Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	< -100	≥4.5
Uncertain[3]	Positive	≥4.5
	Negative	<4.5
	Positive	<4.5

1: From Miller (1996), AMIRA (2002), ACARP (2008) and INAP (2009).
2: Site specific but typically in the range of 5 to 20 kgH_2SO_4/tonne.
3: Further testing required to confirm material classification.

The acid produced from the six samples dot-pointed above is potentially acidity generated from heavy metals hydrolysis rather than being from free acid (H_2SO_4) and/or from soluble ferric iron and/or aluminium generated during the oxidation of sulphide minerals. The oxidation pH values were broadly consistent with the $pH_{1:5}$ values shown in Table 11, with both returning mean pH values of 9.3. This would imply that the indicative leachate pH value from persistent rain on an excavated waste dump on site as represented by the $pH_{1:5}$ results, is a good indicator for pH values when oxidation and reduction reactions go to completion. The only large variance between the two pH data sets was a minimum mean value of 4.6 (pH OX) as against 8.8 ($pH_{1:5}$) for the coaly material and a minimum mean value of 5.2 (pH OX) as against 8.2 ($pH_{1:5}$) for the carbonaceous material. Mean values remained largely consistent however, thereby indicating that the minimum values were statistical outliers and/or the results of organic acid generating during the NAG test.

A further observation is that the coaly material and the carbonaceous material returned the highest reactive sulphide values of all lithological units, being 0.08 and 0.06% respectively (Table 14); which would be consistent with lower minimum pH (OX) values. (This comment notes that the

intrusive unit also had a mean sulphide sulphur value of 0.06% although had a higher mean ANC value of 89.5 kg H_2SO_4 / tonne as against the carbonaceous group (32.2 kg H_2SO_4 / tonne), thereby having a lower NAPP).

As noted above, additional classification of the lithological units based on mean NAPP values (Table 14) and mean NAG values (Table 15) are presented in Table 15. It shows that all lithological units are classified as non-acid forming (NAF), as are the weathered and fresh sample groups, and finally, the entire sample group. The (adjusted considering sulphide or reactive sulphur) NAPP and NAG values for samples in each lithological unit have also been graphed in Figure 16 to Figure 23 inclusive. This classification scheme accepts that no detailed carbon speciation analysis has been undertaken and may therefore slightly overestimate ANC, and therefore slightly underestimate (adjusted) NAPP values. It is, however, deemed an appropriate first pass methodology to be indicative of the AMD potential within the lithological units at Drake for the stated purposes of this report. Note that the scale on the 'x axis' varies between in Figure 16 to Figure 23 to provide a better fit for the data points.

The data plotted in Figure 16 to Figure 23 inclusive indicates that all 284 data points fall within the non-acid forming (NAF) upper left quadrant of the graphs. This translates to all seven lithological waste groups, and therefore, the combined lithologies, being classified as NAF. Interestingly, both the carbonaceous material and coaly material lithological waste group were both classified as NAF.

The lithological waste groups likely to contain higher carbon concentrations, such as the carbonaceous and coaly material groups, may benefit from further sulphur speciation tests (chromium reducible sulphur for example), in addition to sequential NAG testing for example. This would assist with better defining the AMD risk from the two samples with the lowest NAG pH values in Figure 17, and the one sample with the lowest pH value in Figure 16. It would assist with clarifying whether the low pH values are due to the formation of organic acids upon rapid oxidation, rather than from oxidising sulphides.

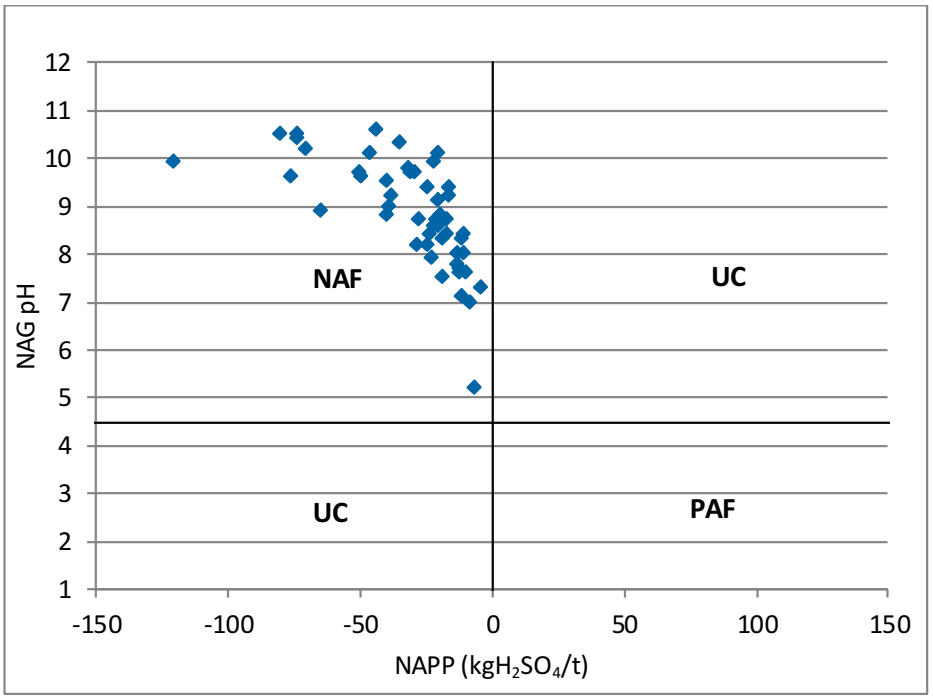


Figure 16: Carbonaceous material NAG/NAPP classification plot

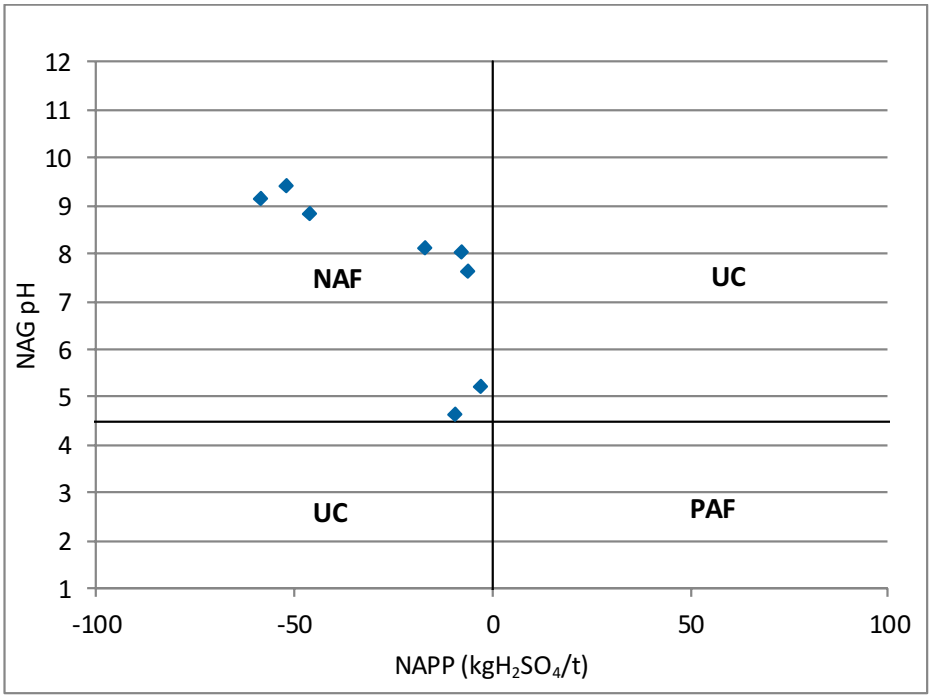


Figure 17: Coaly material NAG/NAPP classification plot

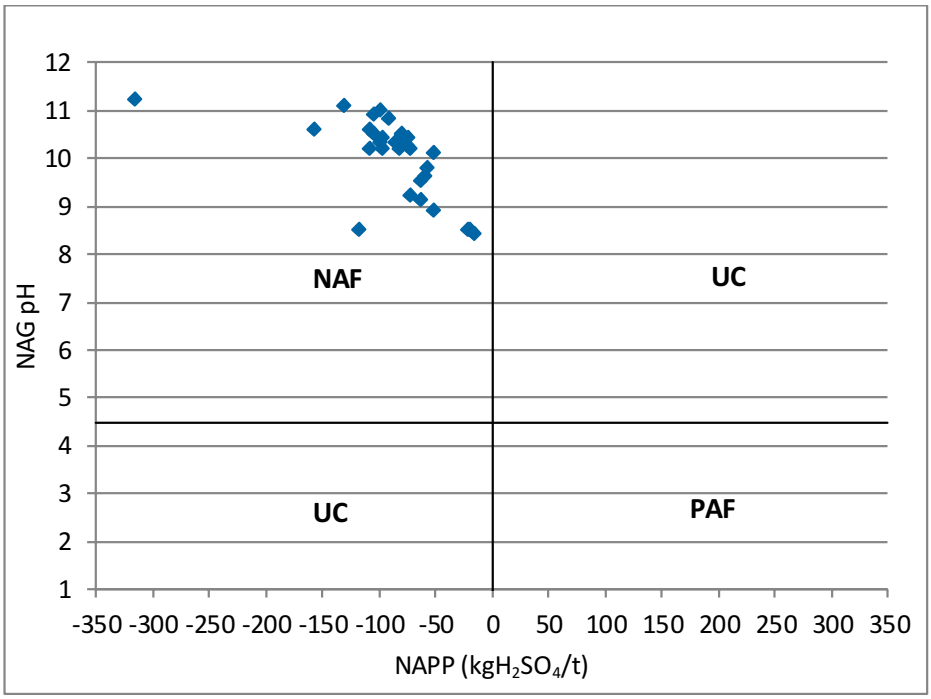


Figure 18: Intrusive material NAG/NAPP classification plot

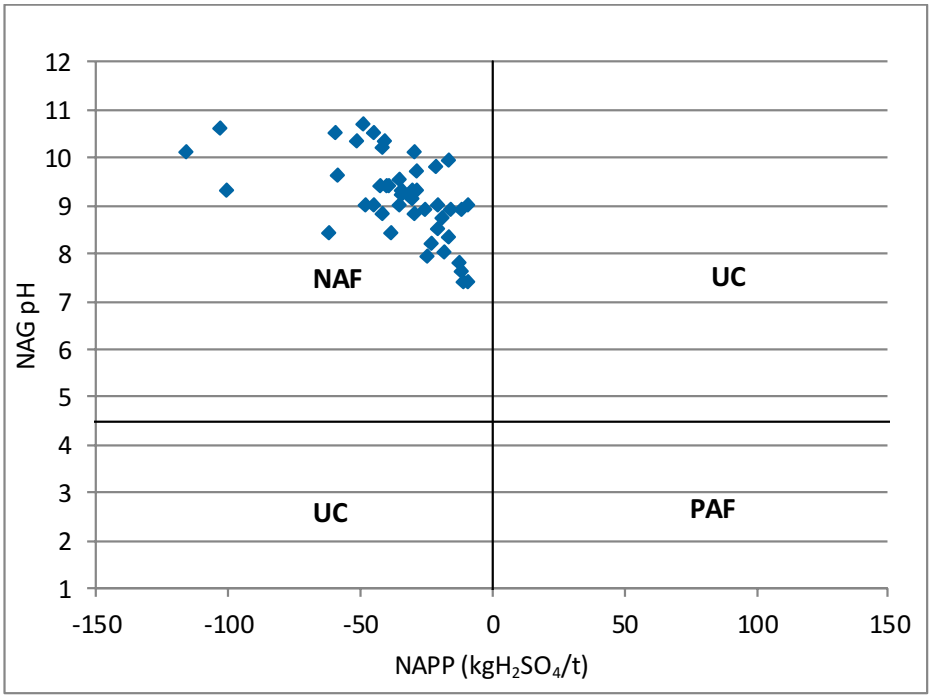


Figure 19: Mudstone NAG/NAPP classification plot

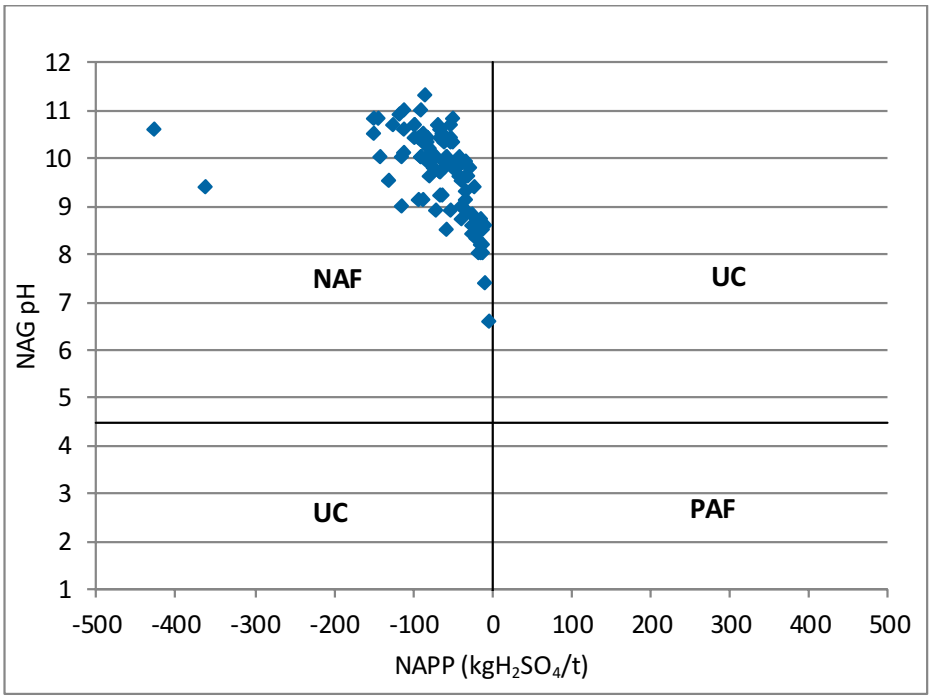


Figure 20: Sandstone NAG/NAPP classification plot

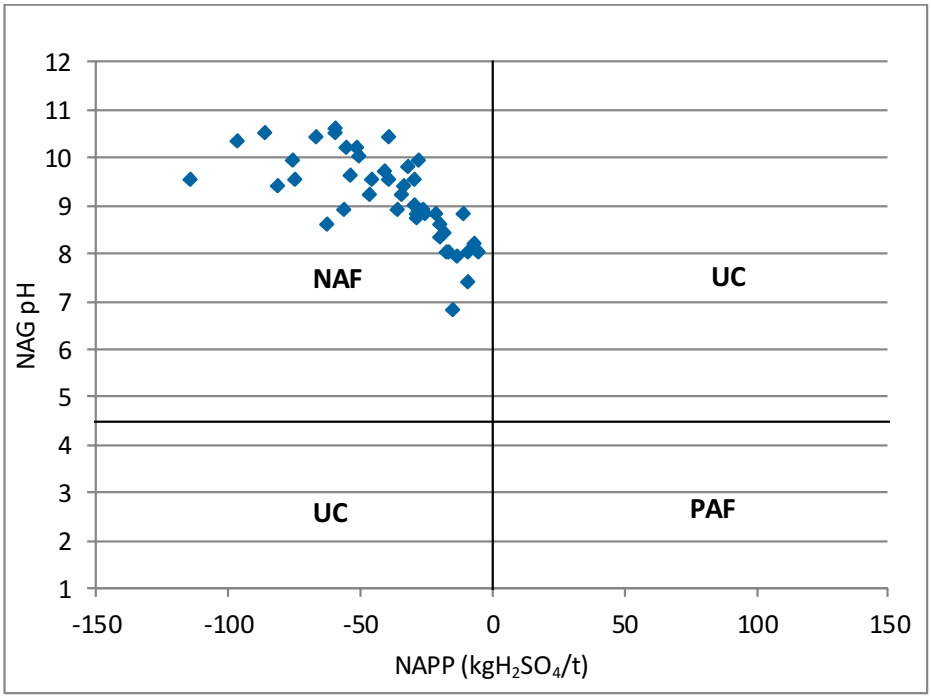


Figure 21: Siltstone NAG/NAPP classification plot

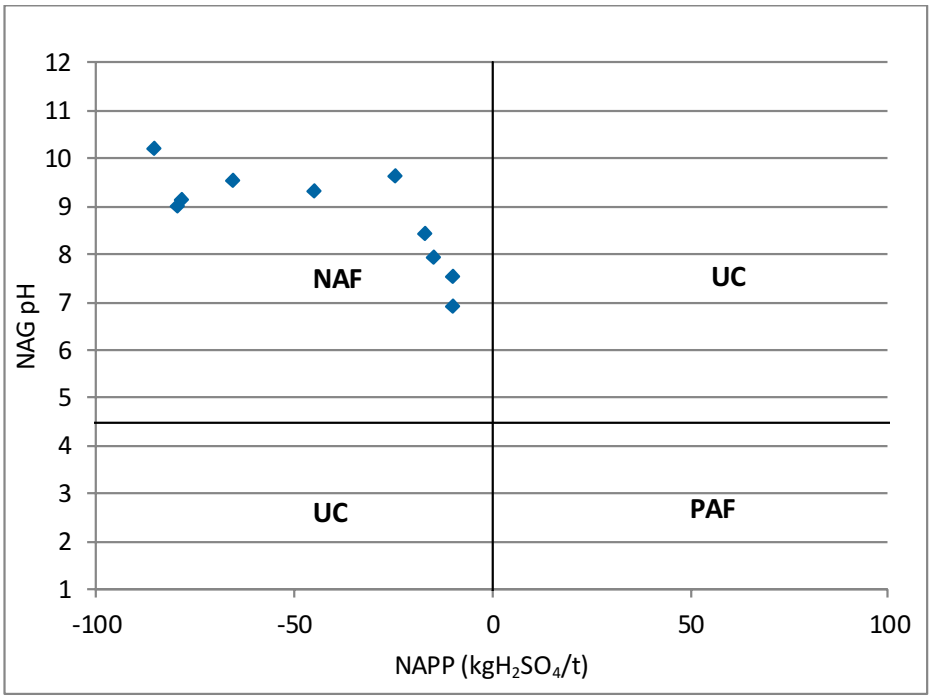


Figure 22: Soil NAG/NAPP classification plot

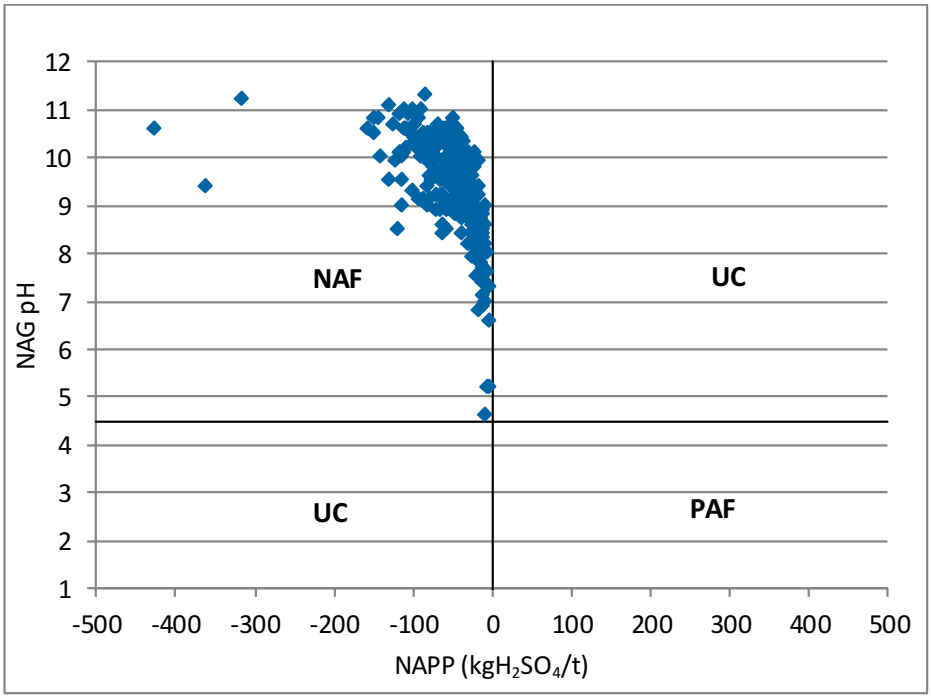


Figure 23: All samples NAG /NAPP classification plot

Similarly, it would be prudent to select a representative sub-set of samples from each lithological waste group on which to have additional carbon speciation (total organic and total inorganic) analysis undertaken, along with some ABCCs completed to better define the availability of any neutralising potential. Nevertheless, it is likely that the majority of the lithological waste groups contain a reasonable amount of available acid neutralising capacity in the form of reactive calcite as evidenced by the pH (1:5), pH (OX) and 'fizz test' results. Refer to Appendix B for the latter results.

4.3 Excavated waste: Metals

To assess the risk of metalliferous drainage at Drake, the process was twofold. The first stage was to undertake a multi-elemental scan of a sub set of geochemical samples. Accordingly, 292 samples across the seven major lithological waste groups were acid digested and analysed for 34 metals and metalloids using ICP-AES, with mercury also analysed using ICP-MS.

A direct comparison of each individual result, in addition to median results by lithological, weathered and fresh group, and finally, all results, was made against the reported abundance of elements found in nature. The latter information was crustal average data sourced from Bowen (1979) and Price (1997). Where there were no data for crustal average, mean values for either shale or sandstone sedimentary rocks were used (Price 1997), as mudstone, claystone, sandstone and siltstone make up the majority of excavated waste at Drake.

As the abundance of elements varies significantly, a log base 2 index has been historically developed to simplify comparison of measured values with average abundance. The index, called the global, or geochemical abundance index (GAI), and method, is documented in INAP (2009).

INAP (2009) describes the Geochemical Abundance Index (GAI) as a measure to compare the elemental concentration in a sample to the median abundance in the most relevant media (soils, crustal abundance etc). It was initially described by Förstner *et al*. (1993). The purpose is to provide a relative indication of any elemental enrichment that may be of environmental importance. The GAI for an element is calculated by:

$$GAI = \log2 [C / (1.5 * S)]$$

Where: C is the elemental concentration in a sample; and S is the median content for that element in the reference material.

The GAI is measured on a scale of 0 to 6; whereby 0 indicates the element is present at a concentration similar to, or less than, median global abundance, and 6 indicates an approximate 100 fold, or greater, enrichment above global abundance (Table 17). As a general guide, a GAI of 3 or above is considered significant, and such enrichment may warrant further investigation. GAI values are presented in Table 17 for individual results.

Table 17: Global abundance exceedances and GAI number

Sample exceeds crustal average by	GAI
1.5 < sample < 3	0
3 ≤ sample < 6	1
6 ≤ sample < 12	2
12 ≤ sample < 24	3
24 ≤ sample < 48	4
48 ≤ sample < 96	5
96 ≤ sample < 192	6

As noted above, 292 samples from the seven major lithological waste groups were submitted for whole rock assay metals analysis. Elements that were identified as enriched as defined by the median value for the discrete lithological waste group exceeding the GAI by a factor of 3 or greater as shown in Table 17, are shown in Table 18. Individual sample exceedances are also shown in Table 18. Note that if the individual sample result returned a non-detect at the laboratory limit of reporting (LOR); a value of 50% of that LOR was used for GAI calculation purposes.

Table 18: Elevated metals by lithological waste group median value

Lithological unit	GAI assessment method	Metals > GAI 3
Carbonaceous material	Median value	Nil
Coaly material	Median value	Nil
Intrusion	Median value	Nil
Mudstone	Median value	Nil
Sandstone	Median value	Nil
Siltstone	Median value	Nil
Sand	Median value	Nil
Weathered	Median value	Nil
Fresh	Median value	Nil
Individual samples exceedances	Individual result	As (19 – carb 3, mudstone 1, sandstone 10, siltstone 3, soil 2), S (1 – carb.).

The results in Table 18 show that there are no elevated metals concentrations relative to the crustal average for the seven lithological waste groups when the median value for each of those seven lithological waste groups was compared to the crustal abundance. When the individual results for the 292 whole rock metals assays were compared to the crustal abundance, there were 19 arsenic concentrations and 1 sulphur result that returned a GAI of 3 or greater.

The second stage in identifying metalliferous drainage risk is to assess the metal leaching potential from the excavated waste at Drake. Due to schedule constraints, leaching analysis was undertaken concurrently with whole rock metals assay for the Drake samples, rather than following whole rock assay. Metal leaching results are presented below in Section 4.4

4.4 Excavated waste: Leachate

In order to determine any leachable elements from the Drake excavated waste, a total of 92 leachate tests were completed on samples from the seven lithological units. Note that the leach tests are intended to be indicative only to identify potentially leachable elements that may require the development of proactive management strategies. The leachate results cannot therefore, be directly extrapolated to predict leachate quality in the field; however, remain useful as being an indicator of potentially leachable elements within the discrete lithological waste groups.

The leachate results reported herein have been compared to 'Stock Watering' water quality guidelines (*ANZECC/ARMCANZ 2000a)* to identify any elevated elements that potentially may be of significance relative to the proposed final site landuse of low intensity grazing (GHD 2012, Volume 1, Chapter 3). It has been assumed for the stated purposes of this indicative leachate investigation that the proposed, engineered surface water management structures being environmental dams, have been appropriately designed to contain and manage any contaminated leachate should it be generated, and that any subsequent aquatic ecosystem risk is minimal GHD (2012; Volume 1, Chapter 9). This assumption notwithstanding, the mean elemental concentrations that returned values in excess of the laboratory detection limits were also compared to 95% freshwater aquatic ecosystem survival guideline trigger values (ANZECC/ARMCANZ 2000). Again, this was an indicative comparison only; as trigger values were not corrected for water hardness as per the ANZECC/ARMCANZ (2000) methodology; a correction that would likely increase the trigger values for metals by a maximum of approximately 27 times, based on the bicarbonate alkalinity values reported on leachate samples at Drake (Appendix D).

The 92 leachate tests were completed using Australian Standard Leaching Procedure (ASLP) which uses an Australian Standard procedure (AS4439 – 1997) to identify elevated concentrations of elements in leachate. ASLP uses a leaching pH value of 7.0 and is intended to provide data that is indicative of *in situ* rainwater leachate. It is designed to provide longer term accelerated weathering data than the $pH_{1:5}$ and $EC_{1:5}$ tests reported earlier, which are intended to provide indicative, 'contact' results between rain water and mineral waste on site.

Summary results comparing the mean value for each discrete lithological waste group to the relevant guideline value for the leaching tests are presented in Table 19, with complete results shown in Appendix D. Again, a value of 50% of the LOR for the respective analyte was used to calculate summary statistics in Table 19 and Appendix D. Summary data presented in Table 19 contains mean leachate results by lithological waste group for the two elements (As and S) reported in Table 18 that were shown to have an individual GAI value of 3 or greater; i.e. were

elevated relative to the global average; to assess their leaching potential. Table 19 also shows summary results for selenium, as it is an element often found in leachable concentrations in the Bowen Basin. Mean results in Table 19 that exceed the stock watering guideline trigger value are italicised, while mean values that exceed the 95% freshwater species survival (unadjusted for hardness) trigger value are highlighted in bold.

In addition to the summary leachate data presented in Table 19, Table 20 presents a summary of leachable elements that returned concentrations of metals or metalloids above the laboratory detection limit for each respective element.

The summary results shown in Table 19 indicate that the leachate is generally slightly alkaline and mildly saline across all seven lithological waste groups, although broadly within the stock watering guidelines. There was one exceedance of the stock watering guidelines for the intrusive lithological group pH values (9.7 pH units); likely a reflection of the geology of the intrusive lithological unit (refer GHD 2012c). There was also evidence of leachable selenium above the stock watering guideline value of 0.02 mg/L; with a maximum mean leachable concentration of 0.4 mg/L in the carbonaceous lithological group. Leachable sulphate and chloride values were low and would not be expected to detrimentally impact water quality based on the data reviewed herein.

The summary data in Table 20 indicates that a total of 16 metals or metalloids were detected in leachates from the 92 leached samples across the seven lithological waste groups. No mean leachate value exceeded the stock watering criteria; however, aluminium, arsenic, copper, lead, selenium and zinc exceeded the 95% species survival trigger value for freshwater ecosystems. Note, however, that once hardness corrections and leachate pH values are considered, it is likely that many of the reported leachable metals would be only sparingly soluble at the alkaline pH values expected *in situ*. This would have concomitant positive implications for drainage ecotoxicity risk given the likely reduced availability of the leachable elements of concern due to solubility constants; and would therefore act as a natural impact mitigation method through natural attenuation.

Table 19: Excavated waste leach test summary data

Lithological Group	Stat.	pH	EC	Sulphate	Chloride	As	Se
		pH value	µS/cm	←|		mg/L	|→
Stock watering trigger value[1]		4-9	7,463[2]	1,000	ND	0.5	0.02
Carbonaceous material	Count	14	14	14	14	14	14
	Mean	7.9	3,941	4.6	5.3	0.014	0.01
	S.D.	0.3	991	2.0	2.9	0.018	0.01
	Range	7.5-8.3	2,300-5,620	2.0-8.0	2.0-12.0	<0.01-0.07	<0.01-***0.04***
Coaly material	Count	5	5	5	4	5	5
	Mean	7.9	3,520	3.6	3.5	0.04	0.01
	S.D.	0.3	636	1.5	1.3	0.07	0.01
	Range	7.5-8.3	3,020-4,270	2.0-6.0	2.0-5.0	<0.01-0.17	<0.01-0.02
Intrusion	Count	9	9	9	9	9	9
	Mean	8.3	4,137	2.2	7.4	<0.01	0.01
	S.D.	0.6	1,096	1.8	4.1	0	0.01
	Range	7.8-***9.7***	3,080-6,140	<0.1-6.0	3.0-14.0	<0.01-<0.01	<0.01-0.02
Mudstone	Count	19	19	19	19	19	19
	Mean	8.0	4,164	3.1	10.6	0.015	0.01
	S.D.	0.2	684	2.1	8.7	0.019	0.01
	Range	7.6-8.5	2,370-5,070	<0.1-9.0	2.0-36.0	<0.01-0.08	<0.1-***0.03***
Sandstone	Count	25	25	25	25	25	25
	Mean	8.1	3,904	3.6	8.1	0.015	0.01
	S.D.	0.2	978	2.1	6.5	0.029	0.01
	Range	7.6-8.6	2,320-6,220	0.5-8.0	2.0-29.0	<0.01-0.14	<0.1-***0.03***
Siltstone	Count	15	15	15	15	15	15
	Mean	7.9	4,176	4.8	9.0	<0.01	0.01
	S.D.	0.3	1,161	2.7	9.6	0	0.01

Lithological Group	Stat.	pH	EC	Sulphate	Chloride	As	Se
		pH value	µS/cm	←|		mg/L	|→
	Range	7.5-8.5	2,370-6,470	1.0-12.0	9.6-35.0	<0.01-<0.01	<0.1-***0.03***
Soil	Count	5	5	5	5	5	5
	Mean	7.8	3,884	2.2	6.6	<0.01	0.01
	S.D.	0.1	715	1.1	3.0	0	0.0
	Range	7.7-7.9	3,100-4,500	1.0-4.0	3.0-11.0	<0.01-<0.01	<0.1-0.01
Weathered samples	Count	32	32	32	32	32	32
	Mean	8.0	3,996	2.6	12.2	<0.01	0.01
	S.D.	0.1	827	1.9	9.6	0	0.0
	Range	7.6-8.2	2,320-5,570	0.5-6.0	9.6-36.0	<0.01-<0.01	<0.1-0.02
Fresh samples	Count	60	60	60	60	60	60
	Mean	8.0	4,215	4.2	5.7	0.02	0.1
	S.D.	0.3	989	2.2	3.1	0.03	0.01
	Range	7.5-**9.7**	2,300-6,470	1.0-12.0	2.0-16.0	<0.01-0.17	<0.1-***0.4***
All samples	Count	92	92	92	91	92	92
	Mean	8.0	4,009	3.6	8.0	0.01	0.1
	S.D.	0.3	931	2.2	6.9	0.03	0.01
	Range	7.5-**9.7**	2,300-6,470	0.5-12.0	2.0-36.0	<0.01-0.17	<0.1-***0.4***

1: ANZECC/ARMCANZ (2000a).

2: Adjusted from total dissolved solids guideline value of 5,000 using a conversion factor as recommended in ANZECC/ARMCANZ (2000a).

ND: No data.

Italicised values exceed stock watering criteria (ANZECC/ARMCANZ 2000a); bold exceed 95% aquatic ecosystem criteria ANZECC/ARMCANZ (2000).

Table 20: Elevated leachate metals by lithological waste group – individual summary data

Leachable element	No. detected	Leaching from	Mean leachate concentration	Stock watering trigger value / (95% freshwater value)
	Count	Lithological waste group	←| mg/L |→
Aluminium	69	All 7 units	**0.27**	5.0 / (0.055)
Antimony	2	Coaly material, sandstone	0.02	NGV / (ID)
Arsenic	23	Carbonaceous, coaly, sandstone, siltstone	**0.04**	0.5 / (0.013)
Barium	90	All 7 units	0.94	NGV / (NGV)
Boron	7	Carbonaceous, coaly, mudstone, siltstone	0.13	5.0 / (0.37)
Copper	1	Mudstone	**0.05**	1.0 / (0.0014)[1]
Iron	19	Carbonaceous, mudstone, siltstone, sandstone, soil	0.07	Not sufficiently toxic / (ID)
Lead	8	Carbonaceous, coaly, mudstone, siltstone	**0.05**	0.1 / (0.0034)[2]
Manganese	43	All 7 units	0.03	Not sufficiently toxic / (1.9)
Selenium	25	All 7 units	**0.02**	0.02 / (0.011)
Strontium	92	All 7 units	1.5	NGV / (NGV)
Titanium	23	Carbonaceous, coaly, mudstone, siltstone, sandstone	0.02	NGV / (NGV)
Vanadium	3	Intrusion, mudstone	0.03	NGV / (ID)
Zinc	52	All 7 units	**0.23**	20 / (0.008)[3]
Molybdenum	35	Carbonaceous, coaly, mudstone, siltstone, sandstone	0.02	0.15 / (ID)
Thallium	9	Carbonaceous, mudstone, siltstone, sandstone, soil	0.01	NGV / (ID)

NGV: No given value. The value in brackets is the default criteria of 95% freshwater species survival (ANZECC/ARMCANZ 2000a).
ID: Insufficient data so no trigger value provided.
1: Laboratory detection limit (0.01) exceeds trigger value (0.0014).
2: Laboratory detection limit (0.01) exceeds trigger value (0.0034).
3: Laboratory detection limit (0.01) exceeds trigger value (0.008).

4.5 Excavated waste: Dispersivity

In order to assess the suitability of the Drake excavated waste lithological groups for use in progressive site rehabilitation, a soil and land suitability report was completed as part of this EIS (GHD 2012a; Volume 2a, Appendix C). This section, therefore, provides an indicative first pass to assess the suitability of deeper lithological units as cover material for mine rehabilitation at the Project site. It also incorporates selected soil chemistry data from the November/December 2011 soils study (as reported in GHD 2012c; Volume 2a, Appendix C), by combining that data with data from weathered samples from all lithological waste groups assessed herein. The sum of these data groups subsequently represents the CENZ stratigraphic waste unit, which represents approximately 479 million tonnes, or 25%, of the excavated waste at Drake.

Soil salinity / sodicity classification guidelines are reproduced below in Table 21, with the summary results provided in Table 22. Individual results are provided in Appendix E. Soil total chloride data as presented previously in Table 13 was also considered when classifying lithological waste units.

Generally speaking, a soil may be considered sodic when sodium concentrations begin to affect soil structure. This is generally recognised to occur in Australia when the exchangeable sodium percentage (ESP) is greater than 6; while strongly sodic soils are reported to have ESPs of greater than 14 (Northcote and Skene 1972) or greater than 15 (Isbell *et al* 1983). When sodic soils become wet; as sodium is a monovalent cation as compared with the bivalent cations magnesium and calcium; the bonds weaken and the soils can become dispersive or slake. Therefore, a high level of exchangeable sodium is not desirable in soils for mine rehabilitation, as it can lead to dispersion, tunnel erosion and surface crusting; with individual clay particles going into suspension potentially leading to decreased surface water quality (Charman and Murphy 2001).

Secondary consequences include surface hard-setting as soil structure breaks down, with decreased infiltration leading to difficulties in establishing vegetation and therefore, ongoing erosion from bare surfaces.

Another indicator of dispersion potential in soils is the Ca:Mg ratio. Soils that are high in sodium and magnesium tend to show more dispersion than soils that are high in sodium and calcium (Hazelton and Murphy, 2007). The potential for dispersion may be increased in soils with Ca:Mg ratios of below approximately 1-2. This is based on the fact that Ca^{2+} ions flocculate, or open, soils; while Mg^{2+} ions tend to coagulate, or close, soils. Low Ca:Mg ratio soils are sometimes known as high magnesium soils. A Ca:Mg ratio of approximately 4-6 is generally considered ideal; although ultimately, it becomes a function of the crop/vegetation's tolerance to specific soil chemistry profiles (NSW Agriculture 2002).

At a broader level; low cation exchange capacity (CEC) of, nominally, <5 meq indicates that the soils has a low ability to hold nutrients.

Table 21: Indicative Excavated Waste Salinity / Sodicity Classification Parameters (DME 1995)

Test	Units	Very Low	Low	Medium	High	Very High
pH (1:5)[1]	pH units	<4.5	4.5-5.5	5.5-7.0	7.0-9.0	>9.0
Electrical Conductivity (1:5)[1]	µS/cm	150	150-450	450-900	900-2,000	>2,000
Chloride	(ppm)	<100	100-300	300-600	600-2,000	>2,000
Exchangeable Sodium Percentage (ESP)	%	<2	2-6	6-12	12-20	>20
Ca/Mg	ratio	<1	1-2	2-5	>5	-

1: Values become approx. 200, 200-400, 400-800, 800-1,600 and <1,600 if analysis undertaken by saturated extract/paste. Drake analysis varied between 1:5 and saturated paste; therefore, values are indicative only.

The summary data in Table 22 indicates that all lithological units have low mean salinity values as represented by chloride and EC (1:5) values. The inherent risk of saline leachate forming, based on the information assessed, is therefore deemed low. This goes against the leachate data presented in Section 4.4, with leachate EC values being approximately an order of magnitude higher than $EC_{1:5}$ results. It may be that prolonged agitation of samples promotes breakdown and leaching of salts as shown by the leachate EC results; intended to represent longer term accelerated weathering of samples. The elevated leachate EC values may also be caused by the prolonged leaching tests causing bicarbonates of calcium and/or magnesium to liberate into solution (refer alkalinity data in Appendix D). The $EC_{1:5}$ results remain consistent with baseline local surface water quality data reported for the proposed Drake mine site (GHD 2012e, Volume 3; Appendix B).

The mean Ca:Mg ratios for all lithological units also appear to be at levels that would potentially preclude the excavated wastes being dispersive (3.5 – 11.7). However, the exchangeable sodium percentage (ESP) data suggests that the carbonaceous material (20.3), coaly material (14.5), mudstone (13.2), and siltstone (10.8) are all potentially dispersive; and therefore, should not be used as capping material in progressive site rehabilitation.

Considering the ESP and leachate EC values combined, when agitated, it would appear that the higher relative percentages of exchangeable sodium in the carbonaceous material, coaly material, mudstone and siltstone becomes mobile and enters solution in the ASLP tests. This characteristic was not evident in the shorter term $EC_{1:5}$ results. This has potential implications for longer-term water quality, should the carbonaceous material, coaly material, mudstone and/or siltstone be used as capping material in progressive site rehabilitation activities. Ideally, these four lithological waste units should be backfilled into pits or encapsulated inside waste rock dumps later capped with less reactive material.

The most appropriate units for use as capping material in progressive rehabilitation, based on the mean ESP data in Table 22 would be the soil unit (3.6), intrusive (6.2), and sandstone units (6.7). The intrusive unit has been shown to potentially also have acid consuming capabilities (a mean NAPP of -88 kg H_2SO_4 / tonne), and may therefore be used to actively manage any PAF material on site through co-disposal, blending and/or encapsulation as required.

Perhaps unsurprisingly, the weathered material appears to have a lower dispersivity potential based on the mean ESP value of 3.5 as shown in Table 22 than does the fresh material, which has a mean ESP value of 13.3. This would likely be explained through long term leaching of the upper lithological horizons above the limit of oxidation on site.

Soil chemistry data from an additional 126 soil samples collected to a depth of 1.5 m below ground surface in November and December 2011, and reported by GHD (2012c, Volume 2a, Appendix C) was combined with the 86 data points generated for the combined weathered lithological waste groups reported herein to represent the CENZ stratigraphic waste unit. The mean ESP value for the combined 212 data points was 6.2, which had the material classified as low salinity and at the very low end of the medium sodicity range. Therefore, if appropriately managed, the CENZ unit appears to be suitable for use in progressive site rehabilitation. The CENZ unit also has a high mean (total) cation exchange capacity value of 30.0 meq / 100g; consistent with a 35% clay content as reported by GHD (2012c, Volume 2a, Appendix C) for 111 soil samples. A very high mean calcium value of 21.3 meq / 100g is also consistent with the high mean soil pH value of 8.4 for the CENZ unit. The alkaline pH values within the lithological waste groups is also consistent with local baseline drainage conditions as represented by surface water quality data as reported in GHD (2012c, Volume 1; Chapter 9).

Table 22: Excavated waste dispersivity summary data

Lithological Unit	Stat	pH	EC	Basic Cations							Classification[1]
				Ca	Mg	K	Na	CEC	ESP	Ca/Mg	
		pH units	µS/cm	← meq/100g →					%	Ratio	
Carbonaceous material	Count	55	55	47	47	47	47	47	47	47	Low salinity, high sodicity.
	Mean	9.3	195	11.0	2.9	0.7	3.3	18.0	20.3	5.2	
	S.D.	0.4	84	6.5	2.0	0.2	2.5	5.9	15.6	4.0	
	Range	8.2-10.0	57-402	3.6-25.6	0.9-9.7	0.2-1.1	0.2-8.8	7.4-30.8	1.2-55.1	0.4-16.2	High dispersion risk
Coaly material	Count	8	8	6	6	6	6	6	6	6	Low salinity, high sodicity.
	Mean	9.3	190	10.0	2.4	0.8	2.0	15.2	14.5	5.9	
	S.D.	0.4	140	6.0	1.4	0.3	2.7	4.3	18.2	6.0	
	Range	8.8-9.8	91-544	4.9-19.6	1.1-4.8	0.3-1.1	0.05-2.7	10.1-21.2	0.4-47.1	1.3-17.8	High dispersion risk
Intrusion	Count	32	32	24	24	24	24	24	24	24	Low salinity, medium sodicity.
	Mean	9.5	261	20.7	3.1	0.3	1.4	25.5	6.2	11.7	
	S.D.	0.4	121	7.4	3.9	0.2	1.4	9.8	6.6	6.6	
	Range	8.6-10.1	113-594	6.7-39.2	0.9-18.9	0.1-0.9	0.2-5.4	12.6-57.5	0.9-26.7	1.0-21.9	Low to medium dispersion risk
Mudstone	Count	51	51	41	41	41	41	41	41	41	Low salinity, high sodicity.
	Mean	9.3	278	11.5	4.0	9.6	2.0	18.9	13.2	3.5	
	S.D.	0.4	173	6.6	3.2	0.2	1.9	8.1	13.7	3.0	
	Range	8.2-9.9	46-840	2.5-31.4	0.5-11.7	0.3-1.1	0.2-7.8	6.2-38.8	1.2-49.4	0.7-14.1	High dispersion risk
Sandstone	Count	110	110	101	101	101	101	101	101	101	Low salinity, medium sodicity.
	Mean	9.4	251	15.2	4.7	0.5	1.2	21.6	6.7	4.3	
	S.D.	0.3	144	7.5	3.0	0.2	1.4	8.8	9.1	3.7	
	Range	8.2-9.7	64-763	4.3-33.5	1.3-16.2	0.2-0.9	0.05-7.4	9.4-43.6	0.3-52.9	0.9-18.3	Low to medium dispersion risk
Siltstone	Count	54	54	57	57	57	57	57	57	57	Low salinity, medium sodicity.
	Mean	9.4	259	12.4	4.3	0.6	1.7	19.1	10.8	4.1	
	S.D.	0.3	145	6.6	2.9	0.2	1.7	7.4	11.9	3.3	Medium dispersion risk
	Range	8.5-9.9	80-862	1.2-28.3	0.5-11.0	0.05-1.0	0.05-6.6	1.7-38.3	0.05-42.2	0.9-15.3	
Soil	Count	19	19	19	19	19	19	19	19	19	Low salinity, low

	Mean	8.5	234	29.4	6.8	0.5	0.9	37.7	3.6	6.8	sodicity. Low dispersion risk
	S.D.	0.6	152	12.3	4.2	0.3	1.1	13.7	7.1	6.3	
	Range	7.4-9.7	93-593	2.2-47.2	1.6-15.7	0.1-1.1	0.05-3.5	9.6-61.4	0.1-31.8	0.5-18.4	
Weathered	Count	96	96	86	86	86	86	86	86	86	Low salinity, low sodicity. Low dispersion risk
	Mean	9.0	326	20.5	7.9	0.5	1.0	29.8	3.5	3.5	
	S.D.	0.5	193	10.5	3.3	0.2	1.0	11.4	4.1	3.7	
	Range	7.4-9.8	93-862	2.2-47.2	1.6-18.9	0.1-1.1	0.1-5.4	9.6-61.4	0.1-31.8	0.4-18.4	
Fresh	Count	233	233	209	209	209	209	209	209	209	Low salinity, low sodicity. Low dispersion risk
	Mean	9.5	207	12.4	2.9	0.6	2.1	17.9	13.3	5.8	
	S.D.	0.4	91	6.6	1.6	0.2	2.1	6.1	13.7	4.8	
	Range	8.2-10.1	46-556	1.2-26.6	0.5-8.4	0.1-1.1	0.1-8.8	1.7-31.4	0.1-55.1	0.9-21.9	
All samples	Count	329	329	295	295	295	295	295	295	295	Low salinity, medium sodicity. Medium dispersion risk
	Mean	9.3	245	14.7	4.3	0.6	1.8	21.4	10.4	5.1	
	S.D.	0.4	141	8.7	3.2	0.2	1.9	9.7	12.5	4.6	
	Range	7.4-10.1	46-862	1.2-47.2	0.5-18.9	0.1-1.1	0.1-8.8	1.7-61.4	0.1-55.1	0.4-21.9	
Nov/Dec 2011 soil samples[2]	Count	160	160	126	126	126	126	126	126	126	Low salinity, medium sodicity. Medium dispersion risk
	Mean	8.0	225	21.8	5.9	0.4	2.0	30.1	8.1	5.9	
	S.D.	1.0	286	15.9	3.7	0.2	2.6	18.3	11.0	9.2	
	Range	5.5-9.6	10-1,540	0.7-60.0	0.4-15.0	0.1-1.9	0.01-11.0	1.7-69.5	0.1-53.0	0.4-62.0	
CENZ[3]	Count	256	256	212	212	212	212	212	212	212	Low salinity, medium sodicity. Low to medium dispersion risk
	Mean	8.4	263	21.3	6.7	0.4	1.6	30.0	6.2	4.9	
	S.D.	1.0	259	13.9	3.6	0.2	2.1	15.8	9.1	7.5	
	Range	5.5-9.8	10-1,540	0.7-60.0	0.4-18.9	0.1-1.9	0.01-11.0	1.7-69.5	0.1-53.0	0.4-62.0	

1: Qld DME (1995a). 2: 111 samples for chloride for a mean of 190 ppm. 3: 163 samples for chloride for a mean of 212 ppm.

4.6 CHPP coarse rejects and tailings: Geochemistry

It remains important to assess the AMD risk from CHPP-generated coarse rejects and tailings as cumulatively; they comprise 2.5% of the total mineral waste at Drake. No samples were available to assess the risk of AMD for the tailings waste stream that will be generated from the onsite CHPP at Drake. Therefore, one composite sample from each commercial coal seam (Seams A, B, C, E, P and Q) was sent to ALS in Brisbane for the same suite of geochemical analytes as the waste rock samples (refer Table 9) to be assessed as a surrogate for future tailings waste from the on-site CHPP; being one of the two CHPP waste streams.

The geochemical, whole rock metals assay, leachate and dispersivity data generated from the excavated waste analysis and reported herein in Sections 4.2 to 4.5 respectively, effectively becomes the default data from which AMD risk was assessed from the CHPP coarse rejects; i.e. the second CHPP waste stream.

Sample classification for slurry $pH_{1:5}$, $EC_{1:5}$ and chloride values against indicative values as per DME (1995) guidelines are presented below. The DME (1995) classification data were reproduced in Table 10 for ease of reference.

4.6.1 Slurry $pH_{1:5}$, slurry $EC_{1:5}$ and chloride values

Slurry $pH_{1:5}$, slurry $EC_{1:5}$ and chloride values are shown for the surrogate tailings samples in Table 23. Classification for each composite coal seam sample, in addition to the mean value for all samples as it compares to data in Table 10, is also provided.

The data presented in Table 23 indicates that the surrogate tailings samples at Drake are broadly consistent with the excavated waste mean slurry $pH_{1:5}$, slurry $EC_{1:5}$ and chloride data as shown in Table 11, Table 12 and Table 13 respectively. The data indicates that the coal seam samples, and therefore by default, the tailings, may be classified as having a very high mean $pH_{1:5}$ value (9.3 pH units); the same value as for the excavated waste samples. The surrogate tailings samples have mean slurry $EC_{1:5}$ values of 107 µS/cm, being a very low value and being lower than the mean value of 245 µS/cm for the excavated waste samples. Finally, the surrogate tailings samples have a mean chloride value of 6.7 mg/kg, being a very low value and being lower than the mean value of 78 mg/kg for the excavated waste samples.

Table 23: Surrogate tailings sample slurry $pH_{1:5}$, $EC_{1:5}$ and chloride values

	Count	$pH_{1:5}$ value	$EC_{1:5}$	Chloride	Classification[1]
Coal seam sample	No.	pH units	µS/cm	mg/kg	Table 10
Composite A Seam	1	9.8	192	<10	pH Very high EC Low Chloride Very low
Composite B Seam	1	9.1	74	<10	pH Very high EC Very low Chloride Very low
Composite C Seam	1	8.8	72	10	pH High EC Very low Chloride Very low
Composite E Seam	1	9.9	116	<10	pH Very high EC Very low Chloride Very low
Composite P Seam	1	9.1	41	10	pH Very high EC Very low Chloride Very low
Composite Q Seam	1	9.3	146	<10	pH Very high EC Very low Chloride Very low
All samples (mean)	6	9.3	107	6.7	pH Very high EC Very low Chloride Very low

1: Classification as determined from Table 1 (DME 1995) – refer Table 10.

4.6.2 Acid base accounting

Acid base accounting (ABA) assessment was undertaken on the surrogate tailings samples as per the excavated waste samples reported in Section 4.2.2. Results for the ABA assessment are shown in Table 24. Sample classification using acid base accounting was undertaken using the ANC/MPA ratio (or net potential ratio - NPR) whereby as a general rule, a NPR ratio of approximately 2 or greater signifies that there is a high probability that the material will remain near neutral, and should not be problematic with respect to AMD; all other factors being equal (AMIRA 2002).

The results shown in Table 24 indicate a mean total sulphur concentration from the six seams of 0.22%. This is consistent with low total sulphur concentrations as reported in the literature for the northern Bowen Basin (e.g. Hunt 1987), and suggests that there is little risk of significant AMD being generated from the coal tailings. The A Seam composite sample had the highest total sulphur value of 0.43%, while Seam Q had the lowest, being 0.07%.

Interestingly, all composite samples returned an ANC value ranging from 2.6 to 34 kg H_2SO_4 per tonne, for a mean ANC value of 15.9 kg H_2SO_4 per tonne. Summing the MPA and ANC values results in NAPP values of between -27 and 4.6 kg H_2SO_4 per tonne. An ANC/MPA ratio (or NPR) of between 0.3 and 14.6 indicates some risk of any excess neutralising minerals not being able to neutralise any acid produced; with composite samples from Seams A, B and P being the higher

risk. A mean NPR of 5.3 however, suggests that if all tailings were combined in real time in a storage facility, then there appears to be sufficient neutralising capacity over acid producing potential to mitigate any significant risk, based on the data considered herein. This statement is qualified with the fact that carbon speciation testing was not undertaken on the Drake surrogate tailings samples, and that the ANC of some samples therefore may be overstated. This is further explored in Section 4.6.3 using NAG data.

The acid base accounting data plotted on Figure 24 is simply a visual representation of the information summarised in Table 24.

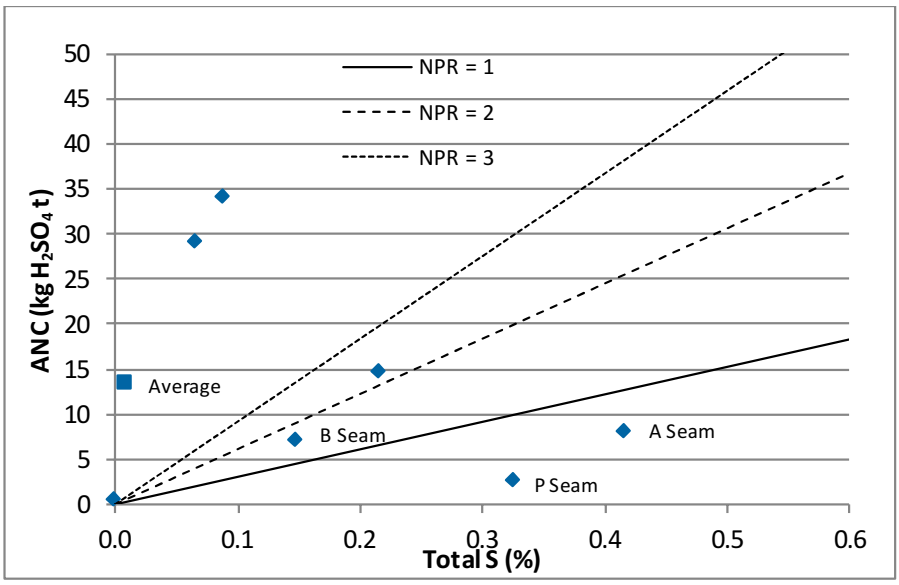


Figure 24: Surrogate tailings sample acid base account plot

The data shows that the A and P Seam composites have NPR values less than 1; while the B Seam composite has an NPR value less than 2. Composite samples from Seams C, E and Q had NPR values greater than 3; as did the mean value for the six composite samples.

Table 24: Surrogate tailings sample acid base accounting results

	Count	Total S	Sulphate S	Reactive S[3]	MPA[1]	ANC	NAPP	NPR[2]
Coal seam samples	No.	%	mg/kg	%	|←	kg H_2SO_4 tonne	→|	ratio
Composite A Seam	1	0.43	140	0.42	12.7	8.1	4.6	0.6
Composite B Seam	1	0.16	120	0.15	4.5	7.1	-2.6	1.6
Composite C Seam	1	0.10	110	0.09	2.7	34.0	-31.3	12.5
Composite E Seam	1	0.22	<100	0.22	6.6	14.6	-8.0	2.2
Composite P Seam	1	0.33	<100	0.33	9.9	2.6	7.3	0.3
Composite Q Seam	1	0.07	<100	0.07	2.0	29.0	-27.0	14.6
All samples (mean)	6	0.22	87	0.21	6.4	15.9	-9.5	5.3

1: Stoichiometrically calculated from results. Adjusted to consider sulphate sulphur results, and is therefore an adjusted value. When total S was <lab PQL of 0.01 mg/kg, a value of 0.005 was used. When sulphate sulphur was <lab PQL of 100 mg/kg, a value of 50 mg/kg was used. MPA (kg H_2SO_4 per tonne) = (total S – sulphate S) * 30.6.
2: Calculated from results. Generally, an ANC /MPA ratio of greater than 2 indicates a suitable excess of inherent acid buffering capacity in the waste material (AMIRA 2002).
3: Total S – sulphate S.

4.6.3 Net acid generation

As per the excavated waste samples, the surrogate tailings samples underwent single addition NAG testing. Results are provided in Table 25.

The samples have been further classified using the mean NAPP data shown in Table 24, and the mean NAGpH (Table 25) as per the classification scheme developed from Miller (1996) and presented in AMIRA (2002), ACARP (2008) and INAP (2009) for example. The classification scheme is shown in Table 16.

Table 25: Surrogate tailings NAG geochemical results

	Count	pH (ox)	NAG[1] (pH 4.5)	NAG[1] (pH 7.0)	Classification
Coal seam sample	No.	pH units	|←kg H_2SO_4 / tonne→|		Table 16
Composite A Seam	1	5.0	<0.1	4.7	UC
Composite B Seam	1	6.4	<0.1	0.4	NAF
Composite C Seam	1	8.8	<0.1	<0.1	NAF
Composite E Seam	1	5.4	<0.1	7.2	NAF
Composite P Seam	1	3.0	32.7	73.9	PAF (low capacity)
Composite Q Seam	1	9.8	<0.1	<0.1	NAF
All samples (mean)	6	6.4	5.5	14.4	NAF

1: When NAG pH was <lab PQL of 0.1 kg H_2SO_4 / tonne, a value of 0.05 was used for statistical purposes.

The summary data in Table 25 indicates that the composite A Seam sample is classified as Uncertain (UC); as it has a positive NAPP value and a NAG pH greater than 4.5. Intuitively, such data represents a conflict, however is best explained by a likely overestimation of the available reactive sulphur. The data in Table 24 shows that the laboratory results returned a total sulphur value of 0.43%; still relatively low for a coal sample. Once adjusted for sulphate sulphur, the net sulphur, or reactive sulphur value of 0.42% leads to a MPA of 12.7 kg H_2SO_4 / tonne. This exceeds the ANC of 8.1 kg H_2SO_4 / tonne, resulting in a positive NAPP. Intuitively, given pyritic sulphur and ANC values that result in a positive NAPP value, the sample should return a NAGpH value of less than 4.5. This was not the case. This composite sample would benefit from undergoing additional sulphur speciation testing, such as chromium reducible sulphur, with any subsequent revisit of the NAG/NAPP classification may see it re-classified as non-acid forming. Additionally, the acidity generated through the NAG test was from titration between 4.5 and 7.0, potentially indicating hydrogen ion release during metals hydrolysis, rather than from free acid formed during pyrite oxidation.

The composite P Seam sample was classified as potentially acid forming (low capacity) as it has a positive NAPP value of between 0 and 10 kg H_2SO_4 / tonne, and a NAG pH value of less than 4.5. A total sulphur value of 0.33%, when adjusted for sulphate sulphur, resulted in a MPA of 9.9 kg H_2SO_4 / tonne. A small ANC value of 2.6 kg H_2SO_4 / tonne means a positive NAPP value of 7.3 kg H_2SO_4 / tonne. When combined with a NAG pH value of 3.0, a NAG pH (4.5) value of 32.7 kg H_2SO_4 / tonne, and a NAG (pH 7.0) value of 73.0 kg H_2SO_4 / tonne; a PAF (low capacity) classification results.

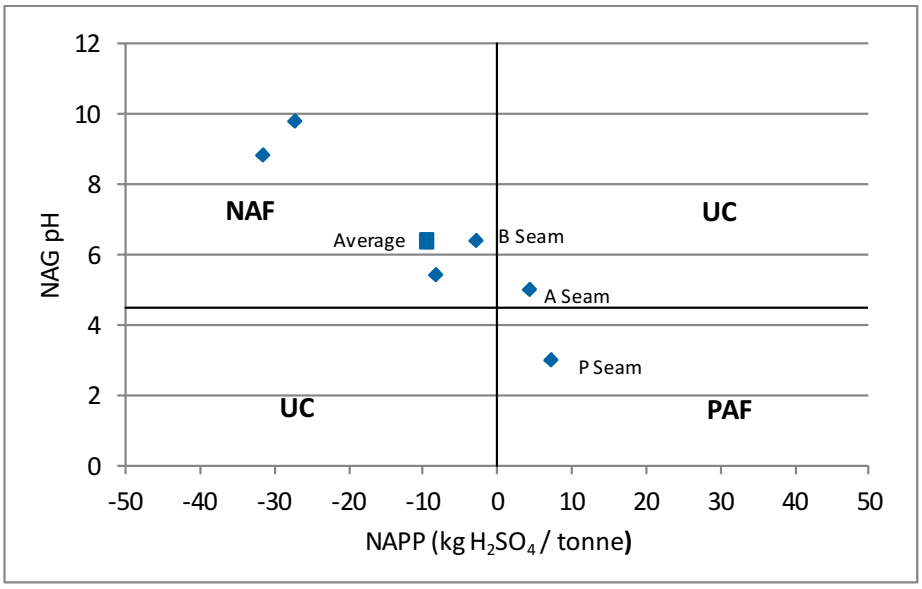


Figure 25: Surrogate tailings NAG/NAPP classification plot

The composite P Seam results may be the result of organic acid generation affecting the NAG tests; given the relatively low reactive sulphur concentration in the coal. This sample would likely also benefit from additional sulphur speciation to refine the classification.

The above commentary notwithstanding, the average NAG/NAPP classification for the six composite coal seam samples is NAF. A mean reactive sulphur value of 0.21%, when combined with a mean ANC value of 15.9 kg H_2SO_4 / tonne, results in a negative NAPP. The mean NAG pH value of 6.4 then confirms the NAF classification. A lack of carbon speciation analysis aside, based on the current data set, it appears that if managed correctly, co-disposal of the tailings from the various seams in a single repository is unlikely to generate acidic drainage in the short term. i.e. there appears to be sufficient self-neutralising capacity in the coal seams to offset any acid generation based on the information at hand. This is demonstrated by a mean NPR of 5.3 (Table 24). This statement, however, must consider relative volumes of the respective coal seam wastes, and an appropriate stoichiometrically based relative assessment being undertaken based on proposed mine plans and schedules to confirm the low risk.

4.7 CHPP coarse rejects and tailings: Metals

To determine the metalliferous drainage risk from the surrogate tailings samples, the six composite coal samples underwent whole rock assay analysis using the same methodology as the 292

excavated waste samples. The analytical methodology and comparative assessment relative to crustal abundances was described in Section 4.3. Results are provided below in Table 29.

Table 26: Elevated whole rock assay metals results by coal seam

Lithological unit	GAI assessment method	Metals > GAI 3
Composite A Seam	Individual result	As (1)
Composite B Seam	Individual result	Nil
Composite C Seam	Individual result	Nil
Composite E Seam	Individual result	Nil
Composite P Seam	Individual result	Nil
Composite Q Seam	Individual result	Nil
All samples (median)	Individual result	Nil

The results in Table 26 show that there was one elevated metal concentrations relative to the crustal average for the six composite coal samples when the concentration of each of those six coal samples was compared to the crustal abundance; being elevated arsenic in the A Seam.

The second stage in identifying metalliferous drainage risk is to assess the elemental leaching potential. Leachate results are presented below in Section 4.8.

4.8 CHPP coarse rejects and tailings: Leachate

Following the whole rock assay reported in Section 4.7, the six composite coal samples underwent leaching tests using the ASLP methodology reported in Section 4.4. Summary leachate data is presented in Table 27.

The summary data presented in Table 27 shows that leachate from the 6 composite coal seam samples is alkaline and slightly saline, although not at levels that exceed stock watering guidelines. All samples returned low leachable chloride and sulphate results, and all samples returned non-detectable leachate concentrations for arsenic and selenium.

In addition to the data presented in Table 27, a summary of individual leachate concentrations that returned results in excess of the laboratory detection limit is provided in Table 28. Results in Table 28 that exceed the stock watering guideline trigger value are italicised (no exceedances), while values that exceed the 95% freshwater species survival (unadjusted for hardness) trigger value are highlighted in bold (zinc).

The data shown in Table 28 indicates that leachable concentrations of barium, manganese, strontium and zinc were detected from all composite coal seam samples. Additionally, boron was detected leaching from the A Seam sample, and molybdenum from the A, C and Q Seam samples. No element leached at mean concentrations that exceeded the stock watering trigger value, while the mean zinc concentration exceeded the 95% freshwater species survival trigger

value (ANZECC/ARMCANZ 2000a). Note, however, that once hardness corrections and leachate pH values are considered, it is likely that many of the reported leachable elements may be only sparingly soluble at the alkaline pH values expected *in situ*. This would have concomitant implications for drainage ecotoxicology given the likely reduced availability of the reported leachate elements.

Table 27: Leachate summary data by coal seam

Lithological Unit	pH	EC	Sulphate	Chloride	As	Se
	pH value	µS/cm	←		mg/L	→
Stock watering trigger value[1]	4-9	7,463[2]	1,000	ND	0.5	0.02
Composite A Seam	8.8	5,540	9	10	<0.01	<0.01
Composite B Seam	8.3	5,490	5	9	<0.01	<0.01
Composite C Seam	8.2	5,550	6	10	<0.01	<0.01
Composite E Seam	8.8	5,560	2	9	<0.01	<0.01
Composite P Seam	7.8	5,460	3	9	<0.01	<0.01
Composite Q Seam	8.4	5,540	5	10	<0.01	<0.01
All samples (mean)	8.4	5,523	5	10	NA	NA

1: ANZECC/ARMCANZ (2000a).

Table 28: Elevated leachate elements from coal composite samples

Leachable element	No. detected	Leaching from	Mean leachate concentration	Stock watering trigger value (95% freshwater value)
	Count	Lithological unit	mg/L	mg/L
Barium	6	All 6 seams	2.2	NGV (NGV)
Boron	1	A Seam	0.1	5.0 (0.37)
Manganese	6	All 6 seams	0.03	Not sufficiently toxic (1.9)
Strontium	6	All 6 seams	2.4	NGV (NGV)
Zinc	6	All 6 seams	**0.04**	20 (0.008)[1]
Molybdenum	3	A, C and Q Seams	0.02	0.15 (ID)

NGV: No given value. The value in brackets is the default criteria of 95% freshwater species survival (ANZECC/ARMCANZ 2000a).

ID: Insufficient data so no trigger value provided.

1: Laboratory detection limit (0.01) exceeds trigger value (0.008).

4.9 CHPP coarse rejects and tailings: Dispersivity

As per the excavated waste samples, the surrogate tailings samples underwent salinity and sodicity testing to determine the risk of saline and/or alkaline drainage. Results are provided in Table 29. The summary data in Table 29 indicates that whilst all six composite coal samples returned alkaline pH values (8.8 to 9.8 for a mean of 9.3), they returned low salinity values (ECs of 41 to 192 for a mean of 107) and very low chloride concentrations (Table 23; <10 to 10 ppm for a mean of 6.7 ppm).

The sodicity, and therefore dispersibility risk fell into two clear categories. Composite samples from Seams A (28.9), E (46.3) and P (21.3) show very high ESP ratios, while composite seam samples B (3.3), C (2.1) and Q (2.3) have low ESP ratios. A mean ESP of 17.4 for all six composite samples suggests that if all tailings were co-disposed in equal proportions into one repository, the material is sodic, although non-saline based on the data in Table 29 Based on the data shown in Table 29, therefore, the combined surrogate tailings material has a low risk of generating saline drainage. As for the excavated waste samples, these data somewhat contradict the EC data from the leaching tests reported in Section 4.8. The elevated leachate EC values may be caused by the prolonged leaching tests causing bicarbonates of calcium and/or magnesium to liberate into solution (refer alkalinity data in Appendix D), rather than sodium salts.

As a general rule, however, coal rejects and tailings should not be used as surface rehabilitation material, and should be stored on site in designated repositories as proposed by Drake Coal.

Table 29: Surrogate tailings NAG salinity and sodicity summary data

Sample	Count	pH	EC	Ca	Mg	K	Na	CEC	ESP	Ca:Mg	Classification[1]
Unit	No.	pH units	µS/cm	|←		meq/100g		→|	%	ratio	Table 21
Composite A Seam	1	9.8	192	10.3	2.1	0.4	5.2	18.0	28.9	4.9	Low salinity, very high sodicity High dispersivity risk
Composite B Seam	1	9.1	74	3.8	1.7	0.2	0.2	6.0	3.3	2.2	Low salinity, low sodicity Low dispersivity risk
Composite C Seam	1	8.8	72	6.0	7.4	0.6	0.3	14.3	2.1	0.8	Low salinity, low sodicity Low dispersivity risk
Composite E Seam	1	9.9	116	6.5	1.0	0.4	6.8	14.7	46.3	6.5	Low salinity, very high sodicity High dispersivity risk
Composite P Seam	1	9.1	41	3.3	1.3	0.2	1.3	6.1	21.3	2.5	Low salinity, very high sodicity High dispersivity risk
Composite Q Seam	1	9.3	146	26.0	3.2	0.5	0.7	30.5	2.3	8.1	Low salinity, low sodicity Low dispersivity risk
All samples (mean)	6	9.3	107	9.3	2.8	0.4	2.4	14.9	17.4	4.2	Low salinity, high sodicity High dispersivity risk

1: Qld DME 1995a

4.9.1 Overall material classification and management implications

The previous sections presented analytical data for geochemistry, dispersivity, metals and metals leaching for the seven excavated waste lithologies, in addition to the six composited coal seam samples; intended to be surrogates for tailings samples in lieu of actual tailings samples.

The information was assessed to inform:

- The risk of acid, metalliferous, neutral and/or saline drainage from each individual excavated waste lithological group in addition to CHPP tailings; and
- The salinity/sodicity; and any potential for structural breakdown and dispersion should the waste units be utilised as capping material in progressive mine site rehabilitation.

The characteristics of saline, neutral, and acid rock drainage are illustrated schematically on Figure 26. Not shown on Figure 26; metalliferous drainage is generally found in mine drainage with acidic or highly alkaline pH values that enable certain metals species to remain dissolved in solution. INAP (2009) defines both saline and neutral mine drainage as occurring above a pH value of approximately 6.0, with dissolved sulphate concentrations of greater than 1,000 mg/L being the threshold between NMD and saline drainage.

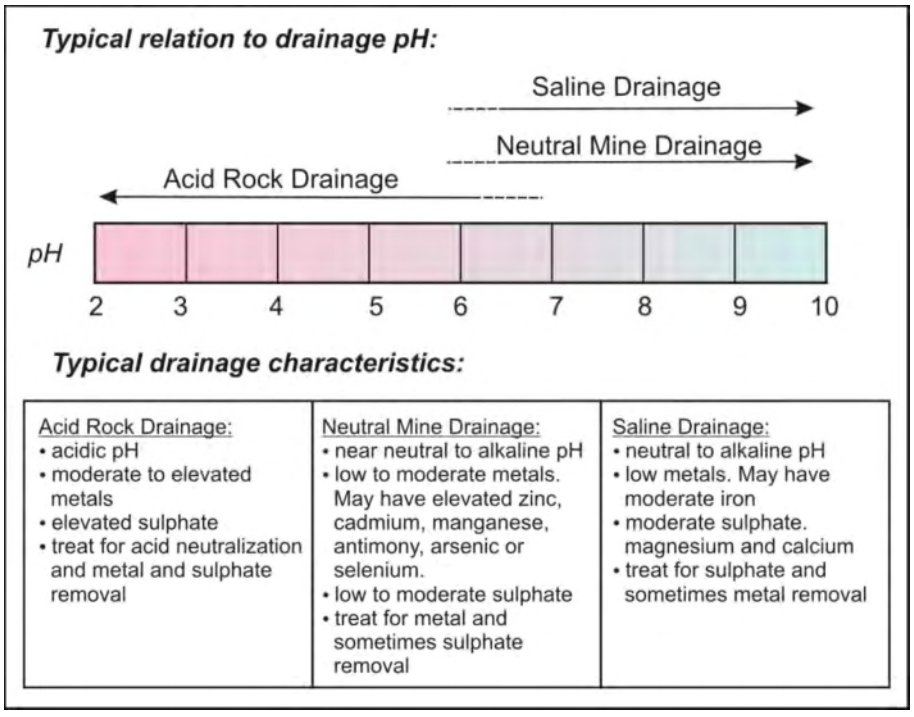


Figure 26: Mine drainage characteristics

Source: INAP 2009.

A summary of the data presented in Section 4 for both excavated and CHPP waste at Drake is presented in Table 30 as a materials characterisation reference source.

Table 30: Summary Waste Materials Classification

	$pH_{1:5}$	$EC_{1:5}$	Chloride	NAG/NAPP	Whole rock metals	Leachability	Dispersivity risk	Comments
Sample nos.	**329**	**329**	**280**	**284**	**292**	**92**	**295**	
Classf'n by:	**DME (1995)**	**DME (1995)**	**DME (1995)**	**AMIRA (2002)**	**Mean GAI ≥ 3**	**ANZECC/ARMCANZ (2000 and 2000a)**	**DME (1995a)**	
Carbonaceous material	Very high	Low	Very low	NAF	Nil[1] (refer comments column)	ANZECC/ARMCANZ (2000) < mean Al, As, Pb, Zn < ANZECC/ARMCANZ (2000a) < Se	*High*	1. Mean is nil. 3 indiv. samples As > GAI 3 and 1 S > GAI 3.
Coaly material	Very high	Low	Very low	NAF[1]	Nil	ANZECC/ARMCANZ (2000) < mean Al, As, Pb, Zn < ANZECC/ARMCANZ (2000a)	*High*	1. Mean is NAF. 1 sample has NPR < 2.
Intrusion	Very high	Low	Very low	NAF[1]	Nil	ANZECC/ARMCANZ (2000) < mean Al, Zn, Se < ANZECC/ARMCANZ (2000a) < pH	Low - *Med*	1. Bordering on acid consuming (ANC ≈ - 85 kg H_2SO_4 / tonne.
Mudstone	Very high	Low	Low	NAF	Nil[1]	ANZECC/ARMCANZ (2000) < mean Al, Cu, Pb, Zn < ANZECC/ARMCANZ (2000a) < Se	*High*	1. Mean is nil. 1 indiv. sample As > GAI 3.
Sandstone	Very high	Low	Very low	NAF	Nil[1]	ANZECC/ARMCANZ (2000) < mean Al, As, Zn < ANZECC/ARMCANZ (2000a) < Se	Low - *Med*	1. Mean is nil. 10 indiv. samples As > GAI 3.
Siltstone	Very high	Low	Very low	NAF	Nil[1]	ANZECC/ARMCANZ (2000) < mean Al, As, Pb, Zn < ANZECC/ARMCANZ (2000a) < Se	*Medium*	1. Mean is nil. 3 indiv. samples As > GAI 3.

	$pH_{1:5}$	$EC_{1:5}$	Chloride	NAG/NAPP	Whole rock metals	Leachability	Dispersivity risk	Comments
Sample nos.	**329**	**329**	**280**	**284**	**292**	**92**	**295**	
Classf'n by:	**DME (1995)**	**DME (1995)**	**DME (1995)**	**AMIRA (2002)**	**Mean GAI ≥ 3**	**ANZECC/ARMCANZ (2000 and 2000a)**	**DME (1995a)**	
Soil	High	Low	Low	NAF	Nil[1]	ANZECC/ARMCANZ (2000) < mean Al, Zn, Se < ANZECC/ARMCA NZ (2000a)	Low	1. Mean is nil. 3 indiv. samples As > GAI 3.
Weathered	Very high	Low	Low	NAF	Nil	Refer individ. units	Low	-
Fresh	Very high	Low	Very low	NAF	Nil	Refer individ. units	Low	-
All samples	Very high	Low	Very low	NAF	Nil	Refer individ. units	*Medium*	-
Tailings (6 samples)	Very low	Very low	Very low	NAF[1]	Nil[2]	ANZECC/ARMCANZ (2000) < Zn < ANZECC/ARMCANZ (2000a)	*High*	1. Mean is NAF. Seams A, B, P have NPR < 2. Seam P is PAF (LC) and Seam A is UC. 2. Mean is nil. Seam A As > GAI 3.

1, 2: refer commentscolumn.

The summary classification data in Table 30 were presented by mean value for each of the seven lithological waste groups, with comments on any individual results or points of note annotated in the comments column. Mean data were calculated from the seven lithological waste groups from 329 samples for paste pH1:5 and EC1:5, 280 chloride samples, 284 NAG/NAPP samples, 292 whole rock assay metals samples with 92 leachability analyses, and 295 dispersivity analyses.

The geochemical characterisation summary results presented in Table 30 can be considered against estimated stratigraphic waste unit volumes and tonnages within the context of excavated waste materials handling and long term on site placement at Drake. Based on geological modelling using the 2011 drilling logs completed when collecting geochemical samples, Table 31 provides estimates of the volume waste by lithological group as a function of the stratigraphic waste units present. This is provided as an example of the mine planning, materials handling and placement information that can be estimated utilising the data in the excavated waste report to reduce forward cost and risk on site. Pits West 1 and 2 were selected as they represent approximately 75%, or approximately 890 million bank cubic metres of excavated waste at Drake, based on current mine plans.

Excluded from Table 31 is the CENZ waste unit, which as noted before in this report, was previously defined as a stratigraphic waste unit by a previous QCoal geological consultant. It has been re-defined herein as the soil lithological waste unit plus all weathered material from all stratigraphic waste units above the limit of oxidation.

The data in Table 30 and Table 31 shows that the largest waste unit on site (other than the CENZ unit) is the sandstone lithological waste group from pits West 1 and 2 from the BC stratigraphic waste unit with a volume of approximately 263 million bank cubic metres (bcm). Subsequent reference to Table 30 indicates that the sandstone unit as a whole contained very high pH1:5 values, low EC1:5 values, very low chloride concentrations, was classified as non-acid forming (NAF) and had a no median whole rock assay metals significantly above the crustal average; despite having 10 individual samples return concentrations of arsenic above the global abundance index.

Additionally, the sandstone lithological group contained mean concentrations of leachable selenium above the stock water guideline ANZECC/ARMCANZ (2000a), and mean concentrations of leachable aluminium, arsenic and zinc above the ANZECC/ARMCANZ (2000) 95% species protection (aquatic ecosystem) guidelines. The sandstone also had a mean dispersivity risk of low to the lower end of medium. Therefore, the sandstone lithological waste group within the BC stratigraphic waste unit in West pits 1 and 2 would be more appropriate for beneficial reuse as waste rock dump capping material for example, than would the 39 million bcm of carbonaceous material, or the 70 million bcm of mudstone removed from the same two pits; based on the mean dispersivity risk.

Similar AMD risk estimates may be made for the excavated waste from the 8 satellite pits based on the summary geochemical characterisation information presented in Table 30, and the detailed characterisation results presented within this report.

Table 31: Estimated West 1 and West 2 pit lithological and stratigraphic waste tonnages

Stratigraphic Waste Unit	Lithological Waste Group							
	Total West 1 and 2 volume.	Carbonaceous Material	Intrusive	Mudstone	Siltstone	Sandstone	Soil	Coaly material
	Total BCM (x 1,000,000)							
AB Waste	131.90	27.00	13.34	32.31	27.00	32.25	0.00	0.00
BC Waste	491.57	38.70	36.12	78.69	75.23	262.83	0.00	0.00
CE Waste	137.20	10.55	20.12	6.20	34.56	59.25	6.53	0.00
EP Waste	96.50	11.39	18.50	6.05	33.82	26.74	0.00	0.00
PQ Waste	21.70	2.88	1.98	2.36	3.68	10.62	0.00	0.18
QR Waste	12.60	0.00	0.00	0.00	2.27	10.33	0.00	0.00
Approx. total	891.47	90.5	90.1	125.6	176.6	402.0	6.53	0.18

1: Differs from total of 886.4 million BCM in Table 3 as data in Table 3 generated by a previous QCoal consultant.
Data in Table 31 generated by GHD.

The key points of note from the geochemical characterisation data presented within this report are:

- That all seven lithological waste groups, in addition to the tailings results, had high to very high mean $pH_{1:5}$ results (DME 1995);
- That all seven lithological waste groups, in addition to the tailings results, had low to very low mean $EC_{1:5}$ results (DME 1995). Using the Anderson-Darling normality test, there was a 95% probability that mean $EC_{1:5}$ for all 329 samples is less than 246 µS/cm; a low classification (DME 1995);
- That all seven lithological waste groups, in addition to the tailings results, had low to very low mean chloride results (DME 1995);
- That all seven lithological waste groups, in addition to the tailings results, were classified as non-acid forming (NAF) using AMIRA (2002) guidelines. This was despite the tailings sample from Seam P being individually classified as potentially acid forming – low capacity (PAF-LC), and Seam A being classified as uncertain. Using the Anderson-Darling normality test, there was a 95% probability that mean total sulphur concentrations from all 284 excavated waste samples of less than 0.54%; leading to a maximum (mean) maximum potential acidity of 1.7 kg H_2SO_4 per tonne. This result is countered by a 95% probability from all 284 excavated waste samples that mean acid neutralising capacity is greater than 47.1 H_2SO_4 per tonne. Based on the data assessed herein, there would appear to be an excess of acid consuming minerals in the excavated waste at Drake relative to potentially acid forming minerals;
- Whilst there is a high degree of confidence on the summary geochemical classification results above, they could be further refined by having a sub-set of samples undergo additional sulphur and carbon speciation, in addition to more detailed NAG testing. These tests may include:
  - Total carbon, total organic carbon, total inorganic carbon, total carbonate carbon, and acid buffering characteristic curve tests (ABCC);
  - Chromium reducible sulphur; and
  - Modified NAG tests such as the extended boil test to eliminate the likely influence of organic acids on the NAG/NAPP classification on higher samples with higher carbon content; such as from the coaly material and carbonaceous material lithological waste groups.

  There remains the opportunity to implement these additional geochemical tests throughout life-of-mine validation testing as required.

  The above notwithstanding, it would appear that there is a very low risk of acid drainage being generated from the excavated waste at Drake. This conclusion is consistent with the low risk in coal mines adjacent to Drake in the northern Bowen Basin including Sonoma and Belmore-Pipeline for example, where alkaline conditions prevail. For example, analysis of the 25 secondary samples from Belmore-Pipeline collected from the QR Waste unit returned a mean total sulphur concentration of 0.01%, a mean ANC of 77.5 kg H_2SO_4/tonne for a mean NAPP of -77.3 kg H_2SO_4/tonne (QCoal 2008, Drake Coal 2011). Such results show the regional nature of the low sulphur, net neutralising material.

  The geochemical results, and in particular, the total sulphur data, are also consistent with the literature; in particular Hunt and Telfer (1983), Hunt and Brakel (1985), and Hunt (1987) who suggested that research showed that the mid to late Permian coal deposits of the Bowen Basin, which include the Moranbah Coal Measures, contain low (<0.55%) to

medium (0.55- 1.0%) sulphur, commensurate with their fluvial depositional environment through time and space.

Hunt (1987) noted that sulphur isotopes from the mid-low sulphur, late Permian Coal Measures correlated with modern day plant matter in freshwater environments (rather than marine sulphur), thereby indicating that the sulphur sources from the late Permian Bowen Basin coal beds (Moranbah Coal Measures and stratigraphically above) were likely derived from fresh water sulphate reduced by the peat-forming flora. Therefore, any residual sulphur from this formative environment tends to be contained in the coal sequences as organically bound, rather than in pyritic form, as would be the case for marine influenced depositional environments (Hunt and Brakel, 1985); the implications of which result in a low net AMD risk. Thus the potential to further speciate the sulphur on Drake samples to fine-tune the information;

- That all seven lithological waste groups, in addition to the tailings results, had no mean individual metal value for the 292 whole rock assays undertaken elevated above a global abundance index (GAI) of above 3. This essentially means, based on the data reviewed, that there are no mean elevated metals concentrations relative to appropriate control data. That said; 19 of the 292 individual samples showed arsenic concentrations elevated above a GAI of 3, in addition to 1 sulphur sample being elevated above a GAI of 3. The surrogate tailings sample from Seam A also showed arsenic elevated above a GAI of 3, despite the mean tailings results showing no metal above crustal abundance;
- That all seven lithological waste groups, in addition to the tailings results, showed that there were some leachable metals from the 92 samples that underwent ASLP tests. The most commonly leached elements from the excavated waste were aluminium, arsenic, lead, zinc and selenium. Leachable concentrations that exceeded stock watering guidelines (ANZECC/ARMCANZ 2000a) included pH values (intrusive lithological group) and selenium (carbonaceous, sandstone, siltstone and mudstone lithological groups); and
- Based on percent exchangeable sodium (ESP) from 295 samples across the seven excavated waste lithological waste groups and the tailings samples; the carbonaceous material, coaly material, mudstone and tailings showed a high dispersivity risk. The siltstone showed a medium dispersivity risk, while the sandstone and intrusive lithological waste groups showed low to medium dispersivity risk. The soil unit showed a low dispersivity risk.

Further, the 96 weathered samples returned a mean ESP value of 3.5 indicating a low dispersivity risk, while the 209 fresh samples returned a mean ESP value of 13.3 indicating a medium dispersivity risk. When the 96 weathered samples were combined with 116 soil samples collected to a depth of approximately 1.5 m below ground surface in a 2011 soil survey (GHD 2012a; Volume 2a, Appendix C), the combined 212 samples returned a mean ESP value of 6.2, indicating a low to medium dispersivity risk (assuming the transition from low to medium occurs at an ESP of approximately 6.0; Northcote and Skene 1972, DME 1995).

Therefore, considering all other factors in Table 30; it would appear that the soil, then weathered sandstone, then fresh sandstone are the most appropriate lithological waste groups to use on site in progressive capping of out of pit waste rock dumps. The CENZ material, which includes the soil lithological waste group in addition to all other weathered material, is also appropriate. Higher risk, potentially dispersive materials that should be managed through on site burial / encapsulation include the carbonaceous material, the coaly material, the mudstone and the tailings; particularly the fresh component of each of those four lithological waste groups.

The intrusive unit is also appropriate for use, although it has very high leachate pH values that exceed stock watering guidelines; therefore, any drainage must be contained and managed

appropriately. This is also the case for all lithological waste groups being utilised in progressive rehabilitation, as all leached selected elements to some degree in ASLP testing. Refer to the Drake Water Management Plan (GHD 2012e; Volume 3, Appendix B) for details of engineered environmental dams on site for site dirty water management. Given its mean net acid production potential (NAPP) value of approximately – 88 kg H_2SO_4 per tonne, the intrusive unit may be useful as a neutralising agent for any marginal acid producing tailings (e.g. Seam P and/or Seam A) through co-disposal in engineered tailings structures on site (refer Figure 2).

The indicative dispersivity assessment undertaken herein, using 295 ESP values, would benefit through additional, representative validation sampling and analysis on individual stockpiles earmarked for reuse in site rehabilitation. Additional testing may include geotechnical, particle size analysis, soil fertility, ESP and/or Emerson aggregate testing for example to ensure that each waste unit is appropriate for use as capping material prior to final landform planning and construction.

These findings are consistent with those of PB (2006) at the adjacent Sonoma site who found that the more weathered sandstones were suitable for use as capping material, while the fresh labile sandstones, mudstones, siltstones, and claystones, particularly around the B Seam, should not be used as capping material as they were deemed erosive and sodic.

In addition to the summary, using the Anderson-Darling normality test, there was a 95% probability that mean leachable sulphur concentrations from the 92 ASLP samples would be less than 4.1 mg/L; well below the INAP (2009) threshold for saline drainage of 1,000 mg/L. That fact notwithstanding, there is also a 95% probability that mean leachable EC concentrations from the 92 ASLP samples would be less than 4,200 µS/cm. While this mean reading cannot be classified under DME (1995) guidelines due to it being leachate from ASLP, rather than a 1:5 soil/water mix, it does suggest that slightly saline leachate may be generated as a result of longer-term weathering, if the excavated material is not effectively managed. It is likely that the EC reading is a function of bicarbonate alkalinity (refer Appendix D), rather than leachate sulphate.

Considering the above, and based on the data assessed herein, it may be concluded that there is a low risk of acid and/or saline drainage at Drake. There is a risk of metalliferous drainage at neutral to alkaline pH values, given the results of the 92 ASLP leachate samples analysed; however, it should be noted that the mean leachate pH value of the same 92 samples was 8.0, meaning that the elements of concern, being Al, As, Pb, Zn and Se, will be sparingly soluble and have limited environmental ecotoxicological risk at such a drainage pH value. This observation is in addition to the existing surface water drainage controls being the proposed - engineered environmental dams and dirty water drainage on site - both of which will also reduce risk.

If there is any risk at all from the excavated waste and tailings, geochemical characterisation data reported upon herein best aligns with the characteristics of neutral mine drainage (Figure 27). INAP (2009) recommend that, should neutral mine drainage be an issue on site, the most common water treatment management required would be for metals, and potentially, sulphate. Based on the data reviewed herein, it is unlikely that elevated sulphate concentrations will be a problem at Drake. There may be low concentrations of drainage metals concentrations to manage; however, the surface water drainage mitigation and management strategies outlined in the Drake Water Management Plan (GHD 2012e; Volume 3, Appendix B) appear appropriate.

Additional to the surface water drainage mitigation and management strategies as outlined in the Drake Water Management Plan (GHD 2012e; Volume 3, Appendix B), would be the excavated waste handling and long-term storage, by lithological waste group, as outlined above based on geochemical risk. This would include storage of the carbonaceous material, the coaly material, the mudstone and the tailings; particularly the fresh component of each of those four

lithological waste groups, in in-pit facilities. Additionally, these materials should not be used as waste rock storage facility capping materials during progressive site rehabilitation activities.

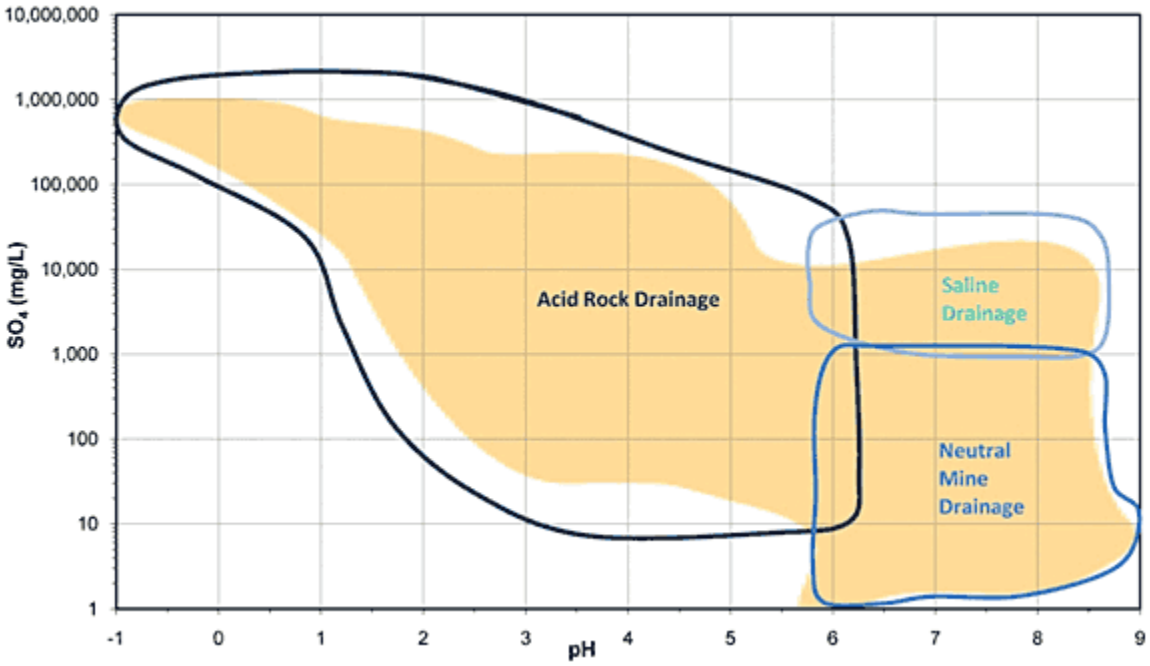


Figure 27: Schematic of mine drainage types

Source: INAP 2009.

5. Summary and Conclusions

5.1 Summary and Conclusions

This report presented, interpreted and reported in analytical data for geochemistry, dispersivity, metals and metals leaching for the seven excavated waste lithological groups at Drake, in addition to the six composited coal seam samples; intended to be surrogates for tailings samples in lieu of actual tailings samples.

The information was assessed to inform:

- The risk of acid, metalliferous, neutral and/or saline drainage from each individual excavated waste lithological group in addition to CHPP tailings; and
- The salinity/sodicity; and any potential for structural breakdown and dispersion should the waste units be utilised as capping material in progressive mine site rehabilitation.

Based on the data reviewed herein, key findings were:

- That all seven lithological waste groups, in addition to the tailings results, were classified as non-acid forming (NAF) using data from 284 samples;
- That all seven lithological waste groups, in addition to the tailings results, had no mean individual whole-rock metal value elevated above a geochemical abundance index using data from 292 samples;
- That all seven lithological waste groups, in addition to the tailings results, had some leachable metals from the 92 samples that underwent ASLP tests. The most commonly leached elements from the excavated waste were aluminium, arsenic, lead, zinc and selenium; and
- Based on data from 295 samples across the seven lithological waste groups and the tailings samples; the carbonaceous material, coaly material, mudstone and tailings showed a high dispersivity risk. The siltstone showed a medium dispersivity risk, while the sandstone and intrusive lithological waste groups showed low to medium dispersivity risk. The soil unit showed a low dispersivity risk.

Therefore, based on the data reviewed herein, the soil, then weathered sandstone, then fresh sandstone appear to be the most appropriate lithological waste groups to use on site in progressive capping of out of pit waste rock dumps. The CENZ material which includes the soil lithological waste group in addition to all other weathered material is also appropriate. Higher-risk potentially dispersive materials that should be managed through on site burial / encapsulation include the carbonaceous material, the coaly material, the mudstone and the tailings; particularly the fresh component of each of those four lithological waste groups.

Based on the data reviewed herein, the intrusive unit is also appropriate for beneficial use, although has very high leachate pH values that exceed stock watering guidelines; therefore, any drainage must be contained and managed appropriately. Additionally, the intrusive unit may be useful as a neutralising agent for any marginal acid producing tailings through co-disposal in engineered tailings structures on site.

Considering the above, and based on the data assessed herein, it is concluded that there is a low risk of acid drainage at Drake. There is a risk of metalliferous drainage at neutral to alkaline drainage pH values given the results of the 92 ASLP leachate samples analysed; however, it should be noted that the mean leachate pH value of the same 92 samples was 8.0, meaning that the elements of concern being Al, As, Pb, Zn and Se will be sparingly soluble and have limited environmental ecotoxicological risk at such a drainage pH value. This observation is in

addition to the existing surface water drainage controls being the proposed engineered environmental dams and dirty water drainage on site; both of which will also reduce risk. The surface water drainage mitigation and management strategies outlined in the Drake Water Management Plan (GHD 2012e; Volume 3, Appendix B) are appropriate to manage this risk.

Additional to the surface water drainage mitigation and management strategies as outlined in the Drake Water Management Plan (GHD 2012e; Volume 3, Appendix B), would be the excavated waste handling and long-term storage by lithological waste group as outlined above, based on geochemical risk. i.e. storage of the carbonaceous material, the coaly material, the mudstone and the tailings; particularly the fresh component of each of those four lithological waste groups, in in-pit facilities. Additionally, these materials should not be used as waste rock storage facility capping materials during progressive site rehabilitation activities

The above notwithstanding, based on the data reviewed herein, there is a very low risk of acid drainage being generated from the excavated waste at Drake. This conclusion is consistent with the low risk in coal mines adjacent to Drake in the northern Bowen Basin including Sonoma and Belmore-Pipeline for example, where alkaline conditions prevail (QCoal 2011).

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Appendices

Appendix A – Geochemical sample details

Hole No.	Waste Interval	Sample No.	From (m)	To (m)	Thickness (m)	Lithology (Qcoal descriptive)	Date Sampled	Geo.	Weathering
Carbonaceous Material Lithological Waste Group (n = 55)									
DK287	Q_P	287017	32.00	36.00	4.00	Siltstone, carbonaceous, indurated	16.10.12	R.McW	F
BR018P	B_A	18012	42.00	45.00	3.00	Carbonaceous mudstone	24.10.12	R.McW	F
BR888C	B_A	888024	58.00	60.00	2.00	Siltstone, carbonaceous, micaceous	30.10.12	R.McW	F
BR888C	B_A	888030	80.00	85.88	5.88	Carbonaceous mudstone, minor coaly laminae	30.10.12	R.McW	F
BR888C	B_A	888027	70.00	74.00	4.00	Carbonceous mudstone	30.10.12	R.McW	F
BR888C	B_A	888029	76.20	80.00	3.80	Carbonceous mudstone	30.10.12	R.McW	F
BR936P	B_A	936035	127.00	128.00	1.00	Carbonaceous mudstone, indurated	14.11.12	R.McW	F
BR940R	B_A	940019	55.00	57.00	2.00	carbonaceous siltstone	26.10.12	S.C	F
BR940R	B_A	940022	59.00	62.00	3.00	carbonaceous siltstone	26.10.12	S.C	F
BR940R	B_A	940026	72.00	74.00	2.00	carbonaceous siltstone	26.10.12	S.C	F
BR940R	B_A	940024	64.00	67.00	3.00	carbonaceous siltstone minor coal and sandstone	26.10.12	S.C	F
BR948CR	B_A	948040	100.00	101.00	1.00	Carbonaceous mudstone	29.10.12	S.C	F
BR948CR	B_A	948039	96.00	100.00	4.00	Carbonaceous siltstone	29.10.12	S.C	F
BR951C	B_A	951037	44.00	49.00	5.00	carbonaceous mudstone	26.10.12	S.C	F
BR951C	B_A	951040	52.00	53.00	1.00	carbonaceous mudstone	26.10.12	S.C	F
BR951C	B_A	951038	49.00	52.00	3.00	carbonaceous siltstone	26.10.12	S.C	F
BR951C	B_A	951043	57.00	59.00	2.00	carbonaceous siltstone	26.10.12	S.C	F
BR951C	B_A	951048	68.00	69.00	1.00	carbonaceous siltstone	26.10.12	S.C	F
DK046C	B_A	46062	102.00	103.00	1.00	carbonaceous siltstone	19.10.12	S.C	F
DK268P	B_A	268036	144.00	145.00	1.00	Carbonaceous mudstone, minor coaly laminae	16.11.12	R.McW	F
DK008C	A_B	8050	70.84	71.82	0.98	carbonaceous siltstone	21.10.12	S.C.	F
DK500	B_A	500019	109.00	110.00	1.00	Carbonaceous mudstone, micaceous	14.10.12	R.McW	F
DK500	B_A	500020	114.00	115.00	1.00	Carbonaceous mudstone, micaceous, coaly laminae	14.10.12	R.McW	F
DK500	B_A	500016	90.00	91.00	1.00	Carbonaceous siltstone, micaceous	14.10.12	R.McW	F
DK053R	B_A	53036	98.00	100.00	2.00	carbonaceous siltstone	23.10.12	S.C.	F
DK500	B_C	500010	56.00	57.00	1.00	Carbonaceous mudstone, indurated	14.10.12	R.McW	F
DK500	B_C	500011	58.20	60.00	1.80	Carbonaceous, siltstone, white micas	14.10.12	R.McW	F
DK500	B_C	500007	31.00	32.00	1.00	Slightly carbonaceous mudstone	14.10.12	R.McW	F
BR015P	C_B	15006	18.00	21.00	3.00	Carbonaceous mudstone, minor cindered coal	17.10.12	R.McW	W
BR888C	C_B	888008	23.00	28.91	5.91	Siltstone, slightly carbonaceous	30.10.12	R.McW	F
BR888C	C_B	888011	31.52	31.82	0.30	Carbonaceous mudstone, indurated	30.10.12	R.McW	F
BR936P	C_B	936008	24.00	25.00	1.00	Carbonaceous mudstone, minor coaly laminae	14.11.12	R.McW	F
BR940R	C_B	940008	16.00	18.00	2.00	carbonaceous siltstone	26.10.12	S.C	W
BR951C	C_B	951007	16.00	19.00	3.00	Carbonaceaous siltstone	25.10.12	S.C	W
DK046C	C_B	46039	68.00	69.00	1.00	carbonaceous siltstone	18.10.12	S.C	F
DK053R	C_B	53026	69.00	71.00	2.00	carbonaceous siltstone	23.10.12	S.C	F
DK053R	C_B	53027	71.00	72.00	1.00	carbonaceous siltstone and intrusion	23.10.12	S.C	F
DK268P	C_B	268022	81.00	82.00	1.00	Carbonaceous mudstone, minor coaly laminae	16.11.12	R.McW	F
DK502	C_B	502007	16.00	18.00	2.00	Carbonaceous mudstone, minor coaly laminae	24.10.12	R.McW	W
DK008	C_B	8018	49.00	50.00	1.00	Carbonaceous siltstone	19.10.12	S.C	F
DK053R	E_C	53015	44.00	45.00	1.00	Carbonaceous siltstone	23.10.12	S.C.	F
DK268P	E_C	268015	47.30	52.00	4.70	Siltstone, slightly carbonaceous	16.11.12	R.McW	F
DK268P	E_C	268019	70.00	73.00	3.00	Carbonaceous mudstone, micaceous	16.11.12	R.McW	F
DK268P	P_E	268010	30.00	32.00	2.00	Carbonaceous mudstone, micaceous	16.11.12	R.McW	F
DK268P	P_E	268013	40.00	42.00	2.00	Carbonaceous mudstone, micaceous	16.11.12	R.McW	F
DK268P	P_E	268014	42.00	45.00	3.00	Carbonaceous mudstone, minor coaly laminae	16.11.12	R.McW	F
DK287	P_E	287015	79.00	83.00	4.00	Carbonaceous mudstone	16.10.12	R.McW	F
BR771C	P_E	771041	114.95	115.76	0.56	Carbonaceous siltstone, tuffaceous	10.10.12	R.McW	F
BR767C	Q_P	767029	53.00	54.00	1.00	carbonaceous mudstone rare intrusion fragments	21.10.12	S.C	F
BR767C	Q_P	767028	51.00	53.00	2.00	carbonaceous siltstone	21.10.12	S.C	F
BR767C	Q_P	767020	26.65	27.40	0.75	Carbonaceous siltstone	21.10.12	S.C	F
BR767C	Q_P	767033	61.00	62.00	1.00	Carbonaceous shale	21.10.12	S.C.	F
BR771C	Q_P	771005	22.00	23.00	1.00	Siltstone, indurated, carbonaceous	10.10.12	R.McW	F
BR771C	Q_P	771025	48.14	51.00	2.86	Carbonaceous mudstone, minor cindered coal	10.10.12	R.McW	F
BR771C	Q_P	771008	27.40	27.75	0.35	Carbonaceous sandstone	10.10.12	R.McW	F
Coaly Material Lithological Waste Group (n = 8)									
BR767C	P_E	767044	71.00	72.00	1.00	Siltstone and coal	21.10.12	S.C	F
DK046C	B_A	951036	43.00	44.00	1.00	Coal stoney frequent mudstone bands	26.10.12	S.C	F
BR951C	B_A	53033	90.00	93.00	3.00	Coaly mudstone	23.10.12	S.C	F
DK053R	BSEA	936022	74.00	75.00	1.00	Cindered coal tending stoney	14.11.12	R.McW	F
DK053R	C_B	46027	48.13	48.81	0.68	Siltstone minor coaly bands	18.10.12	S.C	F
DK287	P_E	287013	68.00	69.00	1.00	Coaly mudstone	16.10.12	R.McW	F
BR767C	Q_P	287003	4.00	7.00	3.00	Coal weathered, earthy	16.10.12	R.McW	W
BR936P	Q_P	767031	55.00	56.00	1.00	Cindered coal	21.10.12	S.C	F
Intrusive Waste Group (n = 32)									
DK053R	B_A	53035	95.00	98.00	3.00	Intrusion	23.10.12	S.C	F
BR940R	B_A	940020	57.00	58.00	1.00	Intrusion	26.10.12	S.C	F
BR951C	B_A	951041	53.00	56.00	3.00	Intrusion	26.10.12	S.C	F
BR888C	B_A	888028	74.00	76.20	2.20	Intrusion	30.10.12	R.McW	F
BR888C	B_A	888032	87.89	88.35	0.46	Intrusion	30.10.12	R.McW	F
BR936P	ASEA	936036	129.00	135.00	6.00	Intrusion	14.11.12	R.McW	F
BR936P	ASEA	936037	135.00	139.00	4.00	Intrusion	14.11.12	R.McW	F
BR948CR	ASEA	948041	101	105	4	Intrusion	29.10.12	S.C	F
DK053R	C_B	53021	56.00	57.00	1.00	Intrusion	23.10.12	S.C	F
DK053R	C_B	53022	57.00	59.00	2.00	Intrusion	23.10.12	S.C	F
BR940R	C_B	940010	21.00	26.00	5.00	Intrusion	26.10.12	S.C	F
DK046C	C_B	46045	82.00	83.69	1.69	Intrusion	19.10.12	S.C	F
DK502	C_B	502008	18.00	20.00	2.00	Intrusion	24.10.12	R.McW	W
BR018P	C_B	18002	1.00	3.20	2.20	Intrusion	24.10.12	R.McW	W
BR888C	C_B	888012	32.41	33.00	0.59	Intrusion	30.10.12	R.McW	F
BR936P	BSEA	936023	75.00	77.00	2.00	Intrusion	14.11.12	R.McW	F
DK268P	C_B	268021	79.40	81.00	1.60	Intrusion	16.11.12	R.McW	F
DK268P	C_B	268035	139.80	142.20	2.40	Intrusion	16.11.12	R.McW	F

BR936P	CSEA	936002	1.20	3.30	2.10	Intrusion	14.11.12	R.McW	W
BR936P	CSEA	936005	9.00	12.00	3.00	Intrusion	14.11.12	R.McW	W
BR936P	CSEA	936007	20.00	23.40	3.40	Intrusion	14.11.12	R.McW	F
DK268P	E_C	268020	74.00	76.00	2.00	Intrusion	16.11.12	R.McW	F
DK287	ESEA	287014	70.00	79.00	9.00	Intrusion	16.10.12	R.McW	F
DK268P	P_E	268008	22.00	25.00	3.00	Intrusion	16.11.12	R.McW	F
DK268P	P_E	268009	25.00	30.00	5.00	Intrusion	16.11.12	R.McW	F
BR767C	Q_P	767030	54.00	55.00	1.00	Intrusion	21.10.12	S.C	F
BR767C	Q_P	767032	56.00	61.00	5.00	Intrusion	21.10.12	S.C	F
DK287	Q_P	287002	0.30	4.00	3.70	Intrusion	16.10.12	R.McW	W
BR771C	Q_P	771019	39.85	41.07	1.22	Intrusion	10.10.12	R.McW	F
BR940R	C_B	940009	18.00	21.00	3.00	Intrusion with some cindedred coal	26.10.12	S.C	W
DK268P	P_E	268007	15.00	16.00	1.00	Intrusion, slightly clayey	16.11.12	R.McW	W
DK287	ESEA	287016	83.00	91.00	8.00	Intrusion_fault repeated	16.10.12	R.McW	F
Mudstone Waste Group (n = 51)									
BR888C	B_A	888021	50.00	55.00	5.00	Interbedded mudstone siltstone	30.10.12	R.McW	F
DK053R	B_A	951029	32.92	33.12	0.20	Mudstone	25.10.12	S.C	F
DK500	B_A	500021	115.00	119.80	4.80	Mudstone	14.10.12	R.McW	F
BR940R	B_A	502012	43.00	46.00	3.00	Mudstone	24.10.12	R.McW	F
BR951C	B_A	888026	65.00	70.00	5.00	Mudstone	30.10.12	R.McW	F
DK500	B_A	936027	91.00	94.00	3.00	Mudstone	14.11.12	R.McW	F
DK502	B_A	888020	49.25	50.00	0.75	Mudstone slightly carbonaceous, micaceous	30.10.12	R.McW	F
BR888C	B_A	15010	46.00	47.00	1.00	Mudstone, indurated	17.10.12	R.McW	F
BR936P	B_A	500017	91.00	94.00	3.00	Mudstone, indurated	14.10.12	R.McW	F
DK053R	B_A	936033	120.00	125.00	5.00	Mudstone, indurated	14.11.12	R.McW	F
BR948CR	B_A	15008	38.00	39.00	1.00	Mudstone, minor coaly laminae	17.10.12	R.McW	F
BR948CR	B_A	18010	32.00	33.00	1.00	Mudstone, slightly carbonaceous	24.10.12	R.McW	F
BR948CR	B_A	948036	83.78	84.71	0.93	Mudstone and siltstone; carbonaceous in part	29.10.12	S.C.	F
BR015P	B_A	936031	111.00	115.00	4.00	Mudstone, slightly carbonaceous	14.11.12	R.McW	F
BR015P	B_A	936032	115.00	120.00	5.00	Mudstone, slightly carbonaceous	14.11.12	R.McW	F
DK500	B_A	936034	125.00	127.00	2.00	Mudstone, slightly carbonaceous, indurated	14.11.12	R.McW	F
BR936P	B_A	502010	37.00	38.00	1.00	Mudstone, slightly carbonaceous, micaceous	24.10.12	R.McW	F
DK268P	B_A	268037	145.00	150.00	5.00	Mudstone, slightly carbonaceous, micas	16.11.12	R.McW	F
BR936P	B_A	502011	38.00	43.00	5.00	Mudstone, slightly tuffaceous	24.10.12	R.McW	F
DK287	B_A	18011	33.00	42.00	9.00	Mudstone, slightly tuffaceous	24.10.12	R.McW	F
BR771C	B_A	15009	39.00	46.00	7.00	Mudstone, tuffaceous, micaceous	17.10.12	R.McW	F
BR948CR	B_C	500008	32.00	42.00	10.00	Mudstone	14.10.12	R.McW	F
BR888C	B_C	500013	72.00	77.00	5.00	Mudstone, slightly carbonaceous	14.10.12	R.McW	F
DK502	C_B	940003	3.00	6.00	3.00	Claystone	26.10.12	S.C	W
BR018P	C_B	53017	48.00	49.00	1.00	Mudstone	23.10.12	S.C	F
BR018P	C_B	948015	24.00	27.00	3.00	Mudstone	28.10.12	S.C	F
BR015P	C_B	15005	13.00	18.00	5.00	Mudstone	17.10.12	R.McW	W
DK500	C_B	15007	21.00	26.00	5.00	Mudstone	17.10.12	R.McW	F
BR936P	C_B	936012	35.00	39.00	4.00	Mudstone	14.11.12	R.McW	F
BR936P	C_B	268034	128.00	129.00	1.00	Mudstone	16.11.12	R.McW	F
BR018P	C_B	502002	0.20	2.70	2.50	Mudstone, clayey	24.10.12	R.McW	W
BR936P	C_B	18003	3.20	4.50	1.30	Mudstone, clayey	24.10.12	R.McW	W
BR771C	C_B	502003	2.70	3.20	0.50	Mudstone, ferruginous	24.10.12	R.McW	W
BR018P	C_B	18004	4.50	5.00	0.50	Mudstone, ferruginous	24.10.12	R.McW	W
BR936P	C_B	18008	12.20	13.00	0.80	Mudstone, minor coaly laminae	24.10.12	R.McW	W
BR936P	C_B	936013	39.00	40.00	1.00	Mudstone, minor coaly laminae	14.11.12	R.McW	F
BR018P	C_B	18009	13.00	20.50	7.50	Mudstone, slightly carbonaceous	24.10.12	R.McW	W
BR018P	C_B	936009	25.00	27.00	2.00	Mudstone, slightly carbonaceous	14.11.12	R.McW	F
BR936P	C_B	268023	82.00	84.00	2.00	Mudstone, slightly carbonaceous	16.11.12	R.McW	F
DK268P	C_B	15003	7.00	8.00	1.00	Mudstone, slightly ferruginous	17.10.12	R.McW	W
DK268P	C_B	502009	20.00	25.40	5.40	Mudstone, slightly tuffaceous	24.10.12	R.McW	F
BR936P	E_C	936004	6.00	9.00	3.00	Mudstone	14.11.12	R.McW	W
DK500	E_C	936003	3.30	6.00	2.70	Mudstone, indurated	14.11.12	R.McW	W
DK502	E_C	500006	24.00	26.00	2.00	Mudstone, slightly carbonaceous, indurated	14.10.12	R.McW	F
DK268P	P_E	287009	43.00	46.00	3.00	Mudstone	16.10.12	R.McW	F
BR015P	P_E	771037	87.00	92.00	5.00	Mudstone	10.10.12	R.McW	F
DK502	P_E	268006	12.00	15.00	3.00	Mudstone, slightly carbonaceous, ferruginous	16.11.12	R.McW	W
BR018P	P_E	771046	124.50	125.00	0.50	Mudstone, slightly tuffaceous	10.10.12	R.McW	F
DK502	Q_P	771026	51.00	64.00	13.00	Mudstone, minor coaly laminae	10.10.12	R.McW	F
BR771C	Quat	53002	1.00	5.00	4.00	Claystone	23.10.12	S.C	W
BR015P	Quat	500002	1.00	5.30	4.30	Claystone	14.10.12	R.McW	W
Sandstone Waste Group (n = 110)									
BR888C	C_B	888005	10.00	14.00	4.00	Interbedded sandstone, siltstone	30.10.12	R.McW	W
BR888C	B_A	888023	57.00	58.00	1.00	Sandstone	30.10.12	R.McW	F
BR936P	B_A	936028	94.00	100.00	6.00	Sandstone	14.11.12	R.McW	F
BR936P	B_A	936030	105.00	111.00	6.00	Sandstone	14.11.12	R.McW	F
BR940R	B_A	940013	40.00	43.00	3.00	Sandstone	26.10.12	S.C	F
BR940R	B_A	940014	43.00	44.00	1.00	Sandstone	26.10.12	S.C	F
BR940R	B_A	940015	44.00	46.00	2.00	Sandstone	26.10.12	S.C	F
BR940R	B_A	940017	47.00	50.00	3.00	Sandstone	26.10.12	S.C	F
BR940R	B_A	940018	50.00	55.00	5.00	Sandstone	26.10.12	S.C	F
BR940R	B_A	940023	62.00	64.00	2.00	Sandstone	26.10.12	S.C	F
BR940R	B_A	940025	67.00	72.00	5.00	Sandstone	26.10.12	S.C	F
BR951C	B_A	951030	33.12	33.56	0.44	Sandstone	25.10.12	S.C	F
BR951C	B_A	951031	33.56	35.00	1.44	Sandstone	25.10.12	S.C	F
BR951C	B_A	951033	36.00	40.00	4.00	Sandstone	25.10.12	S.C	F
BR951C	B_A	951034	40.00	42.00	2.00	Sandstone	25.10.12	S.C	F
BR951C	B_A	951042	56.00	57.00	1.00	Sandstone	26.10.12	S.C	F
BR951C	B_A	951047	65.00	68.00	3.00	Sandstone	26.10.12	S.C	F
DK046C	B_A	46061	97.00	102.00	5.00	Sandstone	19.10.12	S.C	F

DK053R	B_A	53031	87.00	89.00	2.00	Sandstone	23.10.12	S.C	F
DK053R	B_A	53032	89.00	90.00	1.00	Sandstone	23.10.12	S.C	F
DK053R	B_A	53034	93.00	95.00	2.00	Sandstone and intrusion	23.10.12	S.C	F
DK500	B_C	500009	42.00	48.00	6.00	Sandstone	14.10.12	R.McW	F
DK500	B_C	500012	64.50	72.00	7.50	Sandstone	14.10.12	R.McW	F
BR018P	C_B	18007	7.50	12.20	4.70	Sandstone, slightly carbonaceous	24.10.12	R.McW	W
BR888C	C_B	888002	1.00	3.00	2.00	Sandstone	30.10.12	R.McW	W
BR888C	C_B	888003	3.00	7.00	4.00	Sandstone	30.10.12	R.McW	W
BR888C	C_B	888004	7.00	10.00	3.00	Sandstone	30.10.12	R.McW	W
BR936P	C_B	936015	43.00	50.00	7.00	Sandstone	14.11.12	R.McW	F
BR936P	C_B	936016	50.00	55.00	5.00	Sandstone	14.11.12	R.McW	F
BR936P	C_B	936017	55.00	60.00	5.00	Sandstone	14.11.12	R.McW	F
BR936P	C_B	936018	60.00	65.00	5.00	Sandstone	14.11.12	R.McW	F
BR936P	C_B	936019	65.00	70.00	5.00	Sandstone	14.11.12	R.McW	F
BR936P	C_B	936020	70.00	73.00	3.00	Sandstone	14.11.12	R.McW	F
BR936P	C_B	936010	27.00	33.00	6.00	Sandstone, slightly tuffaceous	14.11.12	R.McW	F
BR940R	C_B	940004	6.00	10.00	4.00	Sandstone	26.10.12	S.C	W
BR948CR	C_B	948016	27.00	32.00	5.00	Sandstone	28.10.12	S.C	F
BR948CR	C_B	948017	32.00	36.00	4.00	Sandstone	28.10.12	S.C	F
BR948CR	C_B	948018	36.00	40.00	4.00	Sandstone	28.10.12	S.C	F
BR948CR	C_B	948020	45.00	50.00	5.00	Sandstone	28.10.12	S.C	F
BR948CR	C_B	948021	50.00	53.00	3.00	Sandstone	28.10.12	S.C	F
BR948CR	C_B	948022	53.00	55.00	2.00	Sandstone	29.10.12	S.C	F
BR948CR	C_B	948023	55.00	59.00	4.00	Sandstone	29.10.12	S.C	F
BR948CR	C_B	948024	59.00	61.00	2.00	Sandstone	29.10.12	S.C	F
BR948CR	C_B	948025	61.00	65.00	4.00	Sandstone	29.10.12	S.C	F
BR948CR	C_B	948026	65.00	68.00	3.00	Sandstone	29.10.12	S.C	F
BR951C	C_B	951002	1.00	5.00	4.00	Sandstone	25.10.12	S.C	W
BR951C	C_B	951004	8.00	11.00	3.00	Sandstone	25.10.12	S.C	W
DK046C	C_B	46020	27.00	30.00	3.00	Sandstone	18.10.12	S.C	F
DK046C	C_B	46021	30.00	33.00	3.00	Sandstone	18.10.12	S.C	F
DK046C	C_B	46022	33.00	37.00	4.00	Sandstone	18.10.12	S.C	F
DK046C	C_B	46024	41.00	46.00	5.00	Sandstone	18.10.12	S.C	F
DK046C	C_B	46026	47.00	48.13	1.13	Sandstone	18.10.12	S.C	F
DK046C	C_B	46019	24.63	27.00	2.37	Sandstone and siltstone	18.10.12	S.C	F
DK053R	C_B	53018	49.00	52.00	3.00	Sandstone	23.10.12	S.C	F
DK053R	C_B	53019	52.00	53.00	1.00	Sandstone	23.10.12	S.C	F
DK053R	C_B	53020	53.00	56.00	3.00	Sandstone	23.10.12	S.C	F
DK053R	C_B	53023	59.00	60.00	1.00	Sandstone	23.10.12	S.C	F
DK053R	C_B	53024	60.00	65.00	5.00	Sandstone	23.10.12	S.C	F
DK268P	C_B	268025	90.00	93.00	3.00	Sandstone	16.11.12	R.McW	F
DK268P	C_B	268026	93.00	96.00	3.00	Sandstone	16.11.12	R.McW	F
DK268P	C_B	268028	97.00	105.00	8.00	Sandstone	16.11.12	R.McW	F
DK268P	C_B	268030	110.00	115.00	5.00	Sandstone	16.11.12	R.McW	F
DK268P	C_B	268031	115.00	120.00	5.00	Sandstone	16.11.12	R.McW	F
DK268P	C_B	268032	120.00	124.00	4.00	Sandstone	16.11.12	R.McW	F
DK268P	C_B	268024	84.00	90.00	6.00	Sandstone, micaceous	16.11.12	R.McW	F
DK502	C_B	502004	3.20	9.00	5.80	Sandstone	24.10.12	R.McW	W
DK502	C_B	502005	9.00	12.00	3.00	Sandstone	24.10.12	R.McW	W
BR948CR	E_C	948002	1.00	5.00	4.00	Sandstone	28.10.12	S.C	W
BR948CR	E_C	948003	5.00	9.00	4.00	Sandstone	28.10.12	S.C	W
BR948CR	E_C	948004	9.00	12.00	3.00	Sandstone	28.10.12	S.C	W
BR948CR	E_C	948005	12.00	14.00	2.00	Sandstone	28.10.12	S.C	W
DK046C	E_C	46002	1.00	4.00	3.00	Sandstone	17.10.12	S.C	W
DK046C	E_C	46003	4.00	9.00	5.00	Sandstone	17.10.12	S.C	W
DK046C	E_C	46004	9.00	13.00	4.00	Sandstone	17.10.12	S.C	W
DK046C	E_C	46005	13.00	14.93	1.93	Sandstone	17.10.12	S.C	W
DK046C	E_C	46006	14.93	15.78	0.85	Sandstone	17.10.12	S.C	W
DK046C	E_C	46007	15.78	16.47	0.69	Sandstone	17.10.12	S.C	W
DK053R	E_C	53003	5.00	8.00	3.00	Sandstone	23.10.12	S.C	W
DK053R	E_C	53006	14.00	16.00	2.00	Sandstone	23.10.12	S.C	W
DK053R	E_C	53008	20.00	25.00	5.00	Sandstone	23.10.12	S.C	F
DK053R	E_C	53010	26.00	30.00	4.00	Sandstone	23.10.12	S.C	F
DK053R	E_C	53011	30.00	33.00	3.00	Sandstone	23.10.12	S.C	F
DK500	E_C	500004	12.00	17.00	5.00	Sandstone	14.10.12	R.McW	W
DK500	E_C	500005	19.00	24.00	5.00	Interbedded sandstone, siltstone	14.10.12	R.McW	W
BR771C	P_E	771039	106.00	111.00	5.00	Interbedded sandstone, siltstone	10.10.12	R.McW	F
BR771C	P_E	771036	75.75	87.00	11.25	Sandstone	10.10.12	R.McW	F
BR771C	P_E	771045	119.67	124.50	4.83	Sandstone, slightly tuffaceous	10.10.12	R.McW	F
DK268P	P_E	268005	9.00	12.00	3.00	Interbedded sandstone, siltstone	16.11.12	R.McW	W
DK268P	P_E	268004	3.00	9.00	6.00	Sandstone	16.11.12	R.McW	W
DK268P	P_E	268003	2.00	3.00	1.00	Sandstone, minor calcrete	16.11.12	R.McW	W
DK268P	P_E	268002	0.50	2.00	1.50	Sandstone, slightly clayey	16.11.12	R.McW	W
DK287	P_E	287011	57.00	62.00	5.00	Sandstone	16.10.12	R.McW	F
BR767C	Q_P	767022	30.00	34.00	4.00	Sandstone	21.10.12	S.C	F
BR767C	Q_P	767023	34.00	38.00	4.00	Sandstone	21.10.12	S.C	F
BR767C	Q_P	767025	42.00	45.00	3.00	Sandstone	21.10.12	S.C	F
BR767C	Q_P	767026	45.00	49.00	4.00	Sandstone	21.10.12	S.C	F
BR767C	Q_P	767027	49.00	51.00	2.00	Sandstone	21.10.12	S.C	F
BR771C	Q_P	771009	27.75	31.13	3.38	Interbedded sandstone, siltstone	10.10.12	R.McW	F
BR771C	Q_P	771011	31.97	32.75	0.78	Interbedded sandstone, siltstone	10.10.12	R.McW	F
BR771C	Q_P	771031	69.33	70.47	1.14	Interbedded sandstone, siltstone	10.10.12	R.McW	F
BR771C	Q_P	771004	14.00	22.00	8.00	Sandstone	10.10.12	R.McW	W
BR771C	Q_P	771013	33.22	34.45	1.23	Sandstone slightly tuffaceous	10.10.12	R.McW	F
BR771C	Q_P	771006	23.00	26.00	3.00	Sandstone, slightly tuffaceous	10.10.12	R.McW	F

DK287	Q_P	287006	20.00	24.00	4.00	Sandstone	16.10.12	R.McW	F
DK287	Q_P	287007	24.00	25.00	1.00	Sandstone	16.10.12	R.McW	F
DK287	Q_P	287008	25.00	32.00	7.00	Sandstone	16.10.12	R.McW	F
BR767C	R_Q	767002	1.00	5.00	4.00	Sandstone	21.10.12	S.C	W
BR767C	R_Q	767003	5.00	8.00	3.00	Sandstone	21.10.12	S.C	W
BR767C	R_Q	767004	8.00	12.00	4.00	Sandstone	21.10.12	S.C	W
BR767C	R_Q	767005	12.00	15.00	3.00	Sandstone	21.10.12	S.C	W
Siltstone Waste Group (n = 54)									
DK008C	A_Exm	8063	77.36	78.52	1.16	Siltstone	21.10.12	S.C	F
BR888C	B_A	888022	55.00	57.00	2.00	Siltstone, micaceous	30.10.12	R.McW	F
BR888C	B_A	888025	60.00	65.00	5.00	Siltstone	30.10.12	R.McW	F
BR936P	B_A	936025	82.00	86.00	4.00	Siltstone	14.11.12	R.McW	F
BR936P	B_A	936026	86.00	91.00	5.00	Siltstone	14.11.12	R.McW	F
BR948CR	B_A	948037	84.71	88.00	3.29	Siltstone	29.10.12	S.C	F
BR948CR	B_A	948038	91.00	96.00	5.00	Siltstone	29.10.12	S.C	F
DK046C	B_A	46060	95.30	97.00	1.70	Siltstone	19.10.12	S.C	F
DK053R	B_A	53030	82.00	87.00	5.00	Siltstone	23.10.12	S.C	F
DK500	B_A	500018	96.00	109.00	13.00	Siltstone, micaceous	14.10.12	R.McW	F
DK008	A_B	8046	64.39	64.52	0.13	Siltstone	20.10.12	S.C.	F
BR015P	C_B	15002	1.30	7.00	5.70	Siltstone	17.10.12	R.McW	W
BR015P	C_B	15004	8.00	13.00	5.00	Siltstone	17.10.12	R.McW	W
BR888C	C_B	888006	14.00	18.00	4.00	Siltstone, indurated	30.10.12	R.McW	W
BR888C	C_B	888007	18.00	23.00	5.00	Siltstone	30.10.12	R.McW	W
BR936P	C_B	936011	33.00	35.00	2.00	Siltstone, slightly tuffaceous	14.11.12	R.McW	F
BR936P	C_B	936014	40.00	43.00	3.00	Siltstone	14.11.12	R.McW	F
BR936P	C_B	936021	73.00	74.00	1.00	Siltstone	14.11.12	R.McW	F
BR940R	C_B	940002	1.00	3.00	2.00	Siltstone ironstone and claystone	26.10.12	S.C	W
BR940R	C_B	940005	10.00	12.00	2.00	Siltstone	26.10.12	S.C	W
BR940R	C_B	940006	12.00	14.00	2.00	Siltstone	26.10.12	S.C	W
BR940R	C_B	940007	14.00	16.00	2.00	Siltstone	26.10.12	S.C	W
BR951C	C_B	951003	5.00	8.00	3.00	Siltstone	25.10.12	S.C	W
BR951C	C_B	951005	11.00	15.00	4.00	Siltstone	25.10.12	S.C	W
BR951C	C_B	951006	15.00	16.00	1.00	Siltstone	25.10.12	S.C	W
DK046C	C_B	46023	37.00	41.00	4.00	Siltstone	18.10.12	S.C	F
DK053R	C_B	53025	65.00	69.00	4.00	Siltstone	23.10.12	S.C	F
DK268P	C_B	268027	96.00	97.00	1.00	Siltstone	16.11.12	R.McW	F
DK268P	C_B	268033	124.00	128.00	4.00	Siltstone	16.11.12	R.McW	F
BR948CR	C_B	948027	68.00	70.00	2.00	Siltstone	29.10.12	S.C.	F
DK053R	E_C	53007	16.00	20.00	4.00	Siltstone	23.10.12	S.C	W
DK053R	E_C	53013	36.00	41.00	5.00	Siltstone	23.10.12	S.C	W
DK053R	E_C	53014	41.00	44.00	3.00	Siltstone	23.10.12	S.C	F
DK268P	E_C	268017	60.00	65.00	5.00	Siltstone, slightly tuffaceous	16.11.12	R.McW	F
DK268P	E_C	268018	65.00	70.00	5.00	Interbedded siltstone, mudstone	16.11.12	R.McW	F
DK268P	E_C	268016	52.00	60.00	8.00	Siltstone	16.11.12	R.McW	F
BR767C	P_E	767043	68.43	71.00	2.57	Siltstone	21.10.12	S.C	F
BR767C	P_E	767045	72.00	74.00	2.00	Siltstone	21.10.12	S.C	F
BR767C	P_E	767042	67.87	68.43	0.56	Siltstone	21.10.12	S.C.	F
BR771C	P_E	771040	111.00	114.95	3.95	Siltstone, indurated	10.10.12	R.McW	F
BR771C	P_E	771038	92.00	106.00	14.00	Siltstone	10.10.12	R.McW	F
DK268P	P_E	268011	32.00	37.00	5.00	Siltstone, slightly tuffaceous	16.11.12	R.McW	F
DK268P	P_E	268012	37.00	40.00	3.00	Siltstone, tuffaceous	16.11.12	R.McW	F
DK287	P_E	287010	46.00	57.00	11.00	Siltstone, indurated	16.10.12	R.McW	F
DK287	P_E	287012	62.00	68.00	6.00	Siltstone	16.10.12	R.McW	F
BR767C	Q_P	767021	27.40	30.00	2.60	Siltstone	21.10.12	S.C	F
BR771C	Q_P	771002	4.00	6.00	2.00	Siltstone, clayey	10.10.12	R.McW	W
BR771C	Q_P	771003	6.00	14.00	8.00	Siltstone	10.10.12	R.McW	W
BR771C	Q_P	771007	26.00	27.40	1.40	Siltstone	10.10.12	R.McW	F
BR771C	Q_P	771010	31.13	31.97	0.84	Siltstone	10.10.12	R.McW	F
BR771C	Q_P	771012	32.75	33.22	0.47	Siltstone	10.10.12	R.McW	F
DK287	Q_P	287004	7.00	12.00	5.00	Siltstone	16.10.12	R.McW	W
DK287	Q_P	287005	12.00	20.00	8.00	Siltstone interbedded sandstone	16.10.12	R.McW	W
BR767C	R_Q	767006	15.00	18.00	3.00	Siltstone	21.10.12	S.C	W
Soil Waste Group (n = 19)									
DK500	Quat	500003	5.30	12.00	6.70	Loose, quartzose sand	14.10.12	R.McW	W
DK008C	Quat	8001	0.00	1.00	1.00	Soil	19.10.12	S.C	W
DK053R	Quat	53001	0.00	1.00	1.00	Soil	23.10.12	S.C	W
BR767C	Quat	767001	0.00	1.00	1.00	Soil	21.10.12	S.C	W
DK046C	Quat	46001	0.00	1.00	1.00	Soil	17.10.12	S.C	W
DK287	Quat	287001	0.00	0.30	0.30	Soil	16.10.12	R.McW	W
DK500	Quat	500001	0.00	1.00	1.00	Soil	14.10.12	R.McW	W
DK502	Quat	502001	0.00	0.20	0.20	Soil	24.10.12	R.McW	W
BR018P	Quat	18001	0.00	1.00	1.00	Soil	24.10.12	R.McW	W
BR888C	Quat	888001	0.00	1.00	1.00	Soil	30.10.12	R.McW	W
BR936P	Quat	936001	0.00	1.20	1.20	Soil	14.11.12	R.McW	W
DK268P	Quat	268001	0.00	0.50	0.50	Soil	16.11.12	R.McW	W
BR940R	Quat	940001	0.00	1.00	1.00	Soil and Siltstone	26.10.12	S.C	W
BR951C	Quat	951001	0.00	1.00	1.00	Soil and weathered sandstone	25.10.12	S.C	W
BR948CR	Quat	948001	0.00	1.00	1.00	Soil and weathered sandstone	28.10.12	S.C	W
BR771C	Quat	771001	0.00	4.00	4.00	Soil, clayey	10.10.12	R.McW	W
BR015P	Quat	15001	0.00	1.30	1.30	Soil, weathered sandstone	17.11.12	R.McW	W
DK053R	E_C	53004	8.00	11.00	3.00	Sand	23.10.12	S.C	W
DK053R	E_C	53005	11.00	14.00	3.00	Sand	23.10.12	S.C	W
Total (n = 329)									



Bowen River Coal Pty Limited

Cows Coal Project

Project Soils Report

Version 2.0

Cows Coal Project

Project Soils Report

DOCUMENT CONTROL

ITEM	DESCRIPTION
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Project Ref	Ecological Assessment Report
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Author	Emma Montgomery
Status	Active
Version	2.0
Date	11 May 2011

REVISION HISTORY

ISSUE/ REV.	DATE	DESCRIPTION	APPROVED
1	30/04/2011	Report Draft for QCoal Review	MC
2	11/5/2011	Final Report for Management Review	
3			
4			

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1.0 INTRODUCTION

1.1 Project Description

The proposed Cows Coal Project (the 'Project') is being developed by Bowen River Coal Pty Ltd (BRC), a wholly owned subsidiary of QCoal Pty Ltd (QCoal). The Project is located approximately 13 km south of Collinsville in the north Bowen Basin. The regional location of the Project is illustrated in **Figure 1**.

BRC has lodged a Mining Lease Application (MLA) No. 10345 over the proposed project area. The Project will involve the mining of 2.5 million tonnes (Mt) of Run of Mine (ROM) coal over 15 years from two pits; the Q-seam pit (0.5 Mt ROM at an average strip ratio of 8:1) and the B-seam pit (2 Mt ROM at an average strip ratio of 6:1).

The Project land and surrounds has been extensively cleared and used over a prolonged period for beef cattle grazing. As a result, the natural landscape has undergone considerable surface disturbance and modification. The Project lies within Exploration Permit for Coal (EPC) 586 and adjoins the Sonoma Coal Mine to the immediate north which is operated by Sonoma Mine Management Pty Limited (SMM). A layout of the Cows Coal Project and the adjoining coal operations are illustrated in **Figure 2**.

1.2 Report Purpose

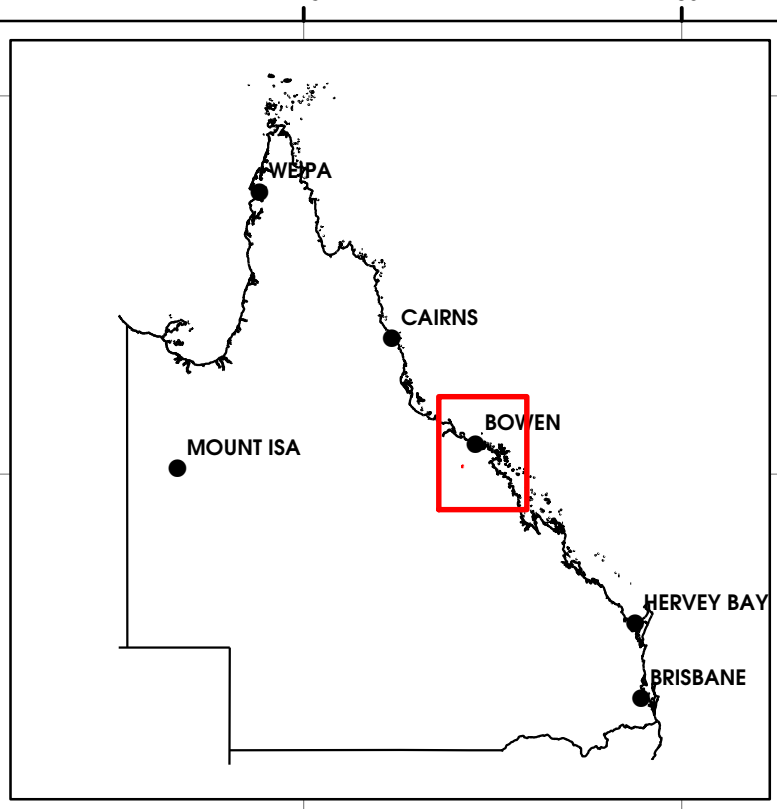
In application to the administering authority, the Queensland Department of Environment and Resource Management (DERM) for an approval to operate, BRC must assess and address in an Environmental Management Plan, the soils and land suitability of the project area.

The objectives of this report are to document information on the land resources, with particular reference to the physical and chemical properties of the materials that will include erosion potential, stormwater run-off quality, rehabilitation and agricultural productivity of the present day land.

1.3 Assessment Methodology

The scope of works adopted to achieve the report purpose included:

- A background study of published literature and existing site information supplied by the QCoal and the neighbouring Sonoma Coal Mine; and
- A field survey of EPC 586 which encompasses MLA 10345; conducted at a density of 1:150,000. The survey extent is illustrated in **Figure 3**.



148 148 149 149 150

-19 -20 -21 -22

AYR
HOME HILL
BOWEN
Bogie River
Whitsunday
Proserpine
Don River
Collinsville
COLLINSVILLE
SONOMA
COWS
Bowen River
O'Connell River
Calen
Bucasia
MACKAY
Marian
Walkerston
Bakers Creek
Sarina
EASTERN CREEK
NEWLANDS
SUTTOR CREEK
Suttor River
HAIL CREEK
WARDS WELL
BURTON
NORTH GOONYELLA
RIVERSIDE
Isaac River
SOUTH WALKER CREEK
GOONYELLA RIVERSIDE BROADMEADOW (UG)
BROADLEA NORTH
COPPABELLA
MORANBAH NORTH
CARBOROUGH DOWNS

148 148 149 149 150

QCOAL PTY LTD

0 10 20 30 40 50
Kilometres

Scale: 1:1,000,000 @ A3

Datum: GDA 1994

N W E S

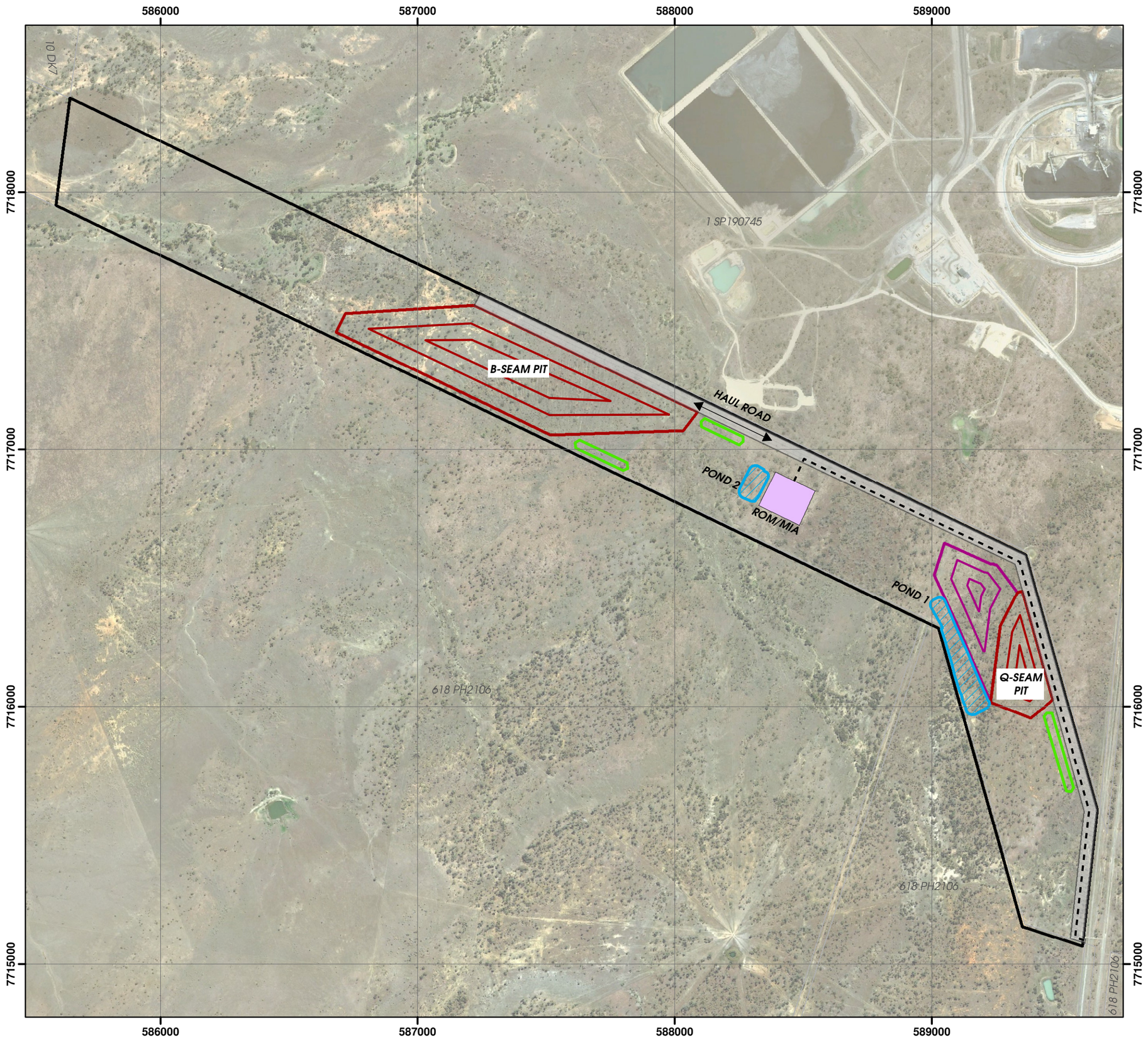
Legend

- Town
- Operational Coal Mine
- Railway
- Drainage
- Cows Coal Project

COWS COAL PROJECT (ML 10345)

FIGURE 1: REGIONAL LOCATION

Date: 29 April 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM & DEEDI



QCOAL PTY LTD

COWS COAL PROJECT (ML 10345)

FIGURE 2: CONCEPT LAYOUT DRAWING

0 250 500 750 1,000

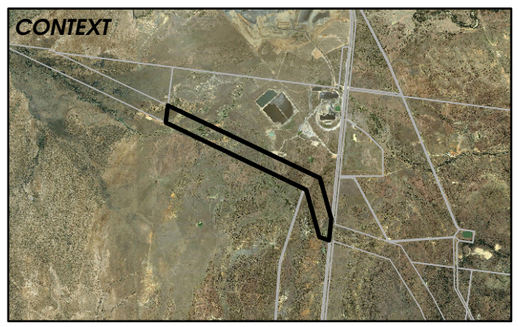
Metres @ A3

Scale: 1:15,000
Projection: UTM Zone 55
Datum: GDA 1994

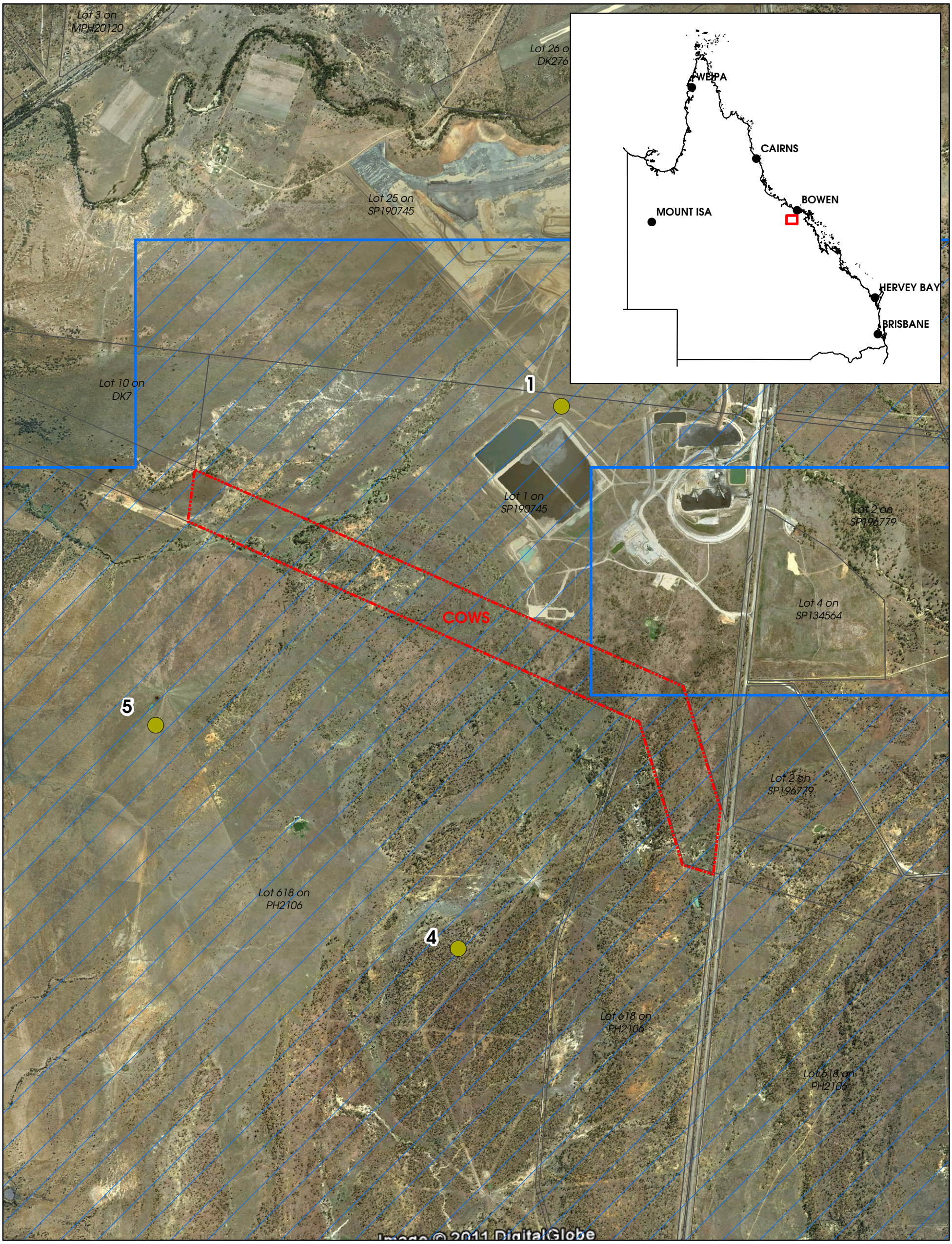
N W E S

Legend

- Internal Access Road (2.5 km)
- Pit (34 ha & 7 ha)
- Out of Pit Waste Dump (9.2 ha)
- Run Of Mine/Mine Infrastructure Area (2.5 ha)
- Pond (1 ha & 3.3 ha)
- Topsoil Locations (2.3 ha)
- Haul Road Corridor (50 m wide; 19 ha)
- Cows ML 10345
- Digital Cadastral Database



Date: 10 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DEEDI, DERM & Google



QCOAL PTY LTD

0 0.3 0.6 0.9 1.2 1.5
Kilometres

Scale: 1:30,000 @ A3

Projection: UTM Zone 55
Datum: GDA 1994

N W E S

Legend

- Soil Sampling Locations on EPC 586
- EPC586
- Cows Coal Project
- DCDB

COWS COAL PROJECT (ML 10345)

FIGURE 3:

EXTENT OF SOIL FIELD SURVEY CONDUCTED ON EPC 586

Date: 11 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM, DEEDI & Google

2.0 SITE DESCRIPTION

2.1 Topography & Landscape

The dominant landform of the Project area is flat to slightly undulating with elevation ranging from 189 m (AHD) in the east to 156 m (AHD) in the west. MLA 10345 is situated on a road reserve cleared for grazing purposes. The land has been used over a prolonged period for beef cattle grazing and as a result, the natural landscape has undergone considerable disturbance and modification.

Un-named drainage features traverse the site and drain to Two Mile Creek which forms an upper tributary of the Bowen River catchment. Two Mile Creek is an ephemeral drainage system.

2.2 Present Land Use & Vegetation

The region has been utilized for the production of beef, sugar and gold since the late 1800s. Coal mining commenced in the early 1900s, as a result the natural landscape has undergone considerable disturbance and modification. Improvements on the land include fencing and thinning of the local vegetation.

The Project area has been largely cleared for grazing, however there are areas of retained vegetation and regrowth. The vegetation communities include mixed eucalypt woodlands, small areas of native grasslands and acacia shrublands.

2.3 Topsoil

Prior to the commencement of operational works, topsoil from all proposed disturbance areas (i.e. pits, dump, dams, roads and industrial area) will be removed by scraper to a nominal depth of 0.2 m, and placed into stockpiles. Approximately 156,600 m^3 of topsoil is scheduled for removal from the Cows Coal Project area. The topsoil stockpiles will be constructed to 2 m in height and their locations will be marked on plans and signposted in the field.

Topsoil will be spread to a minimum depth of 200mm on all disturbed areas (other than the final voids) during the progressive rehabilitation process.

3.0 DESKTOP ASSESSMENT

3.1 Regional Soils Mapping

The Department of Employment Economic Development and Innovation (DEEDI) has reproduced the CSIRO 1:1,000,000 soils maps (Isbell & Murtha, 1970) as a GIS layer in the Interactive Resource Tenures System (IRTM: https://webgis.dme.qld.gov.au/webgis/webqmin/viewer.htm). These regional soil surveys were undertaken by the Department of Primary Industries and Fisheries (DPIF) in 1994 as part of the study into "*Soil fertility of central and northeast grazing lands of Queensland*".

Only one dominant soil type has been mapped for the project area by *Isbell, RF, and Murtha, GG, 1970: Queensland, Burdekin-Townsville region, resources series. Soils Map, Scale 1:1,000,000. Geographic Section, Department of National Development.* This soil type is summarised in **Table 1**.

Table 1: Burdekin – Townsville Resource Series. Soils (1:1,000,000)

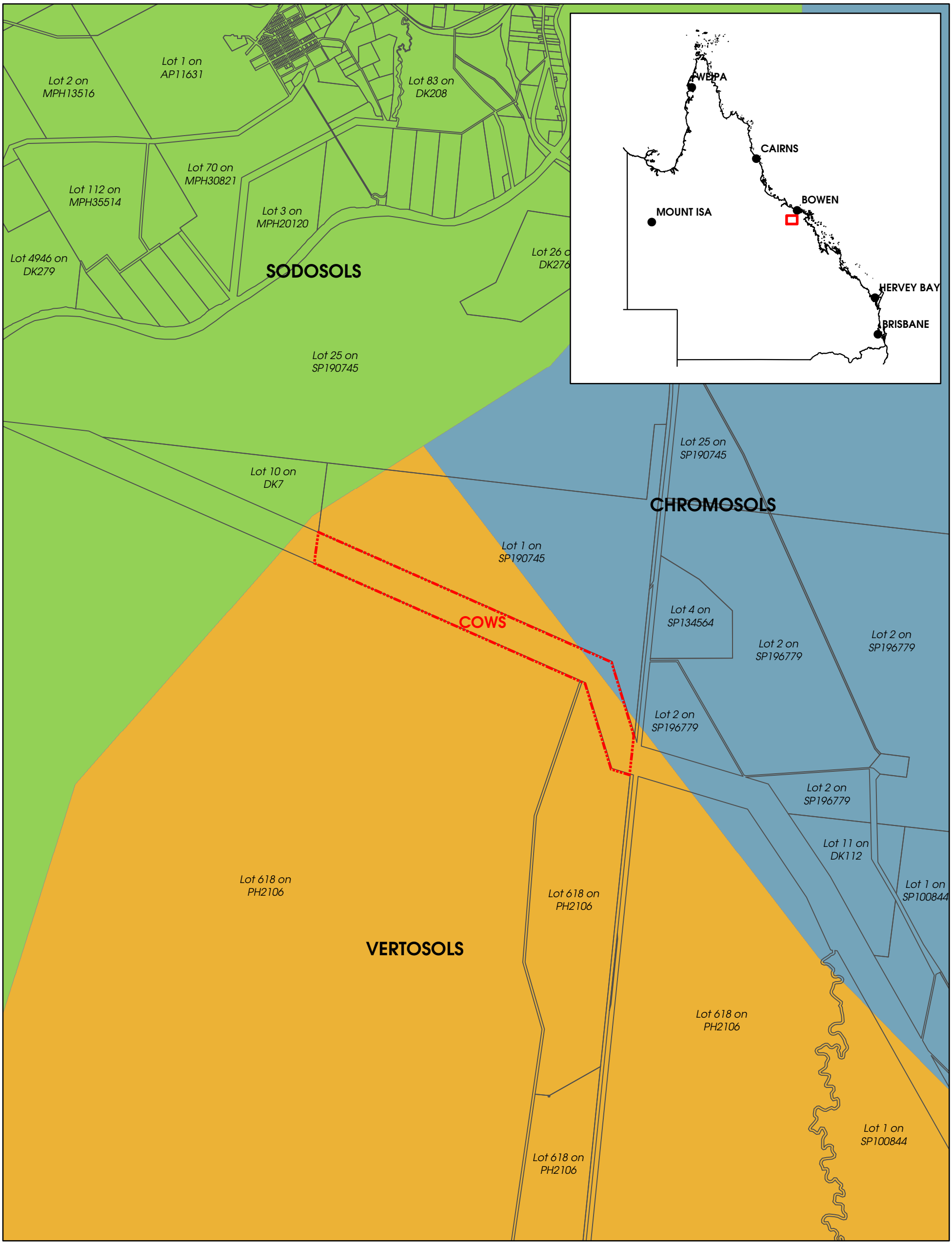
CODE	LANDFORM	DOMINANT SOIL	SOIL TYPE	GENERAL DESCRIPTION	SUBSOIL
CB7	Moderate to undulating plains with very broad valleys	Ug5.22	Fine cracking, smooth faced peds, grey clay horizon underlain by weathered rock before 1.5m	Grey self-mulching cracking clays. Usually pronounced gilgai.	Ug5.32 Ug5.25 Ug5.16 Ug5.15 Ug5.24 Ug5.37 Dr2.13 Dr2.12 Dy2.13 Db1.13 Db1.33 Dd1.33 Dy2.33 Uf6.3

This desktop information was used to develop an initial site map of the expected landforms and soil patterns of the project area (**Figure 4**) prior to the field surveys.

3.2 Regional Land Unit Mapping

A number of published reports were reviewed to identify the background soil classification and condition of the project area, including:

- *Soils. Burdekin-Townsville region*. Queensland Resources Series. Department of National Development (DND, 1970);
- *Land suitability study of the Collinsville-Nebo-Moranbah region.* Queensland Department of Primary Industries (DPI, 1984);
- *Soil fertility of Central and North-east Queensland Grazing Lands.* Queensland Department of Primary Industries. (DPI, 1994);
- *Birralee* (EPC 586) Ecological assessment (ERM, 2007);
- Combined Soils Data published by the Queensland Department of Environmental and Resource Management; and
- Regional Ecosystems mapping of Queensland published by the Queensland Department of Environmental and Resource Management.



QCOAL PTY LTD

0 0.6 1.2 1.8 2.4 3
Kilometres

Scale: 1:50,000 @ A3

Projection: UTM Zone 55
Datum: GDA 1994

N W E S

Legend

Dominant Soils

- Chromosols
- Sodosols
- Vertosols
- Cows Coal Project
- DCDB

COWS COAL PROJECT (ML 10345)

FIGURE 4: DESKTOP REGIONAL SOILS MAP

Date: 11 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM & DEEDI

The aforementioned reports identified the following land units as common in the region and likely to occur with the Cows Coal Project are.

- *Vertosols on level to moderately undulating plains with some strongly undulating rises.* This includes lands with Vertosol clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and / or lenticular structural aggregates. The Vertosols in this area are reported to be deep structured, self mulching, cracking clay soils that exhibit gilgai and melon holes with micro relief. The underlying geology consists of sedimentary rocks and associated unconsolidated sediments. The vegetation is either:
    - Mitchell and Queensland bluegrass grasslands containing a high proportion of black speargrass with isolated trees and gidgee, brigalow and blackwood scrub on plains; or
    - open woodlands dominated by mountain coolibah, gum-topped bloodwood, inland bloodwood and cabbage gum;
- *Dermosols on uplands moderately undulating to strongly undulating rises.* These lands have soils that are structured and have a gradual change in texture, which increases with clay content with depth. In this study area they are reported as overlaying sedimentary rocks and have a shallow to moderate depth. Vegetation is Eucalypt open woodlands with Queensland grey ironbark, mountain coolibah, gum-topped bloodwood and cabbage gum, with Black speargrass pastures grading to Queensland bluegrass pastures; and
- *Sodosols on level plains to strongly undulating rises and high hills.* Sodosols are soils with a strong texture contrast between A horizons and sodic B horizons [1] which are not strongly acid. The soils in the area are reported as being yellow and grey duplex soils with sodic subsoils overlying sedimentary rocks and associated unconsolidated sediments. Vegetation is Eucalypt woodlands and open woodlands dominated by Queensland grey ironbark, narrow-leaved ironbark, silver-leaved ironbark, Reid River box, poplar box, poplar gum and other box trees, with black speargrass pastures.

3.3 Pre-Mining Land Suitability

3.3.1 Land Suitability Classes

Land suitability is classified into five classes with suitability decreasing progressively from Class 1 to Class 5. Land is classified on the basis of a particular land use that allows optimum production with minimal degradation to the land resource in the long-term. These five land classes are as follows:

- **Class 1: Very High - Suitable land with negligible limitations.** This is highly productive land requiring only simple management practices to maintain economic production;
- **Class 2: High - Suitable land with minor limitations** which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production;
- **Class 3: Fair - Suitable land with moderate limitations** which either further lower production or require more than those management practices of Class 2 land to maintain economic production;
- **Class 4: Low - Marginal land, which is presently considered unsuitable due to severe limitations**. The long term significance of these limitations on the proposed land use is unknown. The use of this land is dependent upon undertaking additional studies to

[1] The A horizon typically refers topsoil, whilst the B horizon refers to the underlying subsoil.

determine whether the effect of the limitation(s) can be reduced to achieve sustained economic production; and

- **Class 5: Very Low - Unsuitable land with extreme limitations** that preclude its use.

The Cows Coal Project comprises two land units, Land Unit 1 and Land Unit 5, as discussed in section 2.2 above. A land suitability assessment for these two land units, with reference two types of land uses, that being, *rainfed broadacre cropping* and *beef cattle grazing,* was performed by GHD Pty Ltd (February 2010).

3.3.2 Desktop Findings

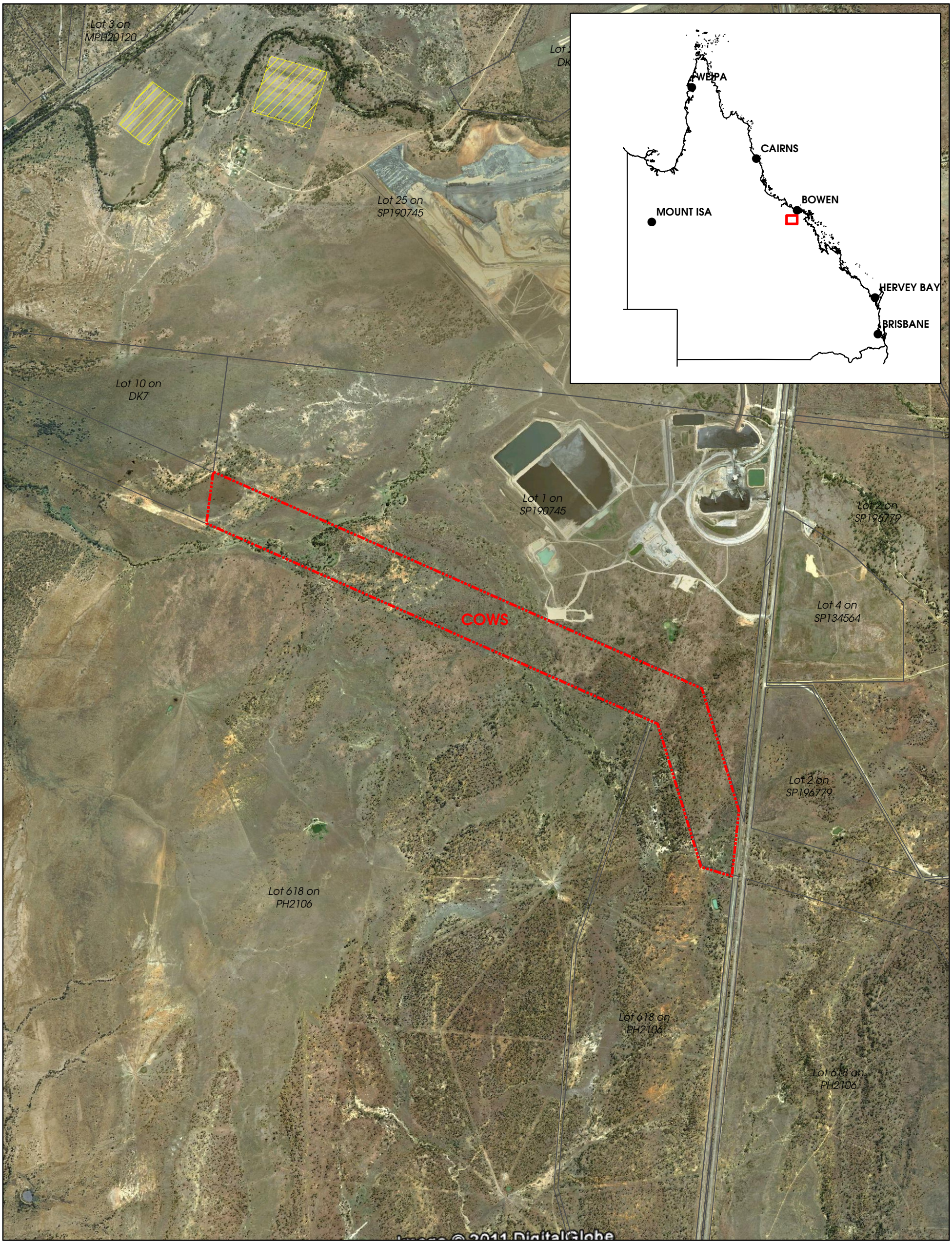
3.3.2.1 Rainfed Broadacre Cropping

In 1984, a land suitability study of the greater Collinsville – Nebo – Moranbah region was conducted by the former Queensland Department of Primary Industries (DPI). The study was undertaken to determine the cropping potential of the region. With reference to these land units of the project area (refer to section 4.0), the following relevant conclusions were drawn from the DPI assessment:

- Rainfed broadacre raingrown cropping in the Collinsville – Nebo - Moranbah region is restricted to soils with a high Plant Available Water Capacity (PAWC). The majority of the rainfall (i.e. approximately 70%) occurs in the summer months, when sorghum and sunflower are grown; however, rainfall variability is so high during this period that PAWC is a critical factor for successful cropping of these pastures. In the winter months, rainfall is negligible so any cropping of wheat and sunflower must rely almost entirely on stored soil moisture.
- The only soils of the region that were identified in the study as having some potential for raingrown cropping were the cracking clay Vertosols soil. Cracking clays on sedimentary rocks must be deeper than 60 cm to be suitable for cropping in the Collinsville-Nebo areas. The Vertosols with heavy clay subsoils below the self-mulching layer may be susceptible to hardpan development. Hardpans that develop immediately below the plough layer may severely restrict root and water penetration.
- Vertsosols occur on gently undulating plains and rises. They are moderately to highly erodible and where present on slopes greater than one per cent soil conservation measures would be required to minimise soil losses.
- The Dermosol rocks have a low PAWC, very low fertility and are unsuitable for rainfed cropping. They tend to support eucalypt woodlands that would be expensive to clear and prone to woody regrowth and are more suited to native pasture grazing.

The Queensland Government has developed the *'Protecting Queensland's strategic cropping land: A policy framework'* to provide direction on the protection and management of the state's cropping land. A series of draft trigger maps have been released by the State Government to identify strategic cropping land. The Government's land suitability mapping of the project area, with reference to broadacre cropping, concluded that the project land contains Class 3 and Class 4 land, as described below and depicted in **Figure 5**.

- Class 3: Suitable land with moderate limitations; or
- Class 4: Marginal land, which is presently considered unsuitable due to severe limitations.



QCOAL PTY LTD

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Kilometres

Scale: 1:30,000 @ A3

Projection: UTM Zone 55
Datum: GDA 1994

N W E S

Legend

- Strategic Cropping Land
- Cows Coal Project
- DCDB

COWS COAL PROJECT (ML 10345)

FIGURE 5:

STATE GOVT DRAFT TRIGGER MAP FOR STRATEGIC CROPPING LAND

Date: 11 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM, DEEDI & Google

4.0 FIELD SURVEY

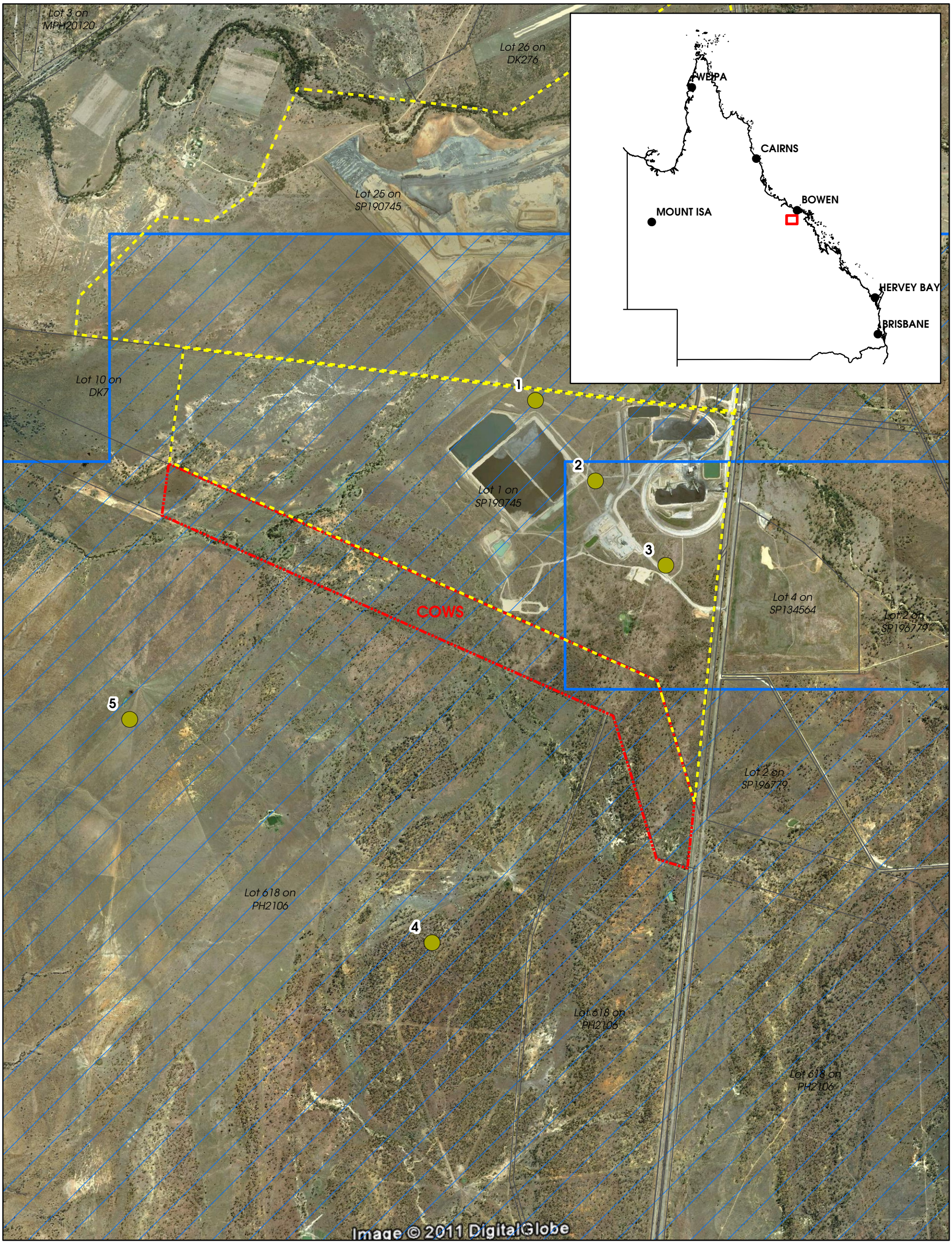
4.1 Soil Orders

A total of sixteen ground observations were conducted across the study area of EPC 586, immediately south of MLA 10345 (**Figure 6**). In total, four different orders of soil were identified across EPC 586. These soil orders include Vertosols, Dermosols, Sodosols, and Rudosols. Broad definitions of these soils are as follows:

- Vertosols. Clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and / or lenticular structural aggregates. Many Vertosol soils exhibit gilgai microrelief, however this feature is not used in their definition;
- Sodosols. Soils with strong texture contrast between A horizons and sodic B horizons which are not strongly acid. Strongly acid sodic soils are also excluded from Sodosols because they usually contain appreciable exchangeable aluminium and thus should be unlikely to disperse. A high pH value (> 8.5) suggests sodicity, but the converse is not true;
- Dermosols. Soils with structured B2 horizons and lacking strong texture contrast between A and *B horizons*. It may be difficult to differentiate between Vertosols and Dermosols because of an apparent lack of cracking and slickensides or lenticular structure; and
- Rudosols. This includes soils that have negligible pedologic organisation and tend to be young soils in the sense that soil forming factors have had little time to pedologically modify parent rocks or sediments. The soils can obviously vary widely in terms of texture and depth; many are stratified and some are highly saline. The soils are apedal or only weakly structured in the A1 horizon and show no pedological colour changes apart from the darkening of an A1 horizon. There is little or no texture or colour change with depth unless stratified or buried soils are present.

4.2 Land Units

Land units are areas of common landform and similar soils that occur across the landscape and they usually have similar vegetation, geology, and soils. In the soils assessment of EPC 586, five separate land units occur. Two of these land units are present across the Cows Coal Project area, as illustrated in **Figure 7**. Land Unit 1 (vertosols developed in the lower areas of broad valleys) and Land Unit 5 (dermosols developed on higher undulating terrains).



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Datum: GDA 1994

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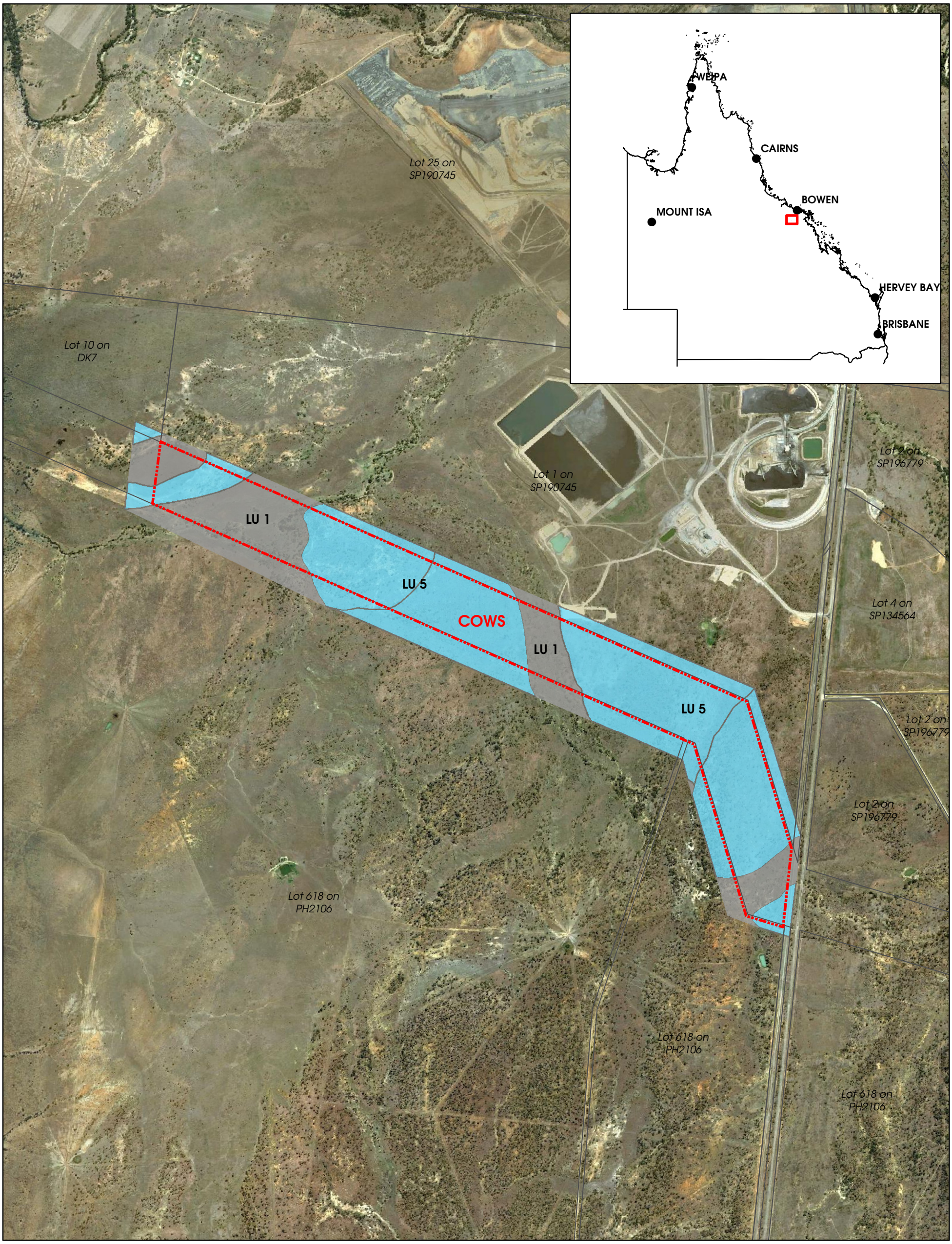
- Soil Sampling Locations
- Sonoma
- EPC586
- Cows Coal Project
- DCDB

COWS COAL PROJECT (ML 10345)

FIGURE 6:

SOIL SAMPLING LOCATIONS ACROSS EPC 586 AND SONOMA COAL MINE

Date: 11 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM, DEEDI & Google



QCOAL PTY LTD

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Kilometres

Scale: 1:25,000 @ A3

Projection: UTM Zone 55
Datum: GDA 1994

N W E S

Legend

- LU 1
- LU 5
- Cows Coal Project
- DCDB

COWS COAL PROJECT (ML 10345)

FIGURE 7: DISTRIBUTION OF LAND UNITS

Date: 11 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM & DEEDI

4.2.1 Land Unit 1: Vertosols on Low Lying Areas

This land unit is easily identified on the site as the primary soil order with its distinctive cracking clay Vertosol soils. The topography of this land unit is relatively low lying between 130 and 150 m AHD, with level to gently inclined slopes less than 3 %. The main vegetation is Rhodes and buffel grass. The main evidence of erosion is in drainage lines; however this tends to be partially stabilised to stabilised. Ground observations and test pits described within this land unit across EPC 586 include GO#1, GO#2, GO#3/ TP#2, GO#8, and GO#10. Photographs of representative sites are shown in **Plate 1** and **Plate 2**.



Plate 1: Site GO#1



Plate 2: Site Test Pit #2 @ GO#3

4.2.2 Land Unit 5: Dermosols & Vertosols on Undulating Terrain

This land unit is present on the higher ground along the eastern portion of EPC 586 at elevations between 150 and 210 m AHD. It mostly contains level to gently inclined slopes less than 3 %. The dominant soil orders are Dermosols, with Vertosols occurring secondary and tending to occur in bands in a north south direction. The dominant vegetation cover is open eucalypt woodland. The occurrence of erosion is considered minor, with sheet erosion being the primary form. Ground observations and test pits described within this land unit include GO#5/TP1 (**Plate 3**) (**Plate 4**).



Plate 3: Site GO#5



Plate 4: Test Pit #1 @ GO#5

4.3 Laboratory Analysis

4.3.1 pH & Salinity

Soil samples from throughout the soil profile at each test pit (TP) across EPC 586 were analysed for soil fertility parameters. Samples from TP1 are from the Dermosol profile and TP2 from the Vertosol profile. Analysis summary tables are included as **Table 2** and **Table 3** below.

Table 2: Soil pH

TEST PIT	DEPTH (M)	PH
TP1 Dermosol	0 – 0.08	6.4
	0.08 – 0.16	6.2
	0.16 – 0.31	6.2
	0.40 – 0.50	6.4
	0.7– 0.86	6.8
TP2 Vertosol	0 – 0.10	7.3
	0.20 – 0.30	8.4
	0.50 – 0.60	8.7
	0.80 – 0.90	8.1
	1.10 –1.20	8.0

The soil pH of the samples is as follows:

- The pH of the Dermosol land unit (from TP1) ranged from relatively *neutral* at the surface A horizon to *slightly acidic* at depth in the B horizon (0.7-0.86 m); and
- In the Vertosol land unit (from TP2) the soil pH was n*eutral* at the surface A horizon. The pH increased to *mildly* to *strongly alkaline* in the B horizon.

Table 3: Soil Salinity Assessment

TEST PIT	DEPTH (M)	EC (DS/M)	TEXTURE	CLAY CONTENT ESTIMATE	SOIL SALINITY RATING
TP1 Dermosol	0 – 0.08	0.05	Sandy clay loam	20 – 30 %	Very low
	0.08 – 0.16	0.04	Sandy clay loam	20 – 30 %	Very low
	0.16 – 0.31	0.03	Light Clay	35 – 40 %	Very low
	0.40 – 0.50	0.04	Light Clay	35 – 40 %	Very low
	0.70 – 0.86	0.04	Weathered sandstone	5 – 10 %	Very low
TP2 Vertosol	0 – 0.10	0.18	Medium clay	45 – 55 %	Low
	0.20 – 0.30	0.15	Medium clay	45 – 55 %	Low
	0.50 – 0.60	0.26	Medium clay	45 – 55 %	Medium
	0.80 – 0.90	1.04	Medium clay	45 – 55 %	Very high
	1.10 – 1.20	0.97	Medium clay	45 – 55 %	Very high

The salinity of the soil samples are as follows:

- The salinity of the Dermosol land unit (from TP1) was *very low* throughout the profile; and
- In the Vertosol land unit (from TP2) the salinity was *low* in the A horizon. The salinity increased throughout the B horizon from *medium* to *very high*.

4.3.2 Soil Sodicity

A soil is considered sodic when sodium reaches a concentration where it starts to affect soil structure. In Australian soils this is commonly when the exchangeable sodium percentage (ESP) is greater than six per cent (Isbell, *et al* 1983).

The sodicity of the soil samples are as follows:

- The ESP throughout the Dermosol land unit (from TP1) was indicated that the soil was *non-sodic*; and
- In the Vertosol land unit (from TP2) the ESP indicated that sodicity increased with depth. The soil became *marginally sodic* to *sodic* at depths below 0.3 m and increased to *strongly sodic* at 0.8 m.

4.3.3 Soil Structural Stability and Dispersion

The Emerson Crumb test may be used as a general guide to sodicity and is used to classify the potential for soils to slake and disperse. When sodic soils are wetted the sodium weakens the bonds between soil particles, resulting in clay swelling causing slaking or dispersion. (Rengasamy and Walters, 1994).

The slaking and dispersion of the soil samples are as follows:

- In the Dermosol land unit (from TP1) the topsoil is susceptible to slaking. The topsoil is not susceptible to dispersion. The subsoil is susceptible to slaking and may disperse after being worked when wet; and
- In the Vertosol land unit (from TP2) the topsoil and subsoil is susceptible to slaking and may disperse after being worked when wet.

4.3.4 Land Suitability Classification

A land suitability assessment of Land Unit 1 and Land Unit 5 in the Cows Project area, and the greater area of EPC 586, was conducted by GHD Pty Ltd (GHD) in February 2010. Findings of their assessment were compared against land suitability criteria published in *Land Suitability Assessment Techniques* (DME, 1995) and the results are summarised in **Table 4** and **Table 5**. Neither land unit, in their pre-mining state, are considered to have *very high* or *high* suitability for either broadacre cropping or beef grazing.

The assessment findings of the pre-mining land suitability of the project area, with reference to broadacre cropping and beef grazing land uses, are illustrated in **Figure 8** and **Figure 9**, respectively.

Table 4: Pre-mining Land Suitability Assessment - Broadacre Cropping Land Use

LAND UNIT	LAND SUITABILITY RATING - BROADACRE CROPPING	MOST LIMITING FACTOR/S
1. *Dermosols on undulating terrain*	Class 4 – Low	Water availability Water erosion
5. *Dermosols and Vertosols on undulating terrain*	Class 4 – Low	Water availability Water erosion

The *Dermosols on undulating terrain* are categorised as being marginal land for broadacre cropping which is presently considered unsuitable due to low water availability and water erosion limitations. The presence of shallow rock at approximately 0.5 m below ground level provides a major restriction to the volume of plant available water that can be stored in the soils profile resulting in an estimated PAWC of 75 to 100 mm, which is low for most crops in the area. In addition the moderate slopes up to 10 % are considered to present a risk for accelerated erosion and would require the extensive construction of contour banks and other erosion control measures (GHD Pty Ltd, February 2010).

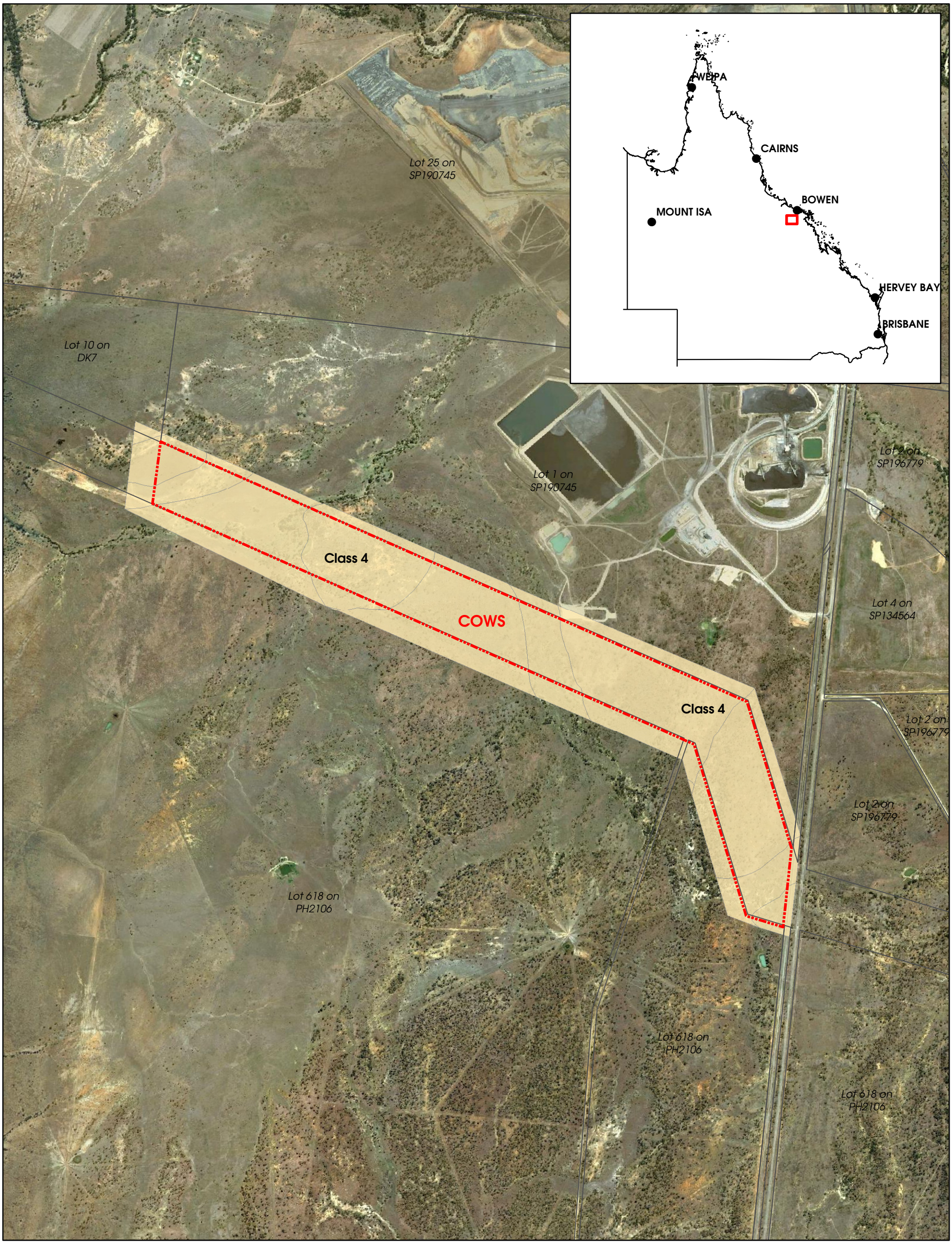
Dermosols and Vertosols on undulating terrain are categorised as being marginal land for broadacre cropping which is presently considered unsuitable due to low water availability and water erosion limitations. This is for the same reasons that the *Dermosols on undulating terrain* were characterised into this category (GHD Pty Ltd, February 2010).

Table 5: Pre-mining Land Suitability – Beef Grazing Land Use

LAND UNIT	LAND SUITABILITY RATING – BEEF GRAZING	MOST LIMITING FACTOR/S
1. *Dermosols on undulating terrain*	Class 3 – Fair	Water availability Nutrient deficiency
5. *Dermosols and Vertosols on undulating terrain*	Class 3 – Fair	Water availability Nutrient deficiency Soil pH

The *Dermosols on undulating terrain* are categorised as suitable for beef grazing with moderate limitations due to water availability and nutritional deficiency limitations. The primary nutritional limitation is low phosphorous of 6 ppm and the shallowness of the soil profile (approximately 0.5 m) results in a reduced plant available water holding capacity (GHD Pty Ltd, February 2010).

The *Dermosols and Vertosols on undulating* terrain are considered suitable for beef grazing with moderate limitations due to water availability, nutritional deficiency, and soil pH. The soil pH between 8.0 and 9.0 are considered moderately to strongly alkaline and may lead to nutritional deficiencies and toxicities (GHD Pty Ltd, February 2010).



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Datum: GDA 1994

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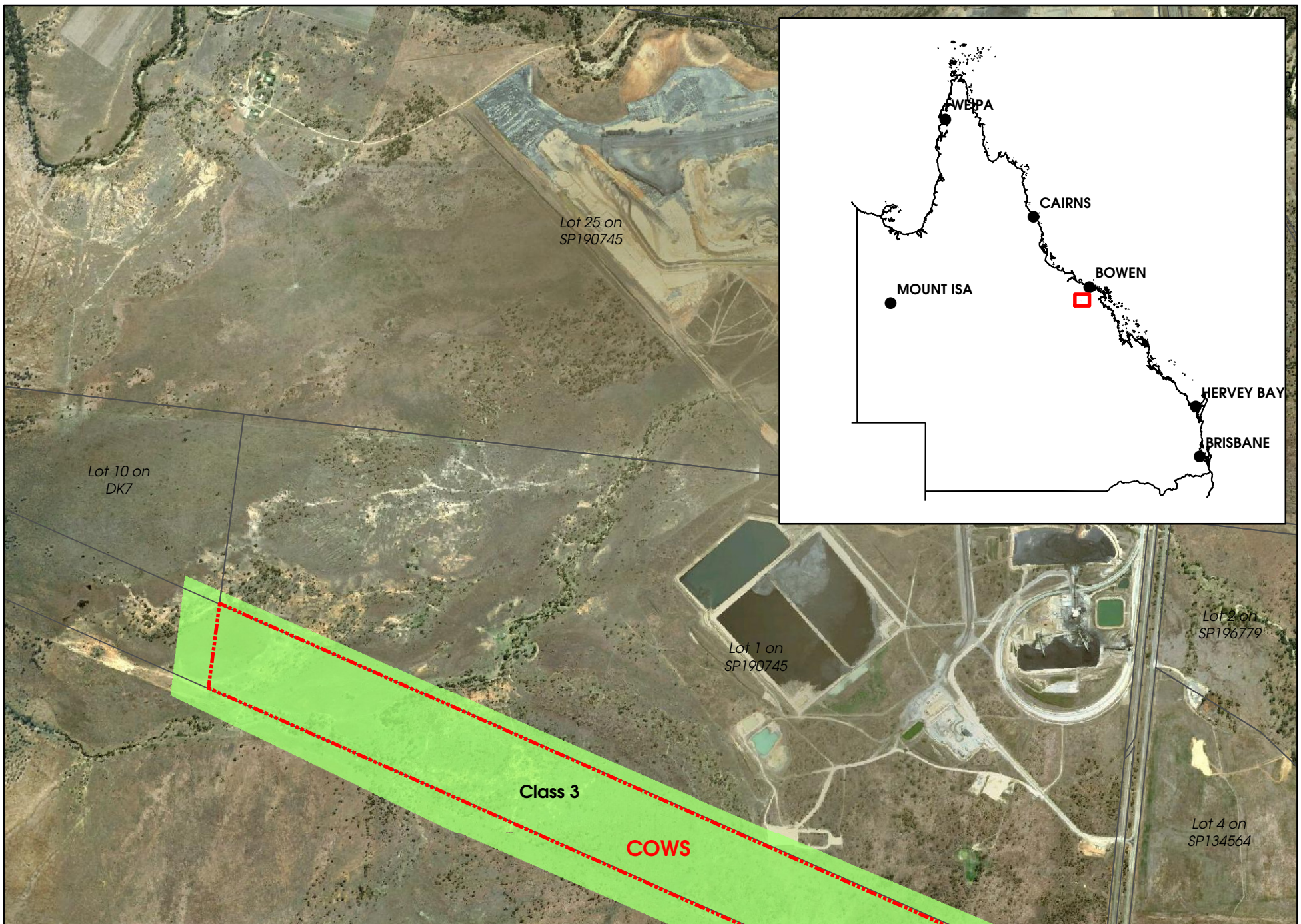
- Class 4
- Cows Coal Project
- DCDB

COWS COAL PROJECT (ML 10345)

FIGURE 8:

LAND SUITABILITY ASSESSMENT FOR BROADACRE CROPPING

Date: 11 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM & DEEDI



QCOAL PTY LTD

0 0.2 0.4 0.6 0.8 1
Kilometres

Scale: 1:25,000 @ A3

Projection: UTM Zone 55
Datum: GDA 1994

N W E S

Legend

- Class 3
- Cows Coal Project
- DCDB

COWS COAL PROJECT (ML 10345)

FIGURE 9:

LAND SUITABILITY ASSESSMENT FOR BEEF GRAZING

Date: 11 May 2011
Drawn By: JB
Project Code: COWS
Data Source/s: DERM & DEEDI

5.0 CONCLUSION

Over the life of the proposed Cows Coal Project, approximately 78.3 ha of land will be disturbed for coal extraction and associated activities. Potential impacts include spreading of declared plants, reduction in the land suitability, loss of remnant habitats, erosion and the release of sediment to waters. The environmental protection objective for the land management program is to prevent contamination from hydrocarbons and to implement progressive rehabilitation that will return the site area to a low-intensity grazing land use, ensure site stability and limit sediment deposition impacts on the drainage system.

The vertosols of Land Unit 1, although limited in lateral extent, is largely outside of the disturbance footprint. The surface soils on these alluvial plains are black to dark grey heavy clays that are colonised by grasslands and scattered trees. These clays represent an abundant source of impervious construction materials and may therefore be used in the construction of the water storage dams.

The dermosols of Land Unit 5 cover the majority of the project area. The clayey soils of Land Unit 5 are shallow (1m) and do not represent a source of construction materials for water containment structures. Activities associated with the pit are not likely to have a significant impact on this Land Unit, as disturbance will be related to access tracks for which standard erosion control measures will be adopted (e.g. take off drains and overland deposition of any eroded fines).

The pre-mining land use suitability and condition of the project area has been assessed to determine acceptable rehabilitation objectives. Two land units, #1 and #5, were identified and assessed on their suitability for broadacre cropping and for beef grazing. None of these land units are considered to have *very high* or *high* suitability for either land use.

The site is currently classified as Class 3 for beef grazing land use with moderate limitations. For the use of broadacre cropping, the land is currently categorised as Class 4, being low conditioned land primarily due to water availability and erosion limitations.

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VOLUME 2a | APPENDIX C
SOILS AND LAND SUITABILITY ASSESSMENT

CLIENTS | PEOPLE | PERFORMANCE

Drake Coal Pty Ltd

Drake Coal Project: Environmental Impact Statement

Soils and Land Suitability Assessment

February 2012



INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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Glossary of Terms

Term	Definition
AHD	Australian Height Datum
ASPAC	Australasian Soil and Plant Analysis Council
Ca:Mg	Calcium to Magnesium Ratio
CEC	Cation Exchange Capacity
^{o}C	Degrees Celsius
EAT	Emerson Aggregate Test
EC	Electrical Conductivity
ECEC	Effective Cation Exchange Capacity
EIS	Environmental Impact Statement
ESP	Exchangeable Sodium Percentage
GHD	GHD Pty Ltd
GQAL	Good Quality Agricultural Land
ha	Hectare
km	Kilometre
m	Metre
mBGS	Metres Below Ground Surface
mm	Millimetre
PAWC	Plant Available Water Capacity
ROM	Run of Mine
SCL	Strategic Cropping Land
ToR	Terms of Reference for the Drake Coal Project EIS

Executive Summary

GHD Pty Ltd (GHD) was engaged by Drake Coal Pty Ltd (the Proponent) to undertake a soil and land suitability assessment as part of the Environmental Impact Statement for the proposed Drake Coal Project. The Project is located 17 kilometres (km) south of the town of Collinsville, Queensland and the Project area covers approximately 9,196 hectares (ha).

The report provides an evaluation of the environmental value of the soils and land suitabilities located within the Project area, in accordance with Sections 4.2.1.5 and 4.2.1.6, respectively, of the Terms of Reference for the Drake Coal Project EIS (DERM, 2010). The investigation addressed the following:

- A description of the soils across the Project and recommendations on soil stripping depths, if required, for use in rehabilitation activities;
- An assessment of the land suitabilities for the site; and
- A description of the Agricultural Land Classes across the Project area.

The soil assessment identified six Land Units within the Project area, being:

- LU1: Vertosols on low lying areas;
- LU2: Vertosols on undulating terrain;
- LU3: Sodosols on undulating low hills;
- LU4: Sodosols on flood plain, with minor Rudosols;
- LU5: Dermosols and Vertosols on undulating terrain; and
- LU6: Tenosols and Rudosols adjacent to Intermittent or Permanent Watercourses.

The first of these Land Units (LU1) was located in the central portion of the site in low lying areas, with a grassland community growing on Vertosols. The second Land Unit (LU2) was also located centrally, appearing as grasslands on gently to moderately inclined slopes with Vertosols. Land Unit 3 (LU3) consisted of Sodosols on the elevated western portion of the site; these are considered highly prone to erosion. In the southern portion of the site, Land Unit 4 (LU4) also contained erosion-prone Sodosols with secondary Rudosol, in the low-lying flood plain of the Bowen River. Land Unit 5 (LU5) was located on the higher ground on the eastern portion of the site, with open eucalypt woodland on Dermosols and Vertosols. The final Land Unit, LU6, was located adjacent to watercourses and drainage features with marked terraces, levees and shallow drainage depressions.

The infrastructure and disturbance areas proposed as part of the Project are largely located in the central and western portions of the mining lease area, coinciding predominantly with Land Units LU1 (2,531 ha), LU2 (852 ha) and LU5 (2,324 ha).

Based on the soil assessment results, topsoil stripping is recommended from three of the Land Units: LU1, LU2 and LU5. These three Land Units cover approximately 62% of the Project area (5,707 ha) and coincide with the majority of Project development. Surface soils from LU3 and LU4 are not suitable for stripping as the high erodibility rating and acidic properties make them unsuitable for plant growth and use in rehabilitation activities. Approximately 58 ha in LU3 and 392 ha in LU4 are proposed for disturbance. Disturbance in these areas is expected to limited to the vicinity of “Central 3” development and the co-disposal facility proposed in LU4 (southern area of the site).

A land suitability assessment was undertaken for the two current and potential land uses in the Project area: Beef Cattle Grazing and Rainfed Broadacre Cropping. The results indicate that all land units in the Project site had a higher suitability for Beef Cattle Grazing than for Rainfed Broadacre Cropping, with the exception of LU2 which was rated fair for both land uses. Approximately 70% of LU2 is located within the mine disturbance area. All Land Units, with the exception of LU3, were assessed as having 'fair' suitability for Beef Cattle Grazing and therefore, approximately 85% of the Project area is considered suitable for this land use. Land Unit LU3, located on the eastern portion of the site, was considered to have 'low' suitability for Beef Cattle Grazing. The table below provides a summary of the land suitability.

Table A Suitabilities of the Land Units for Cropping and their Agricultural Land Classes

Land Unit	Broadacre Crops		Grazing		Agricultural Land Class
	Suitability	Severe Limitation*	Suitability	Severe Limitation	
LU1	4	Workability and Physical Condition	3	-	C
LU2	3	-	3	-	A
LU3	5	Extreme Water Availability	4	Water Availability	C
LU4	4	Dissected Topography	3	-	C
LU5	4	Water Availability & Erosion	3	-	C
LU6	4	Flooding	3	-	C

Class A Good Quality Agricultural Land (GQAL) was identified on the Project site on Land Unit LU2. The remaining land units (LU1, LU3, LU4, LU5 and LU6) were determined to be Class C GQAL for grazing.

Land Units within a 5 kilometres (km) proximity of the Bowen River were also assessed for irrigation suitability. The results indicate the soil is unsuitable for irrigation, based on either the shrink-swell properties of the Vertosols or the sodic subsoil and high erodibility potential of the Sodosols. LU6 comprises of narrow strips adjacent to Intermittent or Permanent Watercourses with terraces and drainage depressions. The local topography makes it unsuitable for large scale irrigation.

A Strategic Cropping Land Assessment was not conducted for this Project as the Terms of Reference were finalised in December 2010 and a certificate of application for mining leases were issued prior to the cut-off date of 31 May 2011.

1. Introduction

GHD Pty Ltd (GHD) was engaged by Drake Coal Pty Ltd (Drake Coal), a subsidiary of QCoal Pty Ltd (QCoal), to undertake a soil and land suitability assessment as part of the Environmental Impact Statement (EIS) for the Drake Coal Project (the Project).

Drake Coal propose to develop the Drake Coal Project, an open-cut coal mine, located in Queensland's Bowen Basin (Figure 1). Truck and excavator operations are proposed to excavate the coal resource. Mining operations will extract approximately 10 million tonnes per year (Mt/y) of run of mine (ROM) coal for processing to produce 6 Mt/y of product coal for export. The anticipated mine life is 30 years (inclusive of construction, operation and rehabilitation), with the potential to extend the mine life as ongoing exploration activities identify further coal reserves.

The aim of this study was to evaluate the environmental value of the soils and land suitability, in accordance with Sections 4.2.1.5 and 4.2.1.6, respectively, of the Terms of Reference (ToR) for the Drake Coal Project EIS (Department of Environment and Resource Management, (DERM), December 2010).

1.1 Study Area

The proposed Drake Coal Project is located in the Whitsunday Regional Council local government area, and is situated 17 kilometres (km) south of the town of Collinsville (Figure 1). The proposed mining activity will take place entirely within Lot 618 on PH 2106 (land lease) and Lot 9 DK 239 (freehold) and covers an area of 9,196 hectares (ha). Lot 9 DK 239 comprises of 0.4 ha, the remainder of the Project site is located on Lot 618 PH 2106. The proposed infrastructure and areas of disturbance are shown in Figure 2. It is estimated that approximately 3,442 ha will be disturbed by mining operation activities, leaving approximately 5,754 ha of the lease undisturbed.

The mining lease area is bordered by the Bowen Developmental Road and Newlands-Abbot Point railway line to the east, and the Bowen River to the south. Twelve Mile Gully traverses the southern section of the site and forms an upper tributary to the Bowen River. The area surrounding the Project also contains the major coal mines of Collinsville, Sonoma and the decommissioned Pipeline Coal Mine.

1.2 Assessment Objectives

The objectives of the assessment are detailed below. They address Section 4.2.1.5: Soils and Section 4.2.1.6: Land Suitabilities of the ToR for the Drake Coal Project EIS (DERM, December 2010).

Table 1 Terms of Reference

Section	Activity / Impact	Description
4.2.1.5	Soils	◗ Conduct a soil survey of the area that would be affected by the Project ◗ Undertake soil tests and laboratory analyses of representative samples down the soil profile, with particular reference to the physical and chemical properties of the materials that will influence soil stability, erosion potential, storm water run-off quality, rehabilitation and agricultural productivity of the land ◗ Describe, map and illustrate, at an appropriate scale, soil types and profiles ◗ Document the depth and quality of useable topsoil and subsoil to be stripped and stockpiled for rehabilitation ◗ For areas of the mining tenure along the Bowen River with access to irrigation water (e.g. within 5 km of the river), assess the soils for suitability for irrigation using the suitability scheme in land suitability for irrigated agriculture along the Fitzroy River
4.2.1.6	Land Suitabilities	◗ Provide an Agricultural Land Class map of the Project site and the surrounding area. Highlight any good cropping land ◗ Describe and map the land use suitabilities and their classes, of the potentially affected area ◗ Show the location of any cropping land in the vicinity of the site, highlighting any potential strategic copping land, and describe the crops commonly grown on the land, including any rotations

1.3 Guidelines and Standards

The soil and land suitability assessment was undertaken using the guidelines, standards and the accepted industry publications listed below:

- *Guideline for Land Suitability Assessment Techniques* (DME, 1995);
- *Guideline for Agricultural Land Evaluation in Queensland* (DPI, 1990);
- *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI/DHLGP, 1993);
- *Protecting Queensland's Strategic Cropping Land: A policy framework* (DERM, 2010);
- *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain, 2009);
- *Australian Soil and Land Survey: Guidelines for conducting surveys* (Gunn et al 1988);
- *Guidelines for Survey Soil and Land Resources* (McKenzie et al, 2nd Ed., 2008); and
- *Australian Soil Classification* (Isbell, 2002).



LEGEND

- Town
- Major Town
- River
- Major Road
- Railway
- Project Area
- Local Government Area

1:1,250,000 (at A4)

0 10 20 30 40 50

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Drake Coal Pty Ltd
Drake Coal EIS

Job Number 41-21894
Revision 1
Date 09 Feb 2012

Project Location Plan

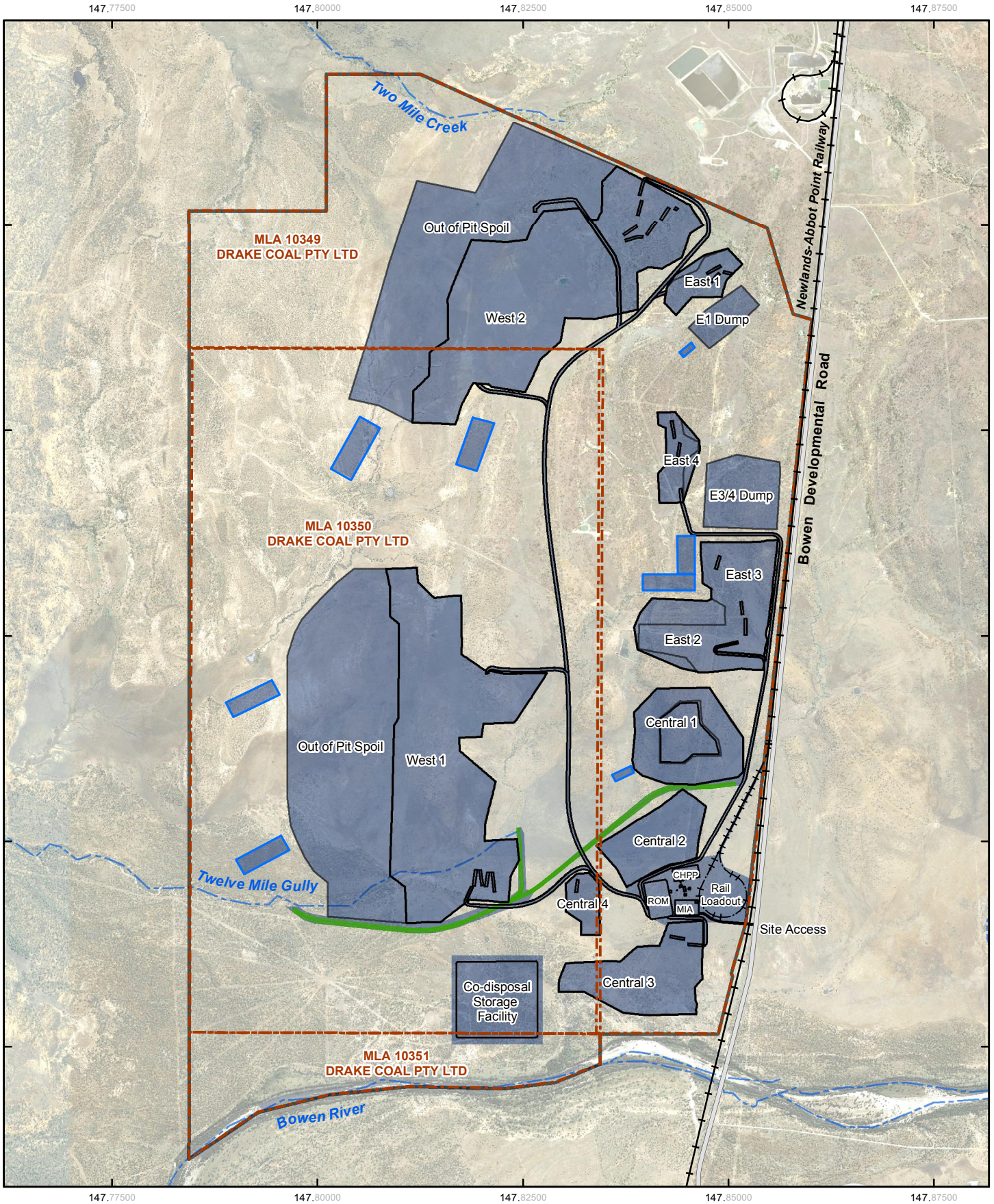
Figure 1

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Data source: QCOAL: Study Area (2010); GA: 250K V3 Topo/2009. Created by: TH, WW



LEGEND

- Major Road
- Existing Railway
- Proposed Railway
- Drainage Feature
- Proposed Diversion Channel
- Project Area
- Mining Lease Application Boundary
- Mine Layout
- Sediment Basin (Indicative)
- Mine Affected Area

1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Revision 1
Date 13 Mar 2012

Proposed Infrastructure and Areas of Disturbance

Figure 2

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Data source: QCOAL: Mine Layout (2011); DME: Mining Lease (2011); GA: 250K V3 Topo (2009). GE: Imagery (06062011). Created by: TH

2. Background Information

Information relevant to the soil survey and land suitability assessment was obtained prior to fieldwork and is documented in the following sections. General background information is provided on the existing biophysical environment for the works associated with Sections 4.2.1.5 and 4.2.1.6 or the ToR, but does not seek to address other sections of the ToR.

2.1 Climate

The Collinsville region is dominated by dry tropical / sub-tropical weather patterns which have distinct wet (November to April) and dry (May to October) seasons. The geographic region is strongly influenced by a range of climate extremes including:

- The Australian monsoon influenced by the *El Niño* and *La Niña* (*El Niño* is associated with lower than average winter / spring rainfall; whilst *La Niña* is associated with higher than average winter, spring and early summer rainfall);
- General storm activity;
- Cyclonic events; and
- Severe heat waves.

Typically the region experiences hot summer months (December to February) and a dry winter season. Heavy rainfall predominately occurs within the summer months (late December to February) of the year, but is not reliable with substantial variation in annual rainfalls. Cloud cover generally increases in the lead up to the wet season with 'build up' thunderstorms starting in late December. Skies are generally clear during the dry season. The average median annual rainfall at Collinsville is approximately 710 mm and rainfall occurs between six to nine days per month in the wet season. The driest months are between May and October when very little rainfall occurs. Rainfall in the area is known to be inconsistent with annual rainfall and commonly is either well above or well below the annual average rainfall for the region. The high annual variability is due to the sporadic incidence of rainfall depressions associated with tropical cyclones and the convective origin of much of the rainfall (Shields, 1984).

Rainfall erosivity risk ratings for the region are based on Bowen (IECA, 2008). Rainfall erosivity is a measure of the ability of rainfall to cause erosion and is a product of the total energy and the maximum intensity for each storm. Rainfall erosivity is an indication of the two most important characteristics of a storm determining its erosivity, being the amount of rainfall, and peak intensity sustained over an extended period.

The rainfall events with the most erosive energies are in the summer months, which also coincide with the highest monthly rainfalls. Contrastingly, the winter months have low rainfalls with low rainfall energies. Details of monthly values in Collinsville for median rainfall, days that rain exceeds 10 mm or 25 mm, and rainfall erosivity risk are included in Table 2.

Table 2 Rainfall Data for Collinsville Region

Month	Rainfall (Median)	Rain Days ≥ 10 mm	Rain Days ≥ 25 mm	Rainfall Erosivity Risk
January	134.0	3.9	1.6	High
February	**164.7**	**4.4**	**2.0**	
March	93.2	2.7	1.1	
April	41.6	1.0	0.4	Medium
May	32.1	0.8	0.3	
June	27.2	0.7	0.3	Low
July	20.0	0.7	0.2	Very Low
August	18.1	0.5	0.2	
September	**11.6**	**0.4**	**0.1**	
October	21.5	0.8	0.2	
November	50.5	1.5	0.6	Medium
December	95.0	2.7	1.2	High
Total	710.0	20.1	8.2	

Source: Bureau of Meteorology (accessed 20/10/2010), being the average of climate data from Collinsville Post Office. Rainfall erosivity risk ratings are based on published values for Bowen (IECA, 2008)

Average daily temperatures range from between 21.6 ^{o}C to 33.3 ^{o}C during the summer months to 10.1 ^{o}C to 25.7 ^{o}C in the winter months. Summer months typically have low relative humidity (67% at 9 am and 48% at 3 pm). Winter months also have low relative humidity (69% at 9 am and 41% at 3 pm) and are typically warm, mild days with cool to cold nights. Morning frosts throughout the months of May to August are common.

The region tends to have light winds with annual average wind speeds of 6.1 km/hr at 9 am increasing to 8.2 km/hr at 3 pm. In spring and summer, winds prevail from the north to north east. The monsoon trough influences wind direction in the area with light winds tending moderate westerly when the trough dips south of the area (P.G. Shields, 1984). South-easterlies occur during the autumn and winter months with an occasional southerly breeze. Strong or gale force winds are normally associated with tropical cyclones which regularly affect the coastal area from December through to April.

Flooding events have previously been recorded in surrounding coastal communities associated with cyclonic activities. A review of the Emergency Management Australia database indicated that the Collinsville region has no recorded flood damage events in the last 100 years. Flooding events are discussed in greater detail in Volume 1, Chapter 4 – Climate and Chapter 9 – Surface Water. The Local Flood Modelling Assessment is contained in Volume 2a, Appendix H and the Regional Bowen River Flood Assessment is contained in Volume 2a, Appendix I.

2.2 Land Use

The region has been utilised for beef and sugar production and gold mining since the late 1800s. Coal mining commenced in the early 1900s and, as a result, the natural landscape has undergone considerable disturbance and modification in the vicinity of coal mines. Infrastructure development, including rail and road development, has largely been associated with mining activities. Besides mining activities, the two current land uses within the vicinity of the Project area have been identified as Rainfed Broadacre Cropping and Beef Cattle Grazing.

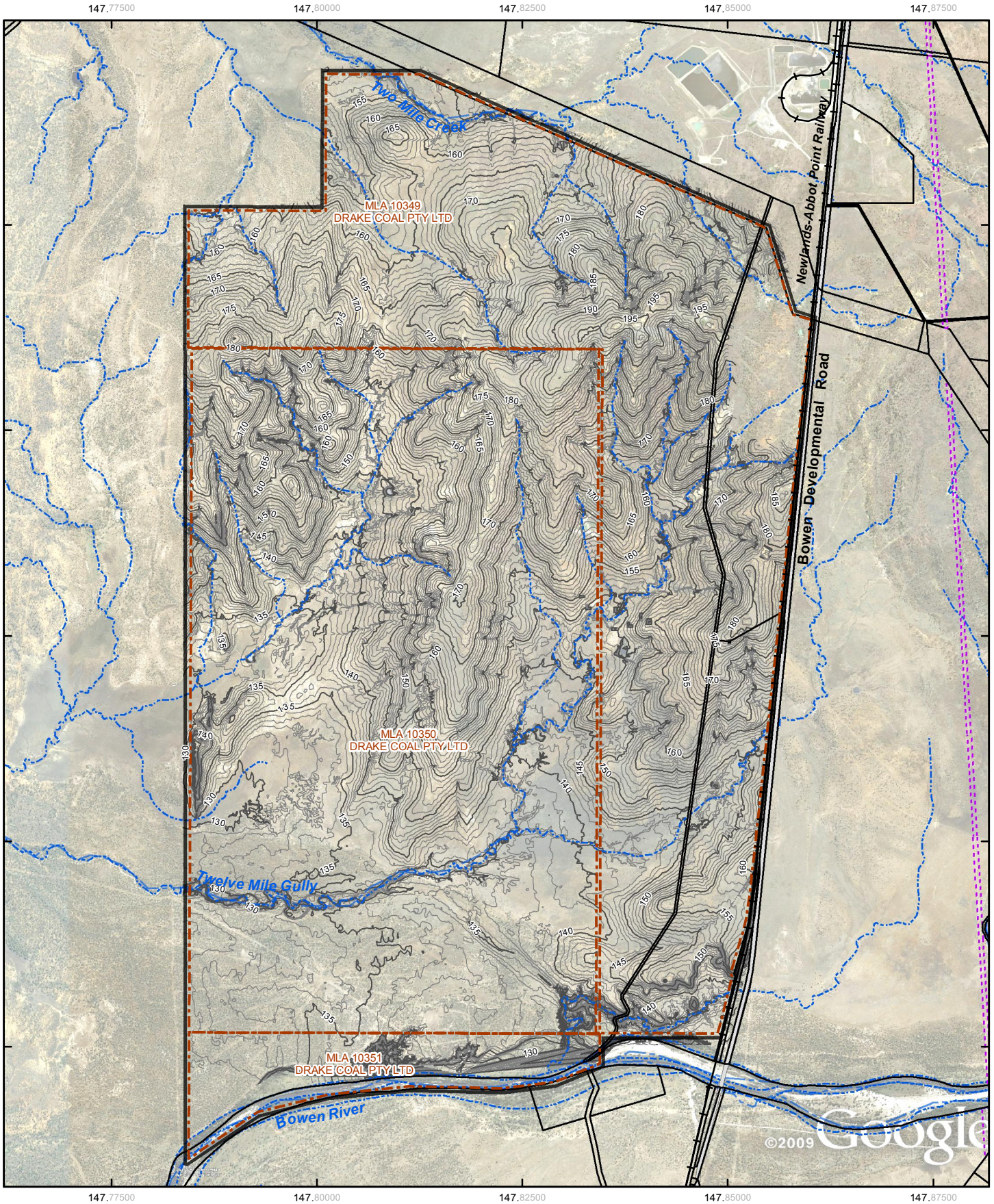
Specifically within the Project area, the land has been largely cleared for cattle grazing. However, there are areas of retained vegetation or regrowth and these remnant vegetation communities include mixed eucalypt woodlands, small areas of native grasslands and acacia shrublands.

2.3 Topography and Drainage

The Project area is characterised by flat to slightly undulating plains across its southern extent, with small hills in the northeast and northwest of the site. The relief ranges between 20 m to 70 m with elevations from 130 to 200 m AHD. The higher elevations occur in the north-eastern corner of the Project area and are associated with a hill crest. Ridge lines descend from this crested area in a radial pattern towards the south, west and north (Figure 3). The slope is ≤ 3% across large areas of the site, with steeper slopes ranging from 3 to 10% in association with hills in the north-eastern section of the site. There are also small pockets of steep gullies, ridgelines and drainage features throughout the site (≤ 50%).

The mining lease area falls within the Burdekin River catchment. The Burdekin River is the second largest river basin on the Queensland coast, covering approximately 130,000 km^2 and delivers a third of the total median annual water discharge from all coastal catchments to the Great Barrier Reef Lagoon. The four major sub-catchments that contribute to the Burdekin River Basin are the Upper Burdekin, Bellyando / Suttor, Bowen / Broken and the lower Burdekin / Coastal plains catchment. Stream flows reflect rainfall variability and seasonality, with summer flooding and an absence of flow between May and November not being uncommon (Roth et al, 2002). The Drake Coal Project area falls within the Bowen / Broken River sub-catchment area of the Burdekin River catchment and is in the jurisdiction of the Whitsundays Regional Council.

The site is intersected by several ephemeral creeks and gullies. The southern portion of the mine lease area drains into Twelve Mile Gully, which flows towards the south-west and discharges into the Bowen River. The northern part of the lease area drains into the Two Mile Creek catchment, which flows towards the north-west into Pelican Creek. Pelican Creek eventually discharges into the Bowen River approximately 28 km downstream of Twelve Mile Gully's discharge point. These streams are ephemeral in character, only flowing during and immediately after heavy rainfall.



LEGEND

- Major Road
- Existing Railway
- Drainage Feature
- Elevation Contour (1m Interval)
- Elevation Contour (5m Interval)
- Project Area
- Mining Lease Application Boundary
- Easement
- Cadastre

Based on or contains data provided by the State of QLD (DERM) [2011]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Topography of the Project Area

Job Number 41-21894
Revision 1
Date 24 Feb 2012

Figure 3

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Data source: QCOAL: Mine Layout (2011), Elevation (2010); DME: Mining Lease (2011); DERM - Drainage (2011) GA: 250K V3 Topo (2009). GE: Imagery (06062011). Created by: TH

2.4 Geology

The Collinsville area has a long history of coal mining with coal extraction and rail transportation to the coast commencing in the 1920s. The major coal mines of Sonoma and Collinsville are located in the area. Mining in the Collinsville area uses both open-cut and underground methods. The Project will be a greenfield open-cut mine. Exploration activities have defined a resource of approximately 200 million tonnes (Mt) of economically recoverable coal. Mining operations will produce up to 6 Mtpa product coal (10 Mtpa ROM) for export markets.

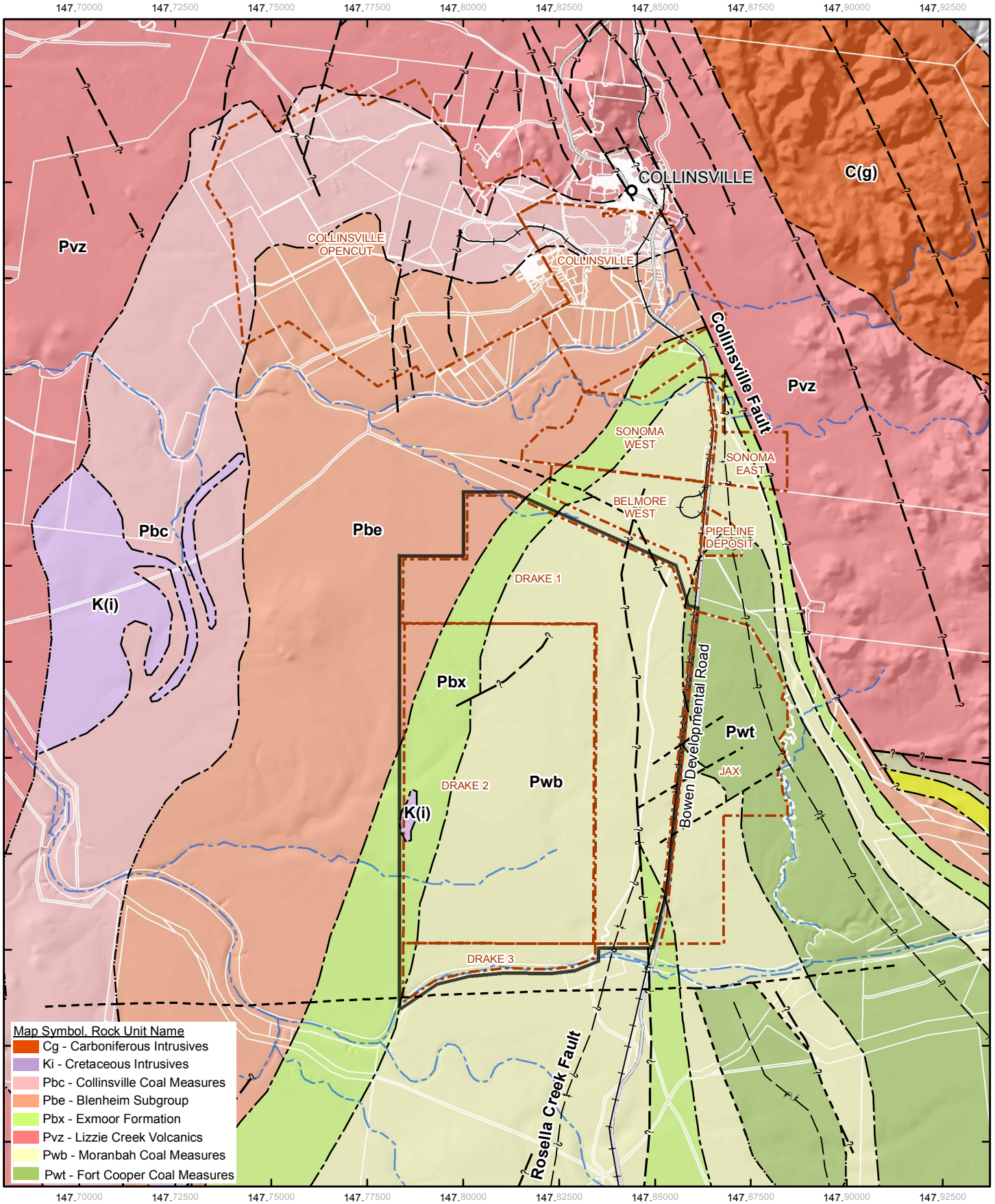
The Project area lies within the Bowen Basin sequence of early Permian to Middle Triassic marine and fluvial deposits, in which thick coal seams are present (Hutton et al., 1998). The sedimentary record shows a series of marine transgressions and regressions, with a significant proportion of the sedimentary units laid down between 299 and 251 million years ago (Permian Age). The overlying sedimentary and volcanic sequences and basalt flows were laid down during the Tertiary or during the past 65 million years (Hutton et al 1998). The Permian sedimentary rocks are dominated by clastic sediments including mudstones, siltstones, sandstones and conglomerates. Limestone and claystone are also present in the Bowen Basin Permian sedimentary sequence but generally are of limited extent. The Permian sediments are unconformably overlain by Tertiary basalt and the younger Tertiary-aged mudstones, siltstones, and sandstones (Hutton et al, 1998). A generalised stratigraphy of the Bowen Basin is provided in Figure 4.

<table>
<tr><td>Cainozoic</td><td></td><td>Sediments & volcanic rocks; and
Suttor Formation</td></tr>
<tr><td rowspan="2">Triassic</td><td rowspan="2">Rewan Group</td><td>Arcadia Formation</td></tr>
<tr><td>Sagittarius Formation</td></tr>
<tr><td rowspan="5">Late Permian</td><td rowspan="3">Blackwater Group</td><td>Rangal Coal Measures</td></tr>
<tr><td>Fort Cooper Coal Measures (NAF)[1]</td></tr>
<tr><td>Moranbah Coal Measures (NAF)</td></tr>
<tr><td rowspan="4">Early Permian</td><td rowspan="4">Back Creek Group</td><td>Exmoor Formation</td></tr>
<tr><td>Blenheim Formation</td></tr>
<tr><td>Collinsville Coal Measures (PAF)
Gebbe Formation</td></tr>
<tr><td>Tiverton Formation</td></tr>
<tr><td rowspan="2">Late Carboniferous</td><td rowspan="2"></td><td>Lizzie Creek Volcanics
Bulgunnuna Volcanics</td></tr>
</table>

[1]NAF: Non Acid Forming; PAF: Potential Acid Forming

Figure 4 Generalised Stratigraphy of the Northern Bowen Basin (QCoal, 2011)

The surface geology of the Project area is dominated by the Moranbah Coal Measures, which lie in a north-south orientation and have a lithology of labile sandstones, siltstones, carbonaceous shale, coal, local cherty mudstone and occasional plant fossils (Hutton *et al,* 1998). The Moranbah Coal Measures were formed from terrestrial deposition in the late Permian. Surface geology in the west of the Project area consists of the Exmoor Formation (fine grained quartzose sandstones and siltstone) and the Blenheim subgroup (carbonaceous/micaceous quartzose sandstones and siltstone). These two formations were marine deposited and are therefore likely to contain elevated salt concentrations. These properties must be considered during mining operations as they are likely to inhibit plant growth if they are in the plant root zone. The rehabilitation landscape should be designed so that these spoil materials are buried and a more favourable material provided for plant growth. Also represented in minor areas are the Cretaceous Intrusives and Fort Cooper Coal Measures (Figure 5). Fault lines occur along the western margin (trending north-south) of the Project area. Several other fault lines, which trend northeast-southwest, occur along the western margin and in the north-east corner of the site. These fault lines (inferred and approximate locations) are shown in Figure 5.



LEGEND

- Existing Railway
- Major Road
- Mining Lease Application Boundary
- Project Area
- Cadastre

Geological Structure

- Fault Approximate
- Fault Inferred
- Geological Boundary Approximate
- Geological Boundary Inferred
- Syncline Approximate
- Syncline Approximate Showing Dip and Plunge

1:150,000 (at A4)

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Surface Geology

Figure 5

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Data source: QCOAL: Project Area (2011), Site Layout (2011); DERM: GeologyRivers (2007), GA: 250K Topography - ©Commonwealth of Australia. Created by: TH/IH

2.5 Coal Resources

The general stratigraphy of the Project area was assessed through desktop review of existing regional information. A detailed description of the coal resource base, exploration activities, quality and estimated volumes of coal is provided in Volume 2a, Appendix G – Waste Rock Characterisation Assessment of the EIS document. The Project area comprises the Back Creek Group basal Blenheim Formation overlain by the marine Exmoor Formation, non-marine Blackwater Group coal measures and the Tertiary sediments of the Suttor Formation and equivalents. The Blackwater Group within the Project site comprises the younger Moranbah and Fort Cooper Coal Measures.

The Lizzie Creek Volcanics (Early Permian) form the basal unit of the Bowen Basin and comprise andesitic to dacitic flows and pyroclastic rocks, conglomerate and black siltstone. These are unconformably overlain by the Collinsville Coal Measures, which comprise up to nine persistent coal seams. Depositional environments vary from initial fluviatile sediments that pass up into marginal marine sandstones. Coal seams grade into carbonaceous shale to the west of Collinsville. The Collinsville Coal Measures are potentially acid forming. The Collinsville Coal Measures are conformably overlain by the Blenheim Formation (Back Creek). The Collinsville Coal Measures are not the target unit for the Project.

Overlying this Back Creek sequence is the Moranbah Coal Measures, which represents the lowermost unit of the Blackwater Group. This is the target sequence for the Project. This unit comprises cross-bedded sandstone, siltstone, mudstone, and coal. Coal seams include only minor tuffaceous and mudstone bands. In turn, the Moranbah Coal Measures are overlain by the Fort Cooper Coal Measures, which are distinguished from the former by the abundance of tuff bands and mudstone partings within coal seams. The sequence contains eight major seams (Figure 6). Historically the seams have been given the letter designations from A to R in accordance with stratigraphic order. The relatively thick, low-ash seams distinguish this unit from the overlying Fort Cooper Coal Measures. Interburden rocks consist of quartz-poor lithic sandstones, siltstone, shale, and mudstone. Some tuffs or tuffaceous mudstone bands are present in the sequence, with the P Tuff (associated with the P seam) being the most prominent.

The Fort Cooper Coal Measures comprise lithic sandstone, conglomerate, mudstone, carbonaceous shale, inferior coal and numerous tuff horizons. The Tertiary Suttor Formation rests unconformably on the underlying Permian Formations and consists predominantly of unconsolidated, fluviatile and lacustrine quartz-rich sediments. Minor Tertiary volcanism in the form of volcanic sills and dykes occur in parts of the mining lease area.

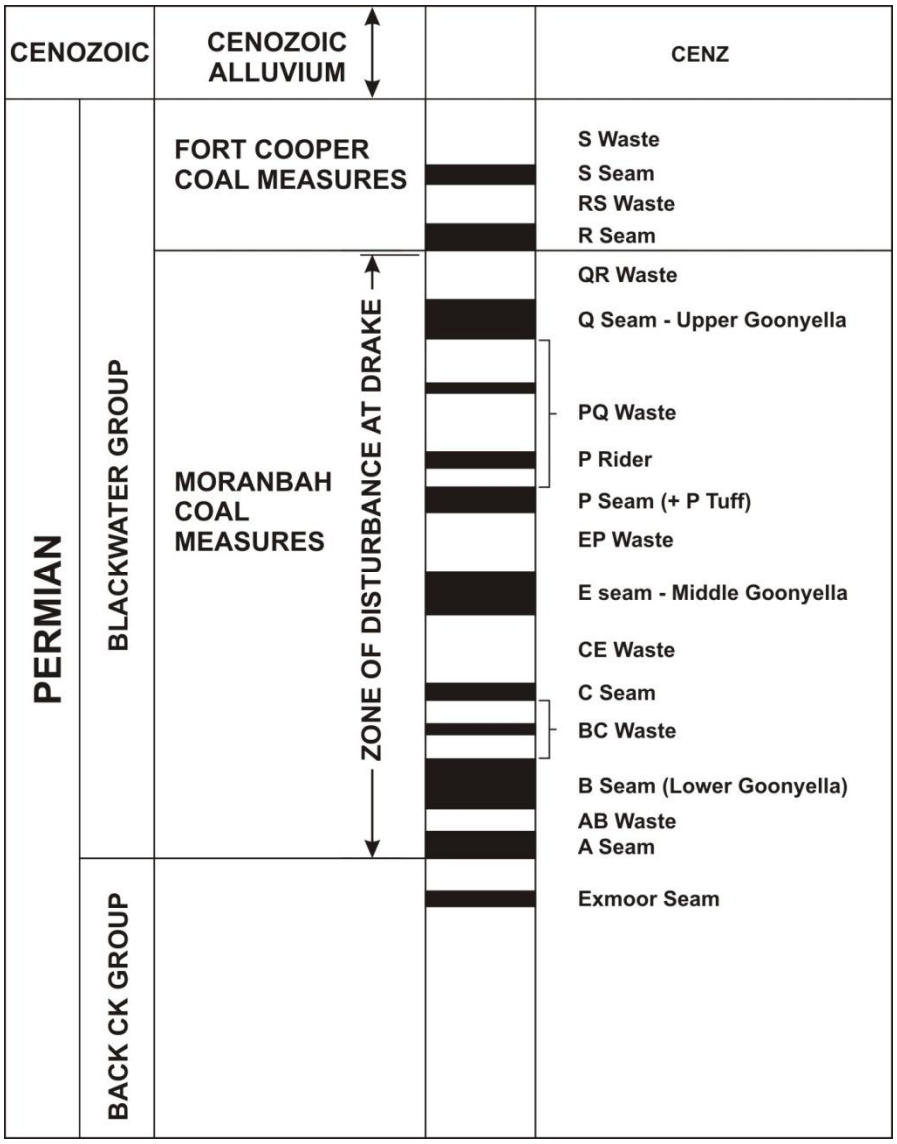


Figure 6 Coal-Seam Nomenclature – Northern Bowen Basin

3. Soil Assessment

The soil assessment provides information of the main types of soils present on the land affected by the proposed mining operations. The methodology and results are provided in the following sections.

3.1 Soil Assessment Methodology

The soil assessment was undertaken in reference to the *Guideline for Land Suitability Assessment Techniques: Section 6.1* (DME, 1995) in the following steps:

- Initial desktop review of available land resource data and preliminary mapping of the soils and terrain;
- Review of previous soil profile information collected for the neighbouring Jax and Sonoma Mine sites;
- Field survey of the site to characterise the soils and landscapes, including laboratory analysis of selected soil samples and classification of the soils in accordance with the Australian Soil Classification; and
- Mapping of the Land Resource Units based on the units of common soils, landforms, geology and vegetation communities.

3.1.1 Initial Desktop Review

Prior to the commencement of fieldwork, a review was undertaken of available information relevant to the Project area. The resources assessed included aerial photography, digital terrain data, vegetation / geology / soils maps and published reports. The following publications and databases were reviewed:

- *Soils. Burdekin-Townsville region*. Queensland Resources Series. Department of National Development (DND, 1970);
- *Land suitability study of the Collinsville-Nebo-Moranbah region.* Queensland Department of Primary Industries (DPI, 1984);
- *Soil fertility of Central and North-east Queensland Grazing Lands.* Queensland Department of Primary Industries. (DPI, 1994);
- *Birralee* (EPC 586) Ecological assessment (ERM, 2007);
- Combined Soils Data published by the Queensland Department of Environmental and Resource Management (various years);
- *Appendix 4 Soils Report* (QCoal, 2010); and
- Regional Ecosystem mapping of Queensland published by the Queensland Department of Environmental and Resource Management.

Information from the desktop review was used to develop initial site maps that broadly identified landform and expected soil patterns. The initial mapping was refined through field study so the soil groups could be further characterised and delineated.

3.1.2 Field Survey Method

The field survey methodology was developed based on the *Guideline for Land Suitability Assessment* (DME, 1995) and the findings of the desktop review and existing regional information. Onsite survey locations were identified from the preliminary land unit map and field investigations were undertaken to confirm soil characterisation at a mapping scale of 1:50,000.

Onsite Soil Survey

Two soil surveys were undertaken within the Project area. The first was undertaken between 17 and 19 November 2009 and the second survey between 30 November and 3 December 2011. A total of 176 ground observation locations were recorded for the 9,196 ha Project area. Detailed soil profile descriptions were undertaken at 53 of these sites. The observation density required by DERM and current guidelines is one site described for every 25 ha of land within the mining area. Consequently, the total disturbance area of 3,442 ha for the Project requires soils to be described from at least 137 sites, with at least 34 of those sites to be described in detail. The number of sites in pit and spoil dump areas is required to be higher than 137 because, taken individually, the smaller pit and dump areas would require additional sites above the absolute minimum in order to provide a statistically valid number of samples; and the guideline states that sampling should be done at a larger scale for disturbance areas. The observation density is greater than one per 52.25 ha which is within the recommended and minimum acceptable range of 1 per 25 ha to 1 to 100 ha in the 1: 50,000 scale mapping.

The techniques used for soil surveying included:

- *Ground observations* were carried out to determine the broad distribution of soil landscapes across the Project area. These *ground observations* were conducted at 16 locations (GO-#) in November 2009 and at 158 locations (G-#) in November-December 2011. At each location, details were recorded regarding:
  - Landform, vegetation, land surface, and the soil to at least the top of the C horizon[1]. Where existing vertical profiles were present, the full soil subsoil profile was described;
  - Erosion, including type (sheet, rill, gully, scald, wind or tunnel) and activity (active, stabilised, partially stabilised) were recorded; and
  - Photographs were taken at all observation sites;
- *Soil profile descriptions* of each major soil type across the study area was undertaken to provide a detailed characterisation of the main soil landscape units over the site.
  - For descriptions undertaken in November 2009, a backhoe was used to excavate test pits (TP-#) at 3 locations to approximately 1.5 metres Below Ground Surface (mBGS) to allow profile descriptions and sample collection:
    - For each test pit, details were recorded regarding horizon thickness, colour, texture, structure, field pH and roots;
    - Topsoil was collected from the surface 0 - 0.1 mBGS. The sample was a composite of soil obtained from 10 to 20 points within a 10 m radius of the test pit. These point samples were bulked, thoroughly mixed and retained for laboratory analysis. Composite sampling was

[1] The term 'horizon' describes each of the distinctive layers that occur in a soil. The A horizon: Surface soil: Layer of mineral soil with most organic matter accumulation and soil life. The B horizon: Subsoil: This layer accumulates iron, clay, aluminum and organic compounds. The C horizon: Parent Rock: Layer of big unbroken rocks.

used to reduce the likelihood of a hot spot concentration being detected and to provide a result that was representative of the topsoil in the vicinity of the test pit; and

- Subsequent discrete samples from the soil profile were collected at depths approximating 0.2-0.3, 0.5-0.6, 0.8-0.9 and 1.1-1.2 mBGS to characterise the physical and chemical properties of the soil;

- In November-December 2011, soil descriptions were recorded from 50 soil cores obtained using a vehicle mounted hydraulic corer (50mm diameter) to a depth of approximately 1.5 mBGS or until refusal on weathered rock:
  - Details were noted regarding horizon thickness, colour, texture, structure, field pH and roots; and
  - Topsoil was sampled from the surface soil (between approximately 0.0 to 0.1 mBGS), as per the 2009 procedure. Subsequent samples were obtained at regular intervals from the soil horizons encountered to a maximum depth of 1.5 mBGS. Selected samples were submitted for analysis to characterise the physical and chemical properties of the soil.

Soil observations obtained during a geotechnical investigation (Ground Environments Pty Ltd, 2010), of the south-east portion of the site provided supporting documentation of soil characteristics and are described in the Desktop Review section (Section 3.2.1).

3.1.3 Laboratory Analysis

To determine the chemical properties for each identified soil landscape unit, soil samples were submitted to analytical laboratories for analysis. Samples obtained during fieldwork conducted in 2009 were submitted to Phosyn Analytical (Andrews, Queensland)[2] and samples from 2011 were submitted to Nutrient Advantage Laboratory Services (Werribee, Victoria)[3]. All samples submitted were analysed for pH, salinity, and sodicity parameters, whilst topsoil samples were additionally analysed for fertility parameters (refer to Table 3). A brief description of the relevance of the chemical analyses to soil salinity, soil sodicity and soil dispersion and other soil characteristics are discussed below and guidelines are provided in Appendix D.

Table 3 Soil Analytical Parameters Assessed

Horizon	Analytes
Topsoil	◗ fertility (nitrogen*, phosphorous*, and potassium), organic matter, trace elements (copper, zinc, manganese, and iron), sulfate and boron* ◗ pH* and electrical conductivity (EC), exchangeable cations* (calcium*, magnesium*, sodium*, potassium* & aluminium*) ◗ calculations of exchangeable sodium percentage (ESP) ratio (% sodium of total cations), effective cation exchange capacity (ECEC), and calcium to magnesium ratio (Ca:Mg)
Subsoil	◗ pH* and electrical conductivity (EC), exchangeable cations* (calcium*, magnesium*, sodium*, potassium* & aluminium*) ◗ calculations of exchangeable sodium percentage (ESP) ratio (% sodium of total cations), effective cation exchange capacity (ECEC), and calcium to magnesium ratio (Ca:Mg) ◗ Emerson Aggregate Testing (EAT) on selected samples

Notes: * indicates the Phosyn Analytical laboratory is ASPAC certified for these analyses.

[2] Phosyn Analytical is certified by the Australasian Soil and Plant Analysis Council (ASPAC) for selected analytes. These analytes are identified in Table 3. Phosyn Analytical is not NATA (National Association of Testing Authorities) accredited.

[3] Nutrient Advantage Laboratory is a NATA accredited laboratory.

Soil pH

Soil pH is a determination of the hydrogen ion activity in solution and measures the intensity of the acidity or alkalinity within the soil matrix. For most plants the optimal $pH_{w1:5}$ in soil ranges between 5.5 and 8.5. Outside of this range plant growth tends to be retarded mostly due to changes in the soil chemistry resulting in nutrients and micronutrients becoming either unavailable or toxic to plants.

Soil Salinity

Soil salinity refers to the presence of water soluble salts in water or soils. The most common base for salts is sodium however; potassium, calcium and magnesium cations can also contribute appreciably to salinity. Salts of these cations may be present as chlorides, sulfates or carbonates. The electrical conductivity (EC) from a soil / water suspension (1:5) is commonly used as a measure of salinity in soil.

The relationship between EC and salinity is largely dependent upon the soil texture, in particular clay content of the soil. Where soils have higher clay content, this can reduce the effect of salinity on plants as the strong electronic bonds that exist between particles in clay soils tend to negate the effect of salinity.

Soil Sodicity and Dispersion

A soil is considered sodic when sodium reaches a concentration where it starts to affect soil structure. In Australian soils this is common when the exchangeable sodium percentage (ESP) is greater than 6% (Isbell, *et al* 1983). When sodic soils are wet the sodium weakens the bonds between soil particles, resulting in clay swelling causing slaking or dispersion (Rengasamy and Walters, 1994).

Slaking refers to the rapid disintegration of large aggregates (2 mm to 5 mm diameter) of soil into finer aggregates (i.e. less than 0.25 mm) when wet and is caused primarily by a lack of strong organic particles and micro aggregates. This changes the macroscopic structure of the soil resulting in loss of macropores and alters the porosity and permeability throughout the soil profile.

Dispersion is a second process of structural breakdown and is caused by either high levels of exchangeable sodium or by excessive mechanical disturbance of a soil, particularly when wet. When dispersive soils are wet, aggregates of clay, silt and sand breakdown with individual clay particles going into suspension. Such dispersion may occur in sodic soils without any disturbance at all. The dispersed clay particles can be easily moved by water or wind and can migrate through the soil clogging soil pores and reducing infiltration and drainage and causing higher run-off. This may lead to a range of problems including high erosion rates, water pollution, tunnel formation, reduced workability, difficulty with vegetation establishment, and reduced vegetation growth due to low water holding capacity and root penetration (Raine and Loch, 2003).

All soil samples were analysed for exchangeable cation concentrations. This allowed for the calculations of cation exchange capacity (CEC), ESP, and calcium / magnesium ratios. The calcium/magnesium ratio may be used to produce an indication of dispersion potential. Soils that are high in sodium and magnesium tend to show more dispersion than soils that are high in sodium and calcium (Hazelton and Murphy, 2007). The potential for dispersion may be increased in soils with calcium / magnesium rations that are less than 1 to 2.

On select samples, Emerson Aggregate Tests (EAT) were conducted to access aggregate stabilities and dispersion. The Emerson Crumb test categorises soils into seven classes on the basis of their coherence in water, with one further class being distinguished by the presence of calcium-rich minerals. The Emerson Crumb test may only be used as a general guide to sodicity and aggregate stability as there are a large number of factors that determine if slaking or dispersion occurs such as sodicity, salinity, clay type, history of working and speed of wetting (Hazelton and Murphy, 2007).

Soil Fertility

Nutrient availability is one of the major environmental variables affecting competitive balance between plant species and therefore species composition and richness change. Nutrient requirements vary between different plant species, and these may vary quite markedly even in the same community. A general range of some elements within which normal plant growth may be expected is presented in Appendix D. It is important to note that this range of normal plant growth is only a guide and some communities, such as native Australian communities which developed on generally infertile soils, require specific conditions outside this range.

3.2 Soil Assessment Results

3.2.1 Initial Desktop Review Results

Burdekin-Townsville Resource Series (Isbell and Murtha, 1970)

A review of the Burdekin-Townsville Resource Series (Isbell and Murtha, 1970) identified three dominant soil types mapped in the Project area. These soil types are described using the Northcote Factual Key (Northcote, 1979) and are summarised in Table 4. In Australian Soil Classification, CB7 is equivalent to Grey Vertosols, Oa9 and Gb27 are mainly Red or Brown Chromosols or Sodosols.

Table 4 Burdekin – Townsville Resource Series, Soils (1:1,000,000)

Code	Landform	Dominant Soil	Soil Type	General Description	Subsoil
CB7	Moderate to undulating plains with very broad valleys	Ug5.22	Fine cracking, smooth faced peds, grey clay horizon underlain by weathered rock before 1.5m	Grey self-mulching cracking clays. Usually pronounced gilgai.	Ug5.32 Ug5.25 Ug5.16 Ug5.15 Ug5.24 Ug5.37 Dr2.13 Dr2.12 Dy2.13 Db1.13 Db1.33 Dd1.33 Dy2.33 Uf6.3
Oa9	Undulating lands with broad rounded ridge crests & wide shallow valleys. Some rock outcrop on higher ridges	Dr2.13	Duplex red, hard setting A horizon, no A2 horizon, alkaline pedal whole column B horizon	Hard pedal red duplex soils	Dr2.22 Dr2.23 Gn3.12 Db1.12 Db1.13 Ug5.22 Ug5.32 Ug5.14 Dy2.43
Qb27	Gently undulating alluvial flood-plains often with marked terraces levees & shallow drainage depressions	Dr2.22	Duplex red, hard setting A horizon, A2 horizon non-bleached, neutral pedal whole column B horizon	Hard pedal red duplex soils	Dr4.22 Dy2.22 Dy2.33 Dy3.33 Db1.13 Dr2.23 Dy2.43 Dy3.43 Um6.11

Published Land Resource and Soil Survey Reports

A review of the remaining published soil survey literature (listed in Section 3.1.1) identified the following soils in the vicinity of the Project area. These are described using the Australian Soil Classification.

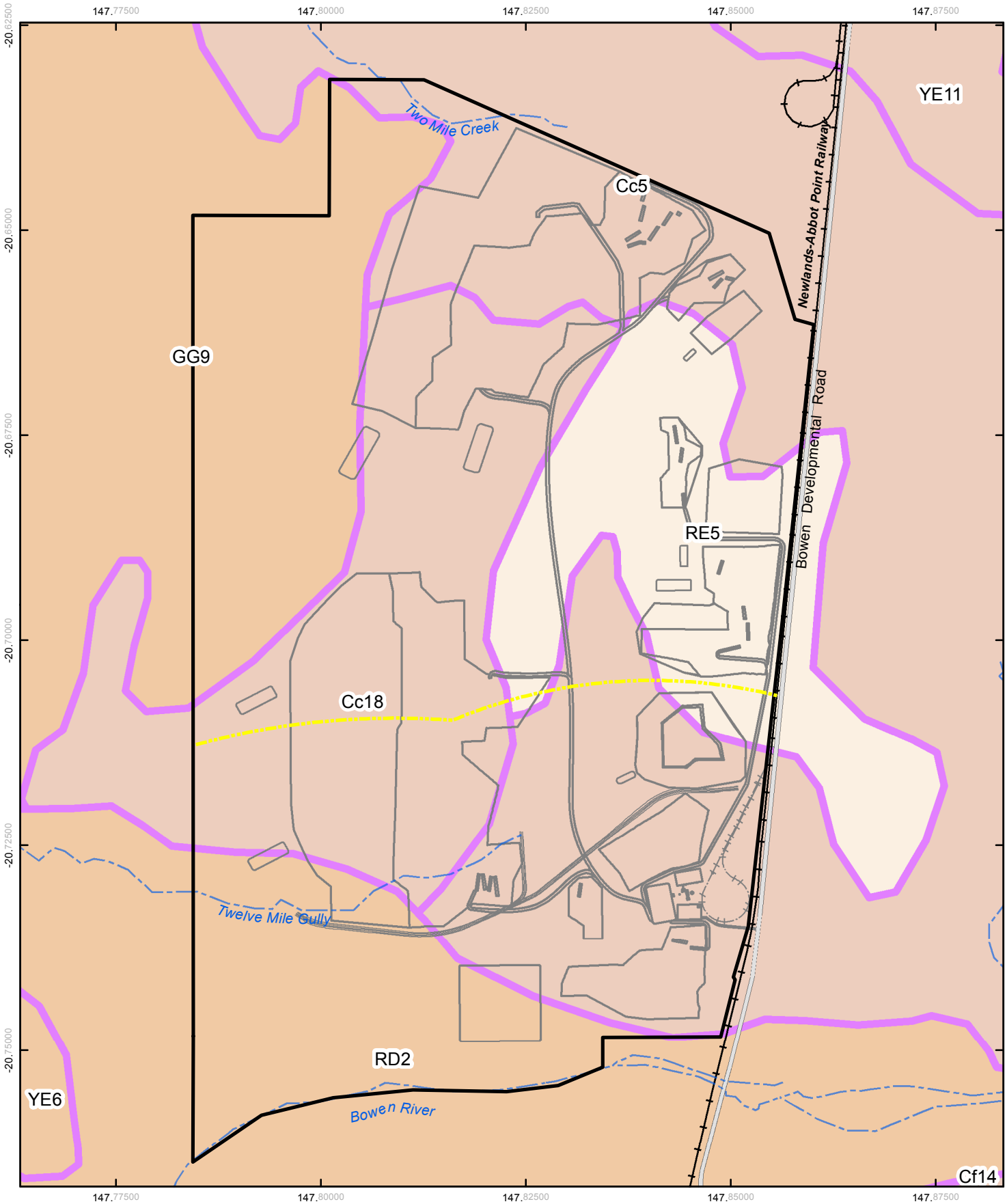
- Vertosols on level to moderately undulating plains and some on strongly undulating rises. This includes lands with Vertosols with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and / or lenticular structural aggregates. The Vertosols in this area are reported to be deep, structured, self-mulching, cracking clay soils that exhibit microrelief of gilgai and melon holes. This soil information corresponds to the CB7 soil identified in the Burdenkin-Townsville Resource Series. The underlying geology consists of sedimentary rocks and associated unconsolidated sediments. The vegetation is either:
  - Mitchell and Queensland bluegrass grasslands containing a high proportion of black speargrass with isolated trees and gidgee, brigalow and blackwood scrub on plains; and
  - Open woodlands dominated by mountain coolibah, gum-topped bloodwood, inland bloodwood and cabbage gum.
- Dermosols on moderately undulating to strongly undulating rises. The soils are structured and have a gradual increase in clay content with depth. In this study area they are shallow to moderately deep overlaying sedimentary rocks. Vegetation is Eucalypt open woodlands with Queensland grey ironbark, mountain coolibah, gum-topped bloodwood and cabbage gum, with Black speargrass pastures grading to Queensland bluegrass pastures; and
- Sodosols on level plains to strongly undulating rises and high hills. Sodosols are soils with a strong texture contrast between A horizons and sodic B horizons which are not strongly acidic. The soils in the area are reported as being yellow and grey duplex soils with sodic subsoils overlying sedimentary rocks and associated unconsolidated sediments. Vegetation is Eucalypt woodlands and open woodlands dominated by Queensland grey ironbark, narrow-leaved ironbark, silver-leaved ironbark, Reid River box, poplar box, poplar gum and other box trees, with black speargrass pastures.

Soil Survey of the Sonoma Project (GSS, 2005)

A detailed soils survey by GSS (2005) on the Sonoma Coal Project located immediately north of the Project area, was completed as part of the Sonoma EIS process. This survey found that grey uniform clays dominated the lease area. These soils are characterised by a self-mulching, grey, medium clay surface horizon grading to a heavier textured grey-brown clay horizon and eventually to brown clay. On the eastern and southern extremities of the Sonoma mining leases, red duplex sandy loam was identified. These duplex soils are characterised by a reddish-brown clay loam near the surface grading to yellow-red, medium clay subsoils. At depth, the medium clay subsoil grades into weathered sandstone.

Geotechnical Investigation Report (Ground Environments, 2010)

Existing soil information for the south-east corner of the site (around the proposed rail loop) and the adjacent land to the east was available from the Geotechnical Investigation Report (Ground Environments Pty Ltd, 2010).



LEGEND

- Major Road
- Existing Railway
- Drainage Feature
- Irrigation within 5km of Bowen River
- Project Area
- Mine Layout
- Soil Code (Burdekin-Townsville Region)

QLD Combined Soils (1:2M scale)

- Dermosols
- Sodosols
- Vertosols

Refer to report for detailed description of Soil Codes for the Burdekin-Townsville Region

Cc5	GG9
RD2	RE5
YE6	YE11

1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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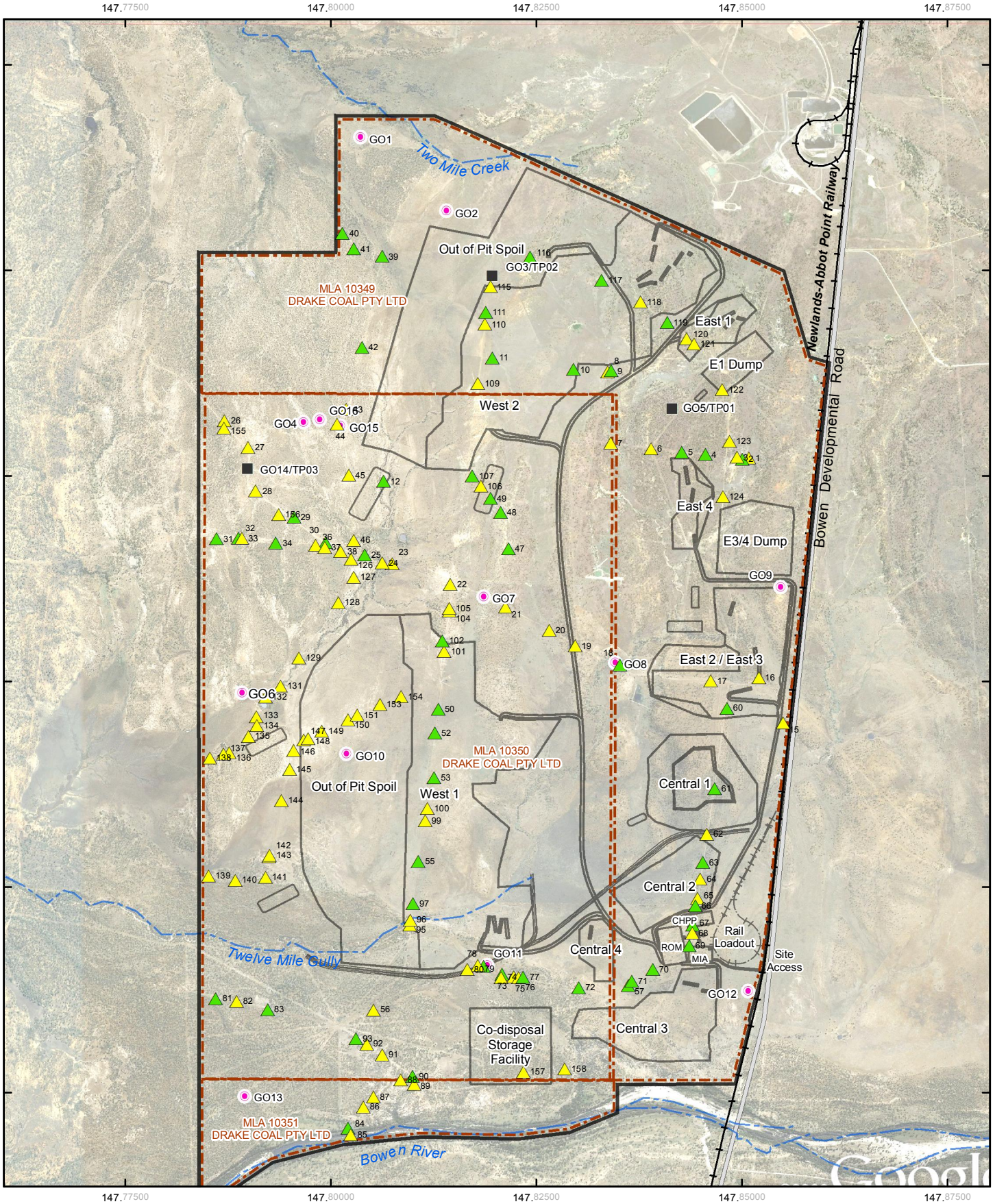
Soil Groups in the Proposed Project Area (DND, 1970)

Figure 7

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Data source: QCOAL: Study Area/2010. GA: 250K Topo Data/2009. QLD Combined Soils. CSIRO/DND - Burdekin Townsville Region Soils. Created by: TH



LEGEND

- Soil Profile
- Ground Observation

Sample Locations (GSS)

- Core Location
- Ground Observation

- Major Road
- Existing Railway
- Drainage Feature

- Project Area
- Mining Lease Application Boundary
- Mine Layout

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1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Soil Sampling and Observation Locations

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Figure 8

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Data source: GHD: Ground Observations/2010; QCOAL: Study Area/2011. GSS: Core Locations (20/01/2012). DERM: Drainage Features (2010); GoogleEarthPro: Image (extracted 01062011). GA: 250K Topo Data/2009.

3.2.2 Overview of the Dominant Soil Orders

The soil survey undertaken on the Project area in November 2009 and November-December 2011 identified five soil orders across the site: Vertosols; Dermosols; Sodosols; Tenosols and Rudosols. A summary of the Land Unit characteristics are provided in Table 5 and an overview of the observation locations for each Land Unit are provided in Table 6. Detailed descriptions of the ground observations and soil profiles are included in Appendix A and Appendix B, respectively. The complete laboratory analysis results and certificates of analysis are included in Appendix C and soil interpretation criteria are presented in Appendix D.

Table 5 Summary of the Land Unit Characteristics

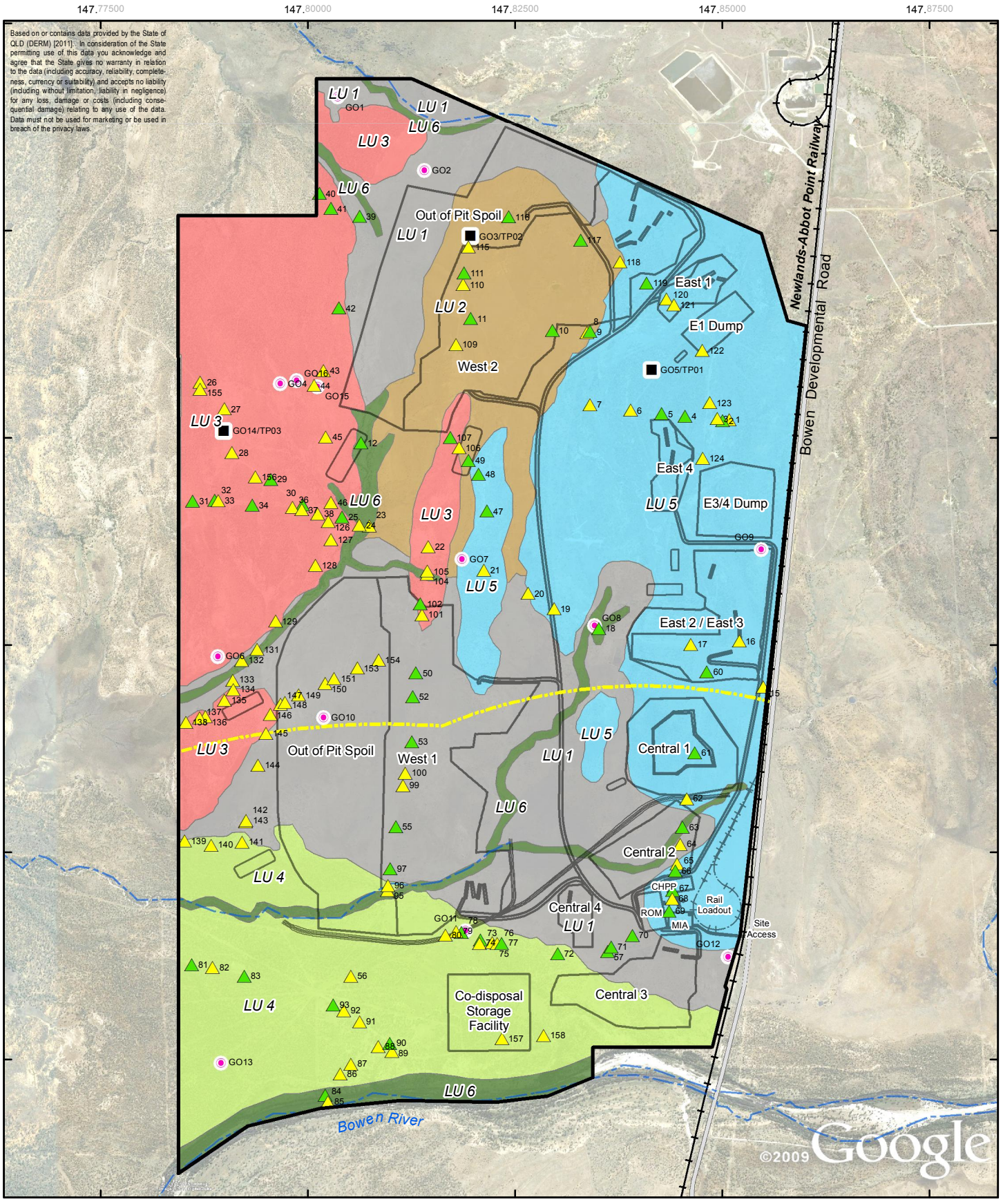
Land Unit	Slope	Dominant Vegetation	Soils
LU1 (2,531 ha)	<3%	Cleared for pasture with grasses remaining (Rhodes and buffel grass)	**Vertosols**: medium clay with high plasticity A horizon to 0.15 mBGS over mottled grey high plasticity clay subsoil to 1.5 mBGS
LU2 (852 ha)	3% to 5%	Cleared for pasture with grasses remaining (Rhodes and buffel grass)	**Vertosols**: medium clay with high plasticity A horizon to 0.15 mBGS over mottled grey high plasticity clay subsoil to weathered rock at approximately 0.7 to 1.0 mBGS
LU3 (1,567 ha)	3% to 10%	Open eucalypt woodland	**Sodosols**: acidic loamy sand A horizon to 0.3 mBGS over a highly sodic sandy clay loam subsoil to between 0.8 and 1.5 mBGS
LU4 (1,487 ha)	<3%	Open acacia woodland (*A. harpophylla*) and Open eucalypt woodland	**Sodosols** and **Rudosols**: slightly acidic sandy or sandy loam topsoil to 0.3 mBGS over a light clay (or sand in the Rudosol) subsoil
LU5 (2,324 ha)	3% to 10%	Open eucalypt woodland (*E. crebra*)	**Dermosols** and **Vertosols**: slightly acidic to slightly alkaline sandy clay and loamy clay A horizons to 0.1 mBGS over a non-sodic medium to heavy clay subsoil
LU6 (435 ha)	<3%	Open eucalypt woodland	**Rudosols** and **Tenosols**: alluvial soils associated with intermittent creek flow deposition or in the immediate vicinity of the Bowen River.

Based on the soil survey and laboratory results, areas with common landform, vegetation communities, geology and soils were grouped into Land Units. The 9,196 ha study area was divided into six separate Land Units that are described above and presented in Figure 9.

Table 6 Summary of the Observation Locations per Land Unit

Land Unit	Ground Observation Locations (G#)	Soil Profile Description Locations (G#)
LU1	GO1, GO2, GO8, GO10, GO12, 20, 64a, 64b, 99, 100, 133, 142a, 142b, 143, 144,145, 147, 148, 149, 150, 151, 153, 154	39(C15), 50(C22), 52(C23), 53(C24), 55(C25), 57(C27), 70(C33), 71(C34), 97(44)
LU2	GO3, 8, 106, 109, 110, 115, 118	TP02, 10(C5), 11(C6), 49(C21), 111(C47), 116(C48), 117(C49)
LU3	GO4, GO6, GO14, GO15, GO16, 22, 26, 27, 28, 32a, 32b, 33, 36, 37, 38, 43, 44a, 44b, 45, 46, 101, 105, 126, 127, 128, 129, 134a, 134b, 135a, 135b, 136, 137, 138, 146, 155, 156	TP03, 25(C9), 29(C10), 30(CC), 31(C12), 32(C13), 34(C14), 40(C16), 41(C17), 42(C18), 102(C45), 107(C46)
LU4	GO11, GO13, 56, 74, 75, 76, 79, 80, 82, 86, 87, 88, 89, 91, 92, 95a, 95b, 96, 139, 140, 141, 157, 158	72(C35), 73(C36), 77(C37), 78(C38), 81(C39), 83(C40), 90(C42), 93(C43)
LU5	GO5, GO7, GO9, 1a, 1b, 1c, 3, 6, 7, 9a, 9b, 15, 16, 17, 19, 21, 60a, 60b, 62, 65, 68, 120, 121, 122, 123, 124	TP01, 2(C1), 4(C2), 5(C3), 9(C4), 47(C19), 48(C20), 60(C28), 61(C29), 66(C30), 67(C31), 69(C32), 119(C50)
LU6	23, 24, 85, 104, 131, 132, 157, 158	12(C7), 18(C8), 63(C26), 84(C41)
Sub Total	123	53
Total	**176**	

Ground Observation Locations – no soil core extracted.
Soil Profile Description Locations – the core identification number is location in the bracket. All November-December 2011 locations were numbered numerically therefore an observation location may coincide with a core e.g. 25(C9) this being the 25th sample location/observation point, and the 9th soil core.



LEGEND

GHD Surveys
- Ground Observation
- Soil Profile

Sample Locations (GSS)
- Core Location
- Ground Observation

- Irrigation within 5km of Bowen River
- Drainage Feature
- Major Road
- Existing Railway
- Project Area
- Mine Layout

Land Unit, Dominant Soil
- LU 1, Vertosols on low lying areas
- LU 2, Vertosols on undulating terrain
- LU 3, Sodosols on undulating terrain
- LU 4, Sodosols on flood plain
- LU 5, Dermosols and Vertosols on undulating terrain
- LU 6, Tenosols & Rudosols on intermittent or permanent watercourses

1:70,000 (at A4)
0 0.5 1 1.5 2 2.5
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Land Units and Dominant Soils

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Figure 9

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Data source: GHD: Ground Observations/2010, Land Units/2009. GSS DERM: Drainage/2010. QCOAL: Study Area/2011. GSS: Core Locations (2012). GoogleEarthPro: Image (extracted 01062011). GA: 250K Topo Data/2009. Created by: TH

3.2.3 Land Unit 1: Vertosols on Low Lying Areas

These areas have the very distinctive cracking clays (Vertosols). The local relief of this Land Unit is relatively gentle, lying between 130 and 150 m AHD, with level to gently inclined slopes less than 3%. The vegetation type is predominantly grasslands consisting of rhodes and buffel grasses with brigalow (*Acacia harpophylla*), whitewood (*Atalaya hemiglauca*), bauhinia (*Lysiphyllum carronii*) and bloodwoods also present.

Soil Overview

These soils have shrink swell properties and exhibit strong cracking when dry and gilgai formations were observed in some areas (for example, G143 and G144). At depth, slickensides and/or lenticular structural aggregates are present. The soils have a neutral to moderately alkaline pH at the surface and become moderately to strongly alkaline with depth. These pH units are not expected to limit plant growth. The soil chemistry summary for profiles described within this Land Unit is provided in Table 7 and Table 8. Photographs of the land unit are provided in Plates 1 and 2. Ground observations and test pits described within this land unit are summarised in Table 6.

Soil Salinity

The salinity is low in the A1 horizon (0 to 0.15 mBGS) and the B21 horizon (0.15 to 0.3 mBGS). However, the salinity increases throughout the B horizon, although it is highly variable between samples. The highest salinity at 1.1 to 1.5 mBGS ranges from medium to very high level (0.48 to 1.53 dS/m). Some of the soils in LU1 will only be suitable for very high salinity tolerant crops

Soil Stability

The soils are sodic at depths below approximately 0.3 mBGS. They are susceptible to slaking and may disperse after being worked when wet and become extremely susceptible to erosion. The main evidence of erosion was noted adjacent to drainage lines; however this was observed to be either 'partially stabilised' or 'stabilised'.

Fertility

Analytical results indicated that surface soil nitrate is low to medium. Phosphorus concentrations were low to very high. Some soils in LU1 may be limiting for crop or improved pasture growth, but are in the range suitable for native species growth. Soil aluminium is the dominant cation accounting for about 50% of the CEC. It is approaching the limit of 60% aluminium saturation which can be toxic to plants. These soils have a relatively high CEC and calcium dominates the Ca:Mg ratio, thus mitigating some of the potentially dispersive ESP. They also have a high water storage capacity and will readily support the germination and growth of native grasses and trees.

Distribution

This Land Unit is located on the central portion of the Project area and covers approximately 28% (2,531 ha) of the site. Proposed development associated with the Project that is likely to be located on this Land Unit is the majority of "West 1" and associated out of pit spoil, a portion of "West 2" and associated out of pit spoil, "Central 2", a portion of "Central 3", "Central 4" and the north-south haul road.

Management

The soil that is recommended for stripping from this land unit is located in horizon A1 (0 – 0.15m), if required for post mining rehabilitation activities. If the rehabilitation plan involves the planting of improved pasture, the soil will need to be amended with fertiliser.

Additional soil from the subsoil (i.e. the upper B21 horizon 0.15 –0.3 mBGS) may also be stripped if required, due to the low salinity and non-sodic properties of this layer. However, the subsoil is considered to be 'marginal' due to the absence of seed stores, reduced nutrient supply and low organic matter content. Therefore, it should only be used in place of topsoil if no other options are available. It will require additional amendment prior to use.





Plate 1 Vertosols on Low Lying Areas





Plate 2 Shrink Swell Properties of Vertosols

Table 7 LU1 Soil Analytical Results Summary

Horizon	Approximate Depth (m)	pH	pH Rating	EC (dS/m)	Texture	Clay Content	Salinity Rating	ESP Ratio (%)	CEC (meq%)	Ca/Mg Ratio
A1	0 – 0.15	7.4 – 8.5	Mildly to moderately alkaine	0.88 – 0.22	Medium clay	45 – 55	Low	0.4 – 1.8	36.7 – 65.4	3.0 – 7.3
B21	0.15 - 0.30	8.5 – 8.9	Strongly alkaline	0.15 – 0.19	Heavy clay	49 - 58	Low	1.4 – 13.5	37.2 – 68.2	5.0 – 5.8
B21	0.30 – 0.70	8.5 – 9.2	Strong to very strongly alkaline	0.16 – 0.47	Heavy clay	45 – 55	Low – Medium	2.2 – 13.5	38.4 – 69.3	2.2 – 5.2
B22	0.70 – 1.10	8.8 – 9.1	Strongly to very strongly alkaine	0.48 – 1.38	Heavy clay	48 - 65	Medium – Very high	2.2 – 22.3	41.3 – 69.5	1.9 – 5.7
B23	1.10 – 1.50	8.0 – 8.9	Strongly alkaline	0.48 – 1.53	Heavy clay	46 - 58	Medium - Extreme	29.2	34.3	1.6

Table 8 Surface Soil (0 - 0.10 mBGS) Fertility for LU1

Analyte	Soil Concentration	Range Below Which Plant Deficiencies Have Been Recorded*	Range Above Which Plant Toxicities Have Been Recorded*
Organic Matter	1.9 – 4.0%	-	-
Nitrate (Total Nitrogen)	8.5 mg kg^{-1} (0.07 – 0.22%)	20-60 mg kg^{-1}	-
Phosphorus	8.0 – 52.0 mg kg^{-1}	10 - 30 mg kg^{-1}	-
Potassium	0.2 – 0.6meq $100g^{-1}$	0.3 – 0.5 meq $100g^{-1}$	-
Magnesium	7.88 meq $100g^{-1}$	0.1 – 0.3 meq $100g^{-1}$	-
Calcium	27.66 meq $100g^{-1}$	0.5 – 1.4 meq $100g^{-1}$	-
Aluminium	25.0 mg kg^{-1}	-	> 3 mg kg^{-1}
Sulfate	3.4 - 11.0 mg kg^{-1}	-	-
Boron	0.73 – 1.1 mg kg^{-1}	-	-
Copper	0.56 – 1.7 mg kg^{-1}	-	-
Iron	11 – 26 mg kg^{-1}	-	-
Manganese	3.4 – 17 mg kg^{-1}	-	-
Zinc	0.14 – 0.69 mg kg^{-1}	-	-
Chloride	22 mg kg^{-1}	-	200 – 600 mg kg^{-1} ǂ

Notes: * refers to concentrations necessary for satisfactory vegetative growth. References are provided in Appendix D
ǂ indicates that at concentrations above this range, plant growth can be retarded.

3.2.4 Land Unit 2: Vertosols on Undulating Terrain

These Vertosol areas occur on gently to moderately inclined slopes between 3% and 10%, with elevations between 160 m and 200 m AHD. The vegetation cover is largely grasslands consisting of rhodes and buffel grasses with brigalow (*Acacia harpophylla*) and Mountain Coolibah (*Eucalyptus orgadophila*) communities present.

Soil Overview

These soils have shrink swell properties and exhibit strong cracking when dry and gilgai formations were observed in some areas (for example, G9 and G10). At depth, slickensides and/or lenticular structural aggregates are present. The A1 horizon is typically of medium clay with high plasticity to 0.15 mBGS over high plasticity clay subsoil. Weathered rock was generally encountered in these profiles at depths of between 0.7 m and 1.0 mBGS. The soils have a neutral to moderately alkaline pH at the surface and become strongly alkaline with depth. The pH is not expected to limit plant growth. The soil chemistry summary for profiles described within this land unit is provided in Table 9 and Table 10. Photographs of this land unit are shown in Plates 3 and 4. Ground observations and test pits described within this land unit are summarised in Table 6.

Soil Salinity

The salinity is low in the A1 horizon (0 to 0.15 mBGS). The B21 and B22 horizons (0.15 to 0.6 mBGS). However, the salinity increases from medium to high below the B22 horizon. Root development is expected to be limited with increasing depth due to salinity, sodicity, and the presence of weathered rock. This was supported by field observations where roots were not recorded below depths of between 0.6 m and 1.1 mBGS.

Soil Stability

Field observations indicated minor water erosion on this land unit. The main evidence of sheet erosion was observed where soil was removed from around the bases of the tussocking grasses. However, erosion activity is currently stabilised.The subsoils are sodic at depths below approximately 0.**6** mBGS and are therefore susceptible to slaking and may disperse after being worked when wet. They have a low erodibility rating when left insitu.

Fertility

Analytical results indicated that surface soil nitrate and phosphorus concentrations were low and may be limiting for crop or improved pasture growth, but are in the range suitable for native species growth. However, the low fertility can be readily ameliorated with appropriate fertilisers. These soils have a relatively high CEC and calcium dominates the Ca:Mg ratio, thus mitigating some of the potentially dispersive ESP. These soils also have a high water storage capacity and will readily support the germination and growth of native grasses and trees.

Distribution

LU2 is located in the central northern portion of the site and covers approximately 9% (852 ha) of the Project area. The proposed Project infrastructure that coincides with this land unit is mainly “West 2”.

Management

The soil is recommended for stripping to recover the surface A1 horizon (0 – 0.15 mBGS) if required for post mining rehabilitation activities. If the rehabilitation plan involves the planting of improved pasture, the soil will need to be amended with fertiliser.

Additional soil from the subsoil (i.e. the B21 and B22 horizons 0.15 –0.6 mBGS) may also be stripped if required, due to the low salinity and non-sodic properties of this layer. However, the subsoil is considered to be 'marginal' due to the absence of seed stores, reduced nutrient supply and low organic matter content. Therefore, it should only be used in place of topsoil if no other options are available. It will require additional amendment prior to use.



Plate 3 Vertosols on Undulating Terrain

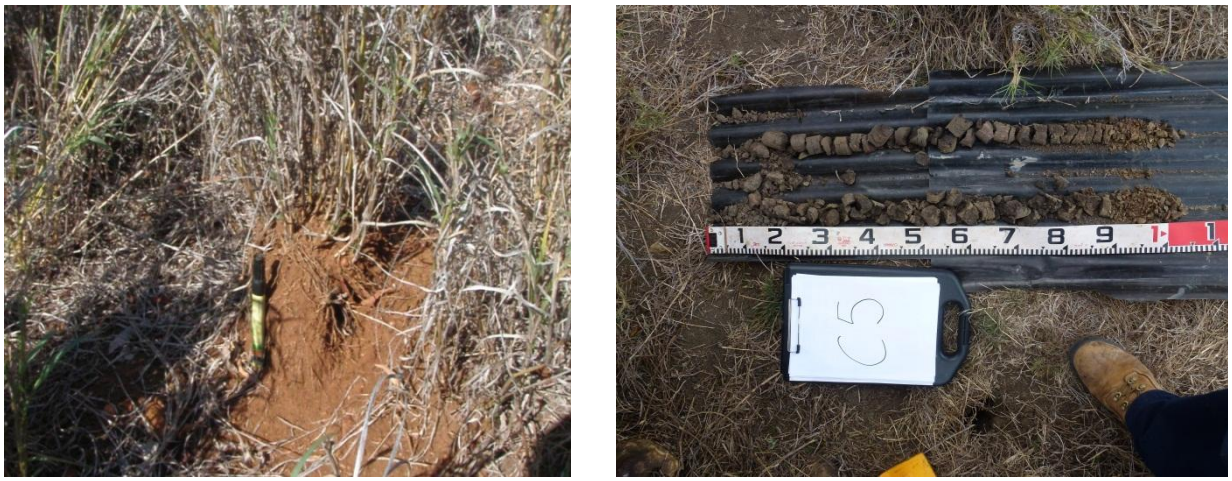


Plate 4 Roots Commonly Observed with Vertosols

Table 9 LU2 Soil Analytical Results Summary

Horizon	Approximate Depth (m)	pH	pH Rating	EC (dS/m)	Texture	Clay Content	Salinity Rating	ESP Ratio (%)	CEC (meq %)	Ca/Mg Ratio
A1	0 - 0.15	7.6 – 8.3	Mildly to moderately alkaline	0.10 – 0.19	Medium - heavy clay	40 – 50	Low	0.2 – 1.6	32.1 – 49.0	2.1 – 6.2
B21	0.15 - 0.35	8.4 – 8.7	Moderate to strongly alkaline	0.13 – 0.23	Heavy clay	49 – 60	Low	0.7 – 3.8	33.9 – 69.5	1.7 – 7.3
B22	0.35 – 0.60	8.7 – 9.1	Strongly to very strongly alkaline	0.10 – 0.26	Heavy clay	46 – 59	Low	1.8 – 6.8	41.3 – 61.7	1.9 – 5.1
B23	0.60 – 0.80	8.7 – 9.1	Strongly to very strongly alkaline	0.22 – 0.45	Heavy clay	58 – 60	Medium	7.2 – 11.7	41.3 – 57.9	2.6 – 4.2
B24	0.80 - 1.30	9.1	Very strongly alkaline	0.60	Medium clay	40	High	16.7	36.5	2.3

Table 10 Surface Soil (0 - 0.10 mBGS) Fertility for LU2

Analyte	Soil Concentration	Range Below Which Plant Deficiencies Have Been Recorded*	Range Above Which Plant Toxicities Have Been Recorded*
Organic Matter	1.9 – 4.8%	-	-
Total Nitrogen	0.13 – 0.29%		-
Phosphorus	6 – 39 mg kg^{-1}	10 - 30 mg kg^{-1}	-
Potassium	0.12 – 0.8 meq $100g^{-1}$	0.3 – 0.5 meq $100g^{-1}$	-
Magnesium	6.6 meq $100g^{-1}$	0.1 – 0.3 meq $100g^{-1}$	-
Calcium	41 meq $100g^{-1}$	0.5 – 1.4 meq $100g^{-1}$	-
Sulfate	3.6 – 8.3 mg kg^{-1}	-	-
Boron	0.68 – 1.3 mg kg^{-1}	-	-
Copper	0.96 – 1.8 mg kg^{-1}	-	-
Iron	17 – 30 mg kg^{-1}	-	-
Manganese	4.9 – 14 mg kg^{-1}	-	-
Zinc	0.28 – 0.9 mg kg^{-1}	-	-
Chloride	<10 – 550 mg kg^{-1}	-	200 – 600 mg kg^{-1} ǂ

Notes: * refers to concentrations necessary for satisfactory vegetative growth. References are provided in Appendix D
ǂ indicates that at concentrations above this range, plant growth can be retarded.

3.2.5 Land Unit 3: Sodosols on Undulating Low Hills

This land unit is present on elevated areas along the western portion of the site and the dominant soil order is Sodosols. The topography ranges between 140 and 180 m AHD, with gentle to moderately inclined slopes of 3% to 10%. Grazing and tree clearing is expected to have contributed greatly to accelerated erosion. The dominant vegetation cover is open eucalypt woodland with whitewood (*Atalaya hemiglauca*), bauhinia (*Lysiphyllum carronii*), cassia, box and brigalow (*Acacia harpophylla*) present.

Soil Overview

These Sodosols have a strong texture contrast between the loamy sand or sandy loam A horizon and the sodic sandy clay or medium clay B horizon. The A horizon is strongly acidic and increasingly alkaline, saline and sodic with depth. This strong sodicidity is likely to cause limitations to plant growth. The reduced number of roots observed below 0.3 to 0.8 mBGS in the test pits and soil cores confirmed that root growth is restricted in the subsoil. The soil chemistry summary for profiles described within this land unit is provided in Table 11 and Table 12. Photographs of this land unit are shown in Plates 5 and Plates 6. Ground observations and test pits described within this land unit are summarised in Table 6.

Soil Salinity

Salinity was low in the A horizon, but increased to high concentrations in the B horizon. Salinity is one of the limitations expected to impact plant growth in this soil.

Soil Stability

The subsoil is strongly sodic and dispersive. Both the topsoil and subsoil are highly erodible if disturbed or if the vegetation is removed. Field observations and analytical results indicate these subsoils are highly prone to erosion. This erosivity is evident by the common occurrence of tunnel, scalding, sheet, rill and gully erosion that was observed and in some places up to 2 m deep (for example at sites G29 and G32).

Fertility

Analytical results indicated that surface soil nitrate and phosphorus concentrations were low and may be limiting for plant growth. The topsoils and the subsoils have a relatively low CEC, high ESP and low water storage capacity, thus they do not readily support the germination of native grasses and trees if the subsoils are exposed.

Distribution

This land unit covers approximately 17% (1,567 ha) of the Project area. The Project footprint impacts a small portion of this land type, with both “West 1” and “West 2” pits and dumps located on LU3.

Management

The topsoil is not recommended for stripping for use in rehabilitation works.



Plate 5 Sodosols on Undulating Low Hills

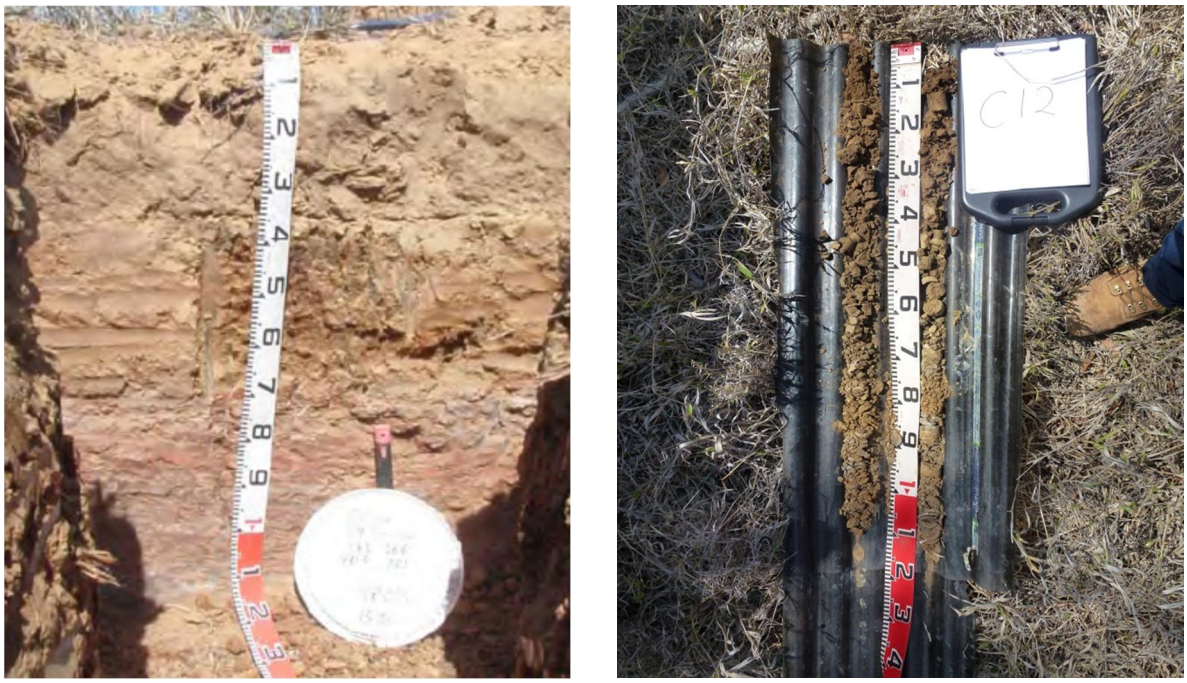


Plate 6 Subsoils are Highly Prone to Erosion if Vegetation is Removed.

Table 11 LU3 Soil Analytical Results Summary

Horizon	Approximate Depth (m)	pH	pH Rating	EC (dS/m)	Texture	Clay Content (%)	Salinity Rating	ESP Ratio (%)	CEC (meq%)	Ca/Mg Ratio
A1	0 – 0.10	5.5 – 7.5	Strongly acidic to mildly alkaline	0.03 – 0.15	Loamy sand	5 - 10	Low	1.1 – 8.1	2.5 – 9.3	1.0 – 3.1
A2	0.10 - 0.30	5.7 – 8.5	Strongly acidic to strongly alkaline	0.30 – 0.46	Loamy sand to sandy loam	10	High	0.80 – 25	5.9 – 16.5	1.1 – 6.7
B21	0.30 – 0.50	6.5 – 9.0	Slightly acidic to very strongly alkaline	0.03 – 0.85	Sandy clay to medium clay	24 - 49	High	9.5 – 38.5	10.2 – 19.2	0.7 -1.1
B22	0.50 - 0.80	8.4 – 9.6	Moderate to very strongly alkaline	0.10 – 0.78	Sandy clay to medium clay	20 - 40	High	15.0 – 53.0	4.0 – 26.5	0.4 – 1.6
BC	0.80 – 1.50	9.0	Very Strongly alkaline	0.08	Loamy sand	6	Low	0.5	26.2	27

Table 12 Surface Soil (0 - 0.10 mBGS) Fertility for LU3

Analyte	Soil Concentration	Range Below Which Plant Deficiencies Have Been Recorded*	Range above which plant toxicities have been recorded*
Organic Matter	0.5 – 2.4%	-	-
Nitrate (Total Nitrogen)	< 1.0 mg kg^{-1} (<0.04 – 0.14%)	20-60 mg kg^{-1}	-
Phosphorus	<5 – 8 mg kg^{-1}	10 - 30 mg kg^{-1}	-
Potassium	0.17 – 0.29meq $100g^{-1}$	0.3 – 0.5 meq $100g^{-1}$	-
Magnesium	2.1 meq $100g^{-1}$	0.1 – 0.3 meq $100g^{-1}$	-
Calcium	6.5 meq $100g^{-1}$	0.5 – 1.4 meq $100g^{-1}$	-
Aluminium	28 mg kg^{-1}	-	> 3 mg kg^{-1}
Sulfate	2.2 – 11 mg kg^{-1}	-	-
Boron	0.14 – 0.4mg kg^{-1}	-	-
Copper	0.17 – 0.82 mg kg^{-1}	-	-
Iron	13 – 210 mg kg^{-1}	-	-
Manganese	4.7 – 35 mg kg^{-1}	-	-
Zinc	0.24 – 2.9 mg kg^{-1}	-	-
Chloride	13.0 mg kg^{-1}	-	200 – 600 mg kg^{-1} ǂ

Notes: * refers to concentrations necessary for satisfactory vegetative growth. References are provided in Appendix D
ǂ indicates that at concentrations above this range, plant growth can be retarded.

3.2.6 Land Unit 4: Sodosols on Flood Plain with Minor Rudosols

This land unit occurs at the southern portion of the site in the low lying flood plain beside the Bowen River. The elevations range between 110 and 130 m AHD, with level to gently inclined slopes of <3%. The dominant soils are Sodosols with minor Rudosols. The dominant vegetation cover is acacia open woodland, including areas of brigalow (*Acacia harpophylla*) and open eucalypt woodlands, of *Eucalyptus platyphylla*, Ironbarks, Bloodwoods and Moreton Bay Ash.

Soil Overview

Sodosols have a strong texture contrast between the A horizon and sodic B horizon. The A horizon is mildly acidic to a depth of approximately 0.35 mBGS. Field observations indicate these soils have a hard setting surface when dry. The soils become increasingly alkaline, saline and sodic with depth, although they are generally not as sodic or as saline in the subsoil as LU3. Field observations supported this, as roots were observed at greater depths (0.7 – 1.5 mBGS) than in LU3. The soil chemistry summary for profiles described within this land unit are provided in Table 13 and Table 14. Photos of the land unit are shown in Plate 7 and Plate 8. Ground observations and test pits described within this land unit are summarised in Table 6.

Soil Salinity

Salinity is generally low but highly variable between soil profiles and is not expected to be a major limitation to plant growth.

Soil Stability

Whilst the subsoils of the Sodosols are highly prone to erosion, there was little occurrence of severe erosion identified during field activities for much of this land unit. This is probably due to the well maintained surface cover and gentle grades preventing exposure of the sodic subsoils. However, in some areas of the land unit, severe gully erosion was noted (for example, in the vicinity of sites G86 to G89 and G95). The soil surface was also noted to be hard setting and once disturbed, soil stability is likely to be low and these soils will need to be managed.

Fertility

Based on the analytical results, nitrate is expected to be a limitation to plant growth. These soils have a moderate to high level of phosphorus. The topsoil characteristics were a low ESP (favourable for plant growth), relatively low water holding capacity and low CEC. The topsoils might be limiting for crop or improved pasture growth, but are in the range suitable for native species growth. The subsoils have a relatively low CEC, high ESP and low water storage capacity, thus do not readily support the germination of native grasses and trees if the subsoils are exposed.

Distribution

This land unit covers approximately 16% (1,487 ha) of the study area. There is some disturbance of this land type by proposed infrastructure, with the development of “West 1” and associated out of pit spoil, the co-disposal storage facility and also “Central 3” on the south-eastern portion of the land unit.

Management

The topsoil is not recommended for stripping for later use in rehabilitation works.



Plate 7 Sodosols on Flood Plains (GO13 and G38)



Plate 8 Ground Observation Location GO-13 and G89

Table 13 LU4 Soil Analytical Results Summary

Horizon	Approx Depth1 (m)	pH	pH Rating	EC (dS/m)	Texture	Clay Content (%)	Salinity Rating	ESP Ratio (%)	CEC (meq%)	Ca/Mg Ratio
A1	0 - 0.15	5.8 – 7.1	Moderately acidic to neutral	0.03 – 0.15	Loam to sandy loam	5	Low	0.3 – 0.3	3.6 – 6.1	2.3 – 2.5
A2	0.15 - 0.35	6.6 – 6.9	Neutral	0.01 – 0.02	Loam to sandy clay loam	3 – 26	Very Low	0.6 – 1.0	2.97 – 6.17	2.0 – 3.5
B21	0.35 – 0.55	7.1 – 8.7	Neutral to strongly alkaline	0.02 – 0.67	Sandy clay to medium clay	23 – 53	Low to High	0.8 – 18.7	2.4 – 22.8	1.2 – 2.9
B22	0.55 – 0.80	6.8 – 9.0	Neutral to strongly alkaline	0.01 – 0.82	Sandy clay to moderate clay	20 – 55	Low to High	1.5 – 17.9	8.4 – 23.2	1.1 – 3.1
B23	0.80 - 1.50	7.6 – 9.6	Mildly to very strongly alkaline	0.02 – 0.28	Medium clay to sandy clay loam	11 – 23	Medium	4.1 – 15.7	7.8 – 14.5	1.2 – 2.7

Table 14 Surface Soil (0 - 0.10 mBGS) Fertility for LU4

Analyte	Soil Concentration	Range below which plant deficiencies have been recorded*	Range above which plant toxicities have been recorded*
Organic Matter	0.8 – 2.1%	-	-
Total Nitrogen	<0.04 – 0.09%		-
Phosphorus	12 - 40 mg kg^{-1}	10 - 30 mg kg^{-1}	-
Potassium	0.19 – 0.58 meq $100g^{-1}$	0.3 – 0.5 meq $100g^{-1}$	-
Magnesium	1.6 meq $100g^{-1}$	0.1 – 0.3 meq $100g^{-1}$	-
Calcium	4.0 meq $100g^{-1}$	0.5 – 1.4 meq $100g^{-1}$	-
Sulfate	1.1 – 3.8 mg kg^{-1}	-	-
Boron	0.06 – 0.33mg kg^{-1}	-	-
Copper	0.14 – 1.3 mg kg^{-1}	-	-
Iron	23 – 100 mg kg^{-1}	-	-
Manganese	15 - 61mg kg^{-1}	-	-
Zinc	0.32 – 0.95 mg kg^{-1}	-	-
Chloride	< 10 – 610 mg kg^{-1}		

Notes: * refers to concentrations necessary for satisfactory vegetative growth. References are provided in Appendix D
ǂ indicates that at concentrations above this range, plant growth can be retarded.

3.2.7 Land Unit 5: Dermosols and Vertosols on Undulating Terrain

LU5 occurs on the higher ground along the eastern portion of the site and is located at elevations between 150 and 200 m AHD. It mostly contains level to gently inclined slopes less than 3% although steeper slopes and rounded crests are also present. The dominant soil orders are Dermosols, with Vertosols occurring secondarily in north-south bands. The dominant vegetation cover is open eucalypt woodland dominated by narrow-leaved ironbark (*Eucalyptus crebra*) with groundcover greater than 90%.

Soil Overview

These soils have slightly acidic to alkaline sandy clay loam or clay loam in the A horizon (0 to 0.15 mBGS) and alkaline sandy clay to medium clay in the upper B horizon (0.15 to 0.30 mBGS). The soil becomes more alkaline with depth until reaching the weathered sandstone (C horizon) at 0.70 to 1.0 mBGS. The soil pH levels are not expected to be limiting to plant growth. The soil chemistry summary for profiles described within this land unit is provided in Table 15 and Table 16. Photographs of the land unit and soil profile morphology are shown in Plates 9 and 10. Ground observations and test pits described within this land unit are summarised in Table 6.

Soil Salinity

The salinity is low throughout the A horizon and increased to medium to high salinity in the B horizon. Root development is expected to be limited with increasing depth due to salinity and sodicity. However, the shallow weathered rock which results in a reduced water storage capacity is likely to be a greater limitation to plant growth. This was supported by field observations where roots were not recorded below depths of approximately 0.6 mBGS.

Soil Stability

The analytical results indicate that these are mainly non-sodic soils that are considered to have low erodibility ratings. This was supported by the field observations, where the occurrence of erosion was noted as being minor, with sheet erosion the primary form.

Fertility

Analytical results indicated that topsoil nitrate and phosphorus concentrations were low and may be limiting for crop or improved pasture growth, but are in the range suitable for native species growth. These soils have a relatively high CEC and calcium dominates the Ca:Mg ratio, thus mitigating some of the potentially dispersive ESP at depth. These soils also have a moderate water storage capacity and will readily germinate and support native grasses and trees.

Distribution

This land unit covers approximately 25% (2,324 ha) on the eastern portion of the site. Proposed Project development located on this land unit are “Central 1”, “East 1”, “East 2”, “MIA”, part of “ West 1”, “East 3”, “East 4”, and the associated out of pit spoils.

Management

The soil is recommended for stripping to recover the surface A1 horizon (0 – 0.15 m), if it is required for post mining rehabilitation activities. If the rehabilitation plan involves the planting of improved pasture, the soil will need to be amended with fertiliser.

Additional soil from the subsoil (i.e. the B1 horizon 0.15 –0.30 mBGS) may also be stripped if required, due to the low salinity and non-sodic properties of this layer. However, the subsoil is considered to be 'marginal' due to the absence of seed stores, reduced nutrient supply and low organic matter content. Therefore, it should only be used in place of topsoil if no other options are available. It will require additional amendment prior to use.



Plate 9 **Dermosols and Vertosols on Undulating Terrain**



Plate 10 **Ground Observation GO5 / TP1**

Table 15 **LU 5 Soil Analytical Results Summary**

Horizon	Approximate Depth[1] (m)	pH	pH Rating	EC (dS/m)	Texture	Clay Content (%)	Salinity Rating	ESP Ratio (%)	CEC (meq%)	Ca/Mg Ratio
A1	0 – 0.15	6.5 – 8.4	Slightly acidic to moderately alkaline	0.06 – 0.21	Sandy clay to clay loam	20 – 30	Low	0.2 – 3.5	14.8 – 48.6	2.4 – 7.6
B1	0.15 – 0.30	7.1 – 8.6	Neutral to strongly alkaline	0.04 – 0.15	Sandy clay loam to medium clay	30 - 55	Low	0.2 – 1.2	30.1 – 45.6	2.1 - 52
B2	0.30 – 0.70	7.6 – 9.2	Mildly to very strong alkaline	0.04 – 0.86	Medium to heavy clay	13 - 46	Low to high	0.3 – 13.1	12.4 – 54.3	2.7 - 62
B22 or BC	0.70 - 1.0	8.8 – 9.2	Strongly to very strongly alkaline	0.11 – 1.5	Medium to heavy clay or weather sandstone	11 - 50	Medium to very high	13.3 – 18.4	38.5 – 50.2	2.7 – 54.3

Table 16 Surface Soil (0 - 0.10 mBGS) Fertility for LU5

Analyte	Soil Concentration	Range below which plant deficiencies have been recorded*	Range above which plant toxicities have been recorded*
Organic Matter	0.9 - 3.8%	-	-
Nitrate (Total Nitrogen)	1.7 mg kg^{-1} (0.08 – 0.21%)	20 – 60 mg kg^{-1}	-
Phosphorus	<5.0 -71.0 mg kg^{-1}	10 – 30 mg kg^{-1}	-
Potassium	0.13 – 0.59 meq $100g^{-1}$	0.3 – 0.5 meq $100g^{-1}$	-
Magnesium	8.52 meq $100g^{-1}$	0.1 – 0.3 meq $100g^{-1}$	-
Calcium	21.60 meq $100g^{-1}$	0.5 – 1.4 meq $100g^{-1}$	-
Aluminium	26.0 mg kg^{-1}	-	> 3 mg kg^{-1}
Sulfate	1.3 – 7.5 mg kg^{-1}	-	-
Boron	0.31 – 1.5 mg kg^{-1}	-	-
Copper	0.17 – 1.7 mg kg^{-1}	-	-
Iron	3.9 – 57 mg kg^{-1}	-	-
Manganese	1.8 - 60mg kg^{-1}	-	-
Zinc	0.13 – 1.4 mg kg^{-1}	-	-
Chloride	17.0 mg kg^{-1}	-	200 – 600 mg kg^{-1} ǂ

Notes: * refers to concentrations necessary for satisfactory vegetative growth. References are provided in Appendix D
ǂ indicates that at concentrations above this range, plant growth can be retarded.

3.2.8 Land Unit 6: Tenosols and Rudosols Adjacent to Intermittent or Permanent Watercourses

This land unit is located in small bands in the vicinity of intermittent or permanent water courses with marked terraces, levees and shallow drainage depressions. It mostly contains level to gently inclined slopes less than 3%. These soils formed due to alluvial processes and the dominant soil orders are Tenosols and Rudosols.

Soil Overview

These soils have neutral to slightly alkaline sandy loam or clayey loam in the A horizon (0 to 0.6 mBGS). The apedal B horizon extended to 1.5 mBGS as coarse sands or loamy sands. In the case of G12, the underlying soil is buried Vertosol, overlain by alluvial material deposited during intermittent creek flow. As a result of deposition and soil development, this land unit is present in thin bands across the Project site. The summary of the chemical analysis is provided in Table 17. Photographs of the land unit and soil profile morphology are shown in Plates 11 and 12. Ground observations and test pits described within this land unit are summarised in Table 6.

Distribution

This land unit covers approximately 5% (435 ha) of the site along the Bowen River terrace, along Twelve Mile Gully and in other narrow bands along intermittent creek beds. Proposed Project development that is likely to be located on this land unit are “West 1”, “Central 2”, north/south haul road and the associated out of pit spoils.

Management

The land unit occurs in small and narrow bands across disturbance areas, making it difficult to treat this area separately for topsoil removal. On its own, LU6 is not suitable for topsoil removal. However, topsoil removal will occur in accordance with the recommendations for the surrounding adjacent land unit. For example, where LU6 is surrounded by LU1, the topsoil stripping recommendations for LU1 will be followed for both areas.



Plate 11 Tenosols on River Plains (G84)



Plate 12 Ground Observation G84

Table 17 LU 6 Soil Analytical Results Summary

Horizon	Approximate Depth (m)	pH	pH Rating	EC (dS/m)	Texture	Clay Content (%)	Salinity Rating	ESP Ratio (%)	CEC (meq%)	Ca/Mg Ratio
A1	0 – 0.20	6.8 – 7.7	Neutral to mildly alkaline	0.02 – 0.05	Sandy loam to clay loam	1 – 10	Very low	[2] -	-	-
A2	0.20 -0.60	7.2 – 8.3	Neutral to moderately alkaline	0.01 – 0.03	Sandy loam to clay loam	3 – 9	Very low	0.3 – 0.6	1.6 – 9.9	3.4 – 3.6
B1	0.60 – 1.0	7.7 – 8.2	Mildly to moderately alkaline	0.01 – 0.02 (0.84)[3]	Sand to sandy loam (Medium clay)	6 – 11	Very low (High)	0.3 – 0.5 (15.9)	2.2 – 8.6 (30.2)	2.8 – 3.4 (2.1)
B2	1.0 – 1.5	8.0	Moderately alkaline	0.03 (1.15)	Medium clay (heavy clay)	14	Very low (Very high)	0.5 (16)	10.3 (25.7)	2.9 (2.4)

Table 18 Surface Soil (0 - 0.10 mBGS) Fertility for LU6

Analyte	Soil Concentration	Range below which plant deficiencies have been recorded*	Range above which plant toxicities have been recorded*
Organic Matter	0.9 - 3.8%	-	-
Nitrate (Total Nitrogen)	1.7 mg kg^{-1} (0.08 – 0.21%)	20 – 60 mg kg^{-1}	-
Phosphorus	<5.0 -71.0 mg kg^{-1}	10 – 30 mg kg^{-1}	-
Potassium	0.13 – 0.59 meq $100g^{-1}$	0.3 – 0.5 meq $100g^{-1}$	-
Magnesium	8.52 meq $100g^{-1}$	0.1 – 0.3 meq $100g^{-1}$	-
Calcium	21.60 meq $100g^{-1}$	0.5 – 1.4 meq $100g^{-1}$	-
Aluminium	26.0 mg kg^{-1}	-	> 3 mg kg^{-1}
Sulfate	1.3 – 7.5 mg kg^{-1}	-	-
Boron	0.31 – 1.5 mg kg^{-1}	-	-
Copper	0.17 – 1.7 mg kg^{-1}	-	-
Iron	3.9 – 57 mg kg^{-1}	-	-
Manganese	1.8 – 60 mg kg^{-1}	-	-
Zinc	0.13 – 1.4 mg kg^{-1}	-	-
Chloride	17.0 mg kg^{-1}	-	200 – 600 mg kg^{-1} ǂ

Notes: * refers to concentrations necessary for satisfactory vegetative growth. References are provided in Appendix D
ǂ indicates that at concentrations above this range, plant growth can be retarded.

3.2.9 Topsoil Management Summary

Soil considered suitable for stripping and subsequent use in rehabilitation works was identified in Land Units LU1, LU2 and LU5. Useable topsoil resources were confined to the surface A1 horizon, which contains seed stock, micro-organisms, organic matter and nutrients required for plant growth. In some cases, and if no alternative exists, the subsoils from LU1, LU2 and LU5 may also be utilised as surface cover. However, nutrient concentrations and organic matter generally decrease with depth. Therefore, the LU1, LU2 and LU5 subsoil material is considered to be 'marginal' when used in place of topsoil and should only be used in place of topsoil if no other options are available. This subsoil will require additional amendment prior to use to amend the alkalinity, low nutrient status, low organic matter, and absent seed stocks.

Planning

The proposed disturbance areas are shown on Figure 2. Based on the land units within the disturbance areas and the recommended stripping depths, the approximate volume of soil to be removed has been calculated (Table 19). These calculations include a bulking factor which incorporates bulk density changes during soil excavation and transport. The main land unit disturbed is LU1 (1,426 ha), followed by LU5 (898 ha), LU 2 (604 ha). Land Units LU3 and LU6 are both likely to have <61 ha each disturbed by planned operations. Where LU6 is disturbed, the small and narrow areas make it difficult to treat the topsoil removal separately. Therefore topsoil will be treated in accordance with the recommendations for the surrounding land unit and the following calculations have taken this into account.

In total, approximately 6,671,250 m^3 of topsoil (from LU1, LU2, LU5 and LU6) and 6,671,250 m^3 of subsoil is considered suitable to be stripped from the disturbance areas. The topsoil material should be utilised for surface cover material in preference to the subsoil material.

The disturbance area is 3,442 ha and, assuming a soil re-spreading thickness of 0.25 m, approximately 8,604,000 m^3 of cover material is required. If only topsoil was used to create the 0.25 m thickness, 75% of this quantity of cover soil can be provided under the current stripping program. This is less than the required cover material volume. However, it is recommended that the subsoil in LU1, LU2 and LU5 (0.15 to 0.3 m depth) be utilised in the rehabilitation landscape as a subsoil (0.15 m depth) and overlain with recovered topsoil (0.15 m depth) on approximately 50% of the disturbance area. This results in approximately 2,150 ha where topsoil is the only cover material at 0.25 m depth (3,335,625 m^3) and 1,300 ha where the soil profile has been recreated with 0.15 m topsoil and 0.15 m subsoil (3,335,625 m^3).

Table 19 Approximate Soil Stripping Volumes by Disturbance Area for the Proposed Operations

Disturbance Area Name	Land Unit	Area (ha)	Soil Horizon	Stripping Depth (mBGS)	Stripped Soil Volume* (m^3)
Co-disposal Storage	LU4	138	-	-	0
Diversion Channel	LU1	27	A1	0.0 – 0.15	60,750
			B21	0.15 – 0.35	60,750
	LU4	34	-	-	0
	LU5	7	A1	0.0 – 0.15	15,750
			B1	0.15 – 0.35	15,750
	LU6	3	-	-	0
Mine Process Plant	LU1	4	A1	0.0 – 0.15	9,000
			B21	0.15 – 0.35	9,000
	LU5	23	A1	0.0 – 0.15	51,750
			B1	0.15 – 0.35	51,750
Out of Pit Spoil	LU1	720	A1	0.0 – 0.15	1,620,000
			B21	0.15 – 0.3	1,620,000
	LU2	170	A1	0.0 – 0.15	382,500
			B21	0.15 – 0.35	382,500
	LU3	10	-	-	0
	LU4	90	-	-	0
	LU5	280	A1	0.0 – 0.15	630,000
			B1	0.15 – 0.35	630,000
	LU6	19	-	-	0
Pit	LU1	640	A1	0.0 – 0.15	1,440,000
			B21	0.15 – 0.35	1,440,000
	LU2	415	A1	0.0 – 0.15	933,750
			B21	0.15 – 0.35	933,750
	LU3	10	-	-	-
	LU4	115	-	-	0
	LU5	430	A1	0.0 – 0.15	967,500
			B1	0.15 – 0.35	67,500

Disturbance Area Name	Land Unit	Area (ha)	Soil Horizon	Stripping Depth (mBGS)	Stripped Soil Volume* (m^3)
	LU6	33	A1	0.0 – 0.15	74,250
			B1	0.15 – 0.3	74,250
Rail	LU5	12	A1	0.0 – 0.15	27,000
			B1	0.15 – 0.35	27,000
Road	LU1	29	A1	0.0 – 0.15	62,250
			B21	0.15 – 0.3	62,250
	LU2		A1	0.0 – 0.15	11,250
			B21	0.15 – 0.3	11,250
	LU4	1	-	-	0
	LU5	55	A1	0.0 – 0.15	123,750
			B1	0.15 – 0.3	123,750
	LU6	2	-	-	4,500
Sediment Basin	LU1	8	A1	0.0 – 0.15	18,000
			B21	0.15 – 0.35	18,000
	LU2	14	A1	0.0 – 0.15	31,50
			B21	0.15 – 0.3	31,500
	LU3	36	-	-	0
	LU4	1	-	-	0
	LU5	23	A1	0.0 – 0.15	51,750
			B1	0.15 – 0.3	51,750
	LU6	5	-	-	0
Miscellaneous	**LU1**	**7**	A1	0.0 – 0.15	15,750
			B21	0.15 – 0.3	15,750
	LU5	63	A1	0.0 – 0.15	141,750
			B1	0.15 – 0.3	141,750
Total		3442			13,342,500
			Topsoil		6,671,250
			Subsoil		6,671,250

Note: The volume estimate includes a soil bulking factor of 1.5 g/g, which compensates for soil density changes during excavation and transportation.

Stripping

The areas to be stripped will be surveyed and marked during the topsoil resource assessment, which will be undertaken prior to commencement of mining operations. Stripping of topsoil should occur before any construction commences. Large trees and shrubs should be cleared first and stockpiled separately to the soil. Topsoil should be stripped to the depths nominated in Table 18 for the different land units and stockpiled in accordance with the following section.

Stockpiling

Where possible, topsoil will be spread directly onto areas being rehabilitated. This is the preferred method as it maximises the viability of the soil seed bank, reduces nutrient loss and reduces the area required for stockpiling. Where progressive rehabilitation is not possible, the stripped soil will be stored in stockpiles.

The topsoil and subsoil will be stockpiled separately. The soil stockpiles should be approximately 1 to 2 metres high and be placed away from drainage lines, roads, machinery and transport corridors. The stockpiles may need to be ripped and seeded with a quick establishment pasture to limit erosion and maintain a viable seed bank if the period of stockpiling is greater than one growing season or six months. Topsoils are the preferred cover media as they have a greater seed bank, nutrients and micro-organism content.

Stockpiles will be clearly signposted for identification and to avoid accidental loss.

When used in rehabilitation, the soil will need to be amended with fertiliser if improved pasture is to be planted.

The approximate locations for the proposed stockpiles are shown in Figure 10. This plan will be refined and updated during the topsoil resource assessment.

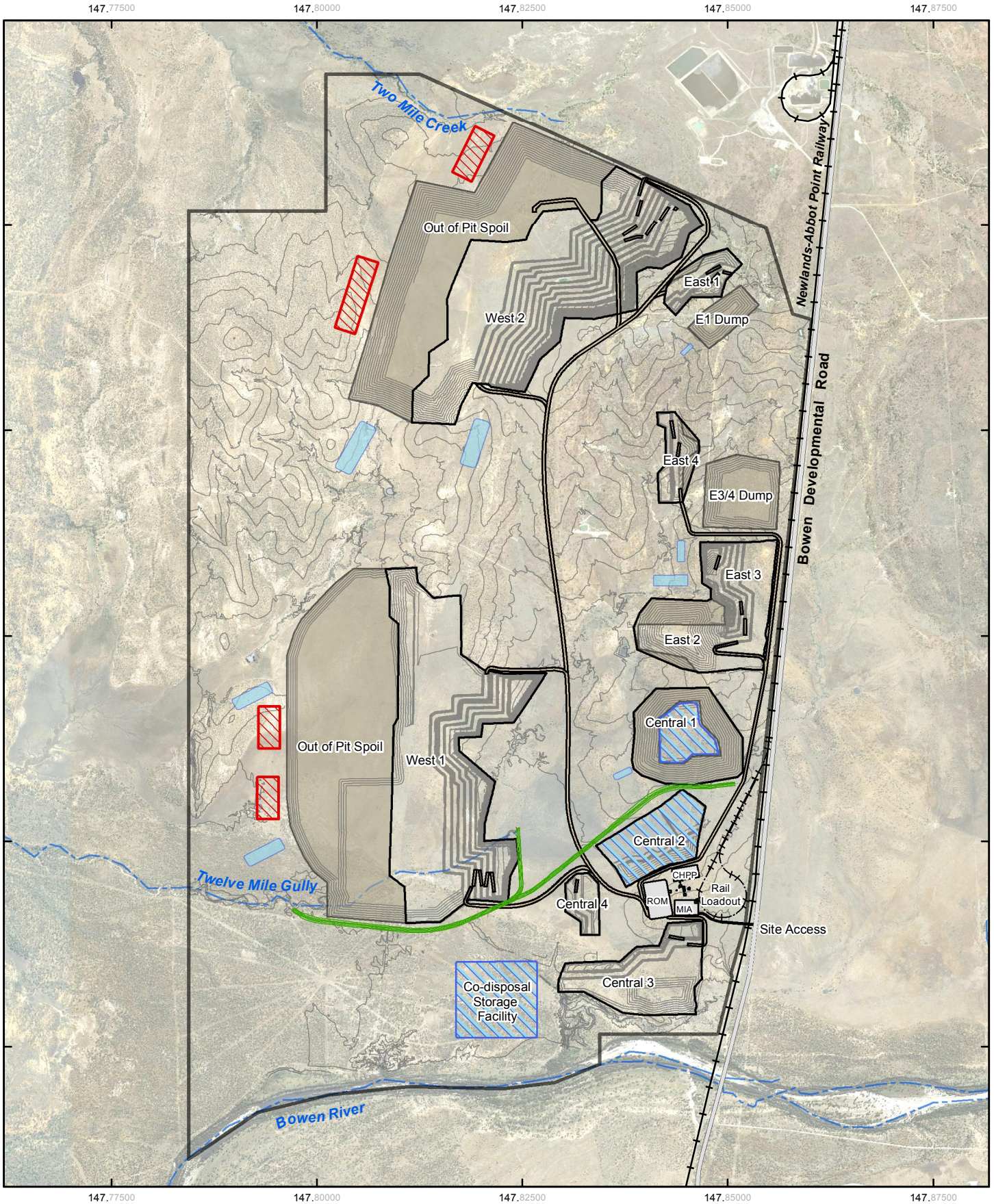
Respreading

Mine rehabilitation planning will include:

- Balancing required topsoil quantities with stored stockpile inventories;
- Planning to maximise the direct spreading of topsoil from stripping areas, rather than stockpiling;
- Minimise the length of time that soil is stored in stockpiles; and
- Use of subsoil in lower relief areas and providing additional amendment to promote vegetation establishment.

Soil will be respread in layers at a thickness appropriate for the intended use of the area being rehabilitated. Once soil is respread, a number of measures will be implemented to protect the topsoil on the rehabilitation areas:

- Contour ripping to encourage infiltration and minimise runoff;
- Fertilisation and reseeding as soon as possible to establish a vegetation cover;
- Installation of slope drainage control to limit slope length and drainage velocity; and
- Installation of sediment control and collection measures.



LEGEND

- Major Road
- Existing Railway
- Proposed Railway
- Proposed Diversion Channel
- Contour (5m interval)
- Project Area
- Mine Process Plant
- Out of Pit Spoil Area
- Haulage Road
- Proposed Stockpile Location (Indicative)
- Co-disposal Storage Facility
- Sediment Basin (Indicative)

1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Proposed Soil Stockpile Locations

Job Number 41-21894
Revision 1
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Figure 10

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Data source: QCOAL: Mine Layout (2011); DME: Mining Lease (2011); GA: 250K V3 Topo (2009). GE: Imagery (06062011). Created by: TH

4. Land Assessment

4.1 Land Suitability Assessment

The two methods of land evaluation traditionally used in Queensland are '*land capability*' and '*land suitability*'. '*Land capability'* assessment, as described by Rosser *et al.* (1974) concerns the allocation of land units to one of eight classes on the basis of the extent of limitations for general agricultural use. It is usually applied to broad scale land resource assessment.

'*Land suitability*' rankings are more refined and apply to the capacity of land resources to sustain particular forms of land use such as arable farming, irrigated agriculture, and forestry. Such rankings can be applied to smaller land units and are thus more useful in determining post-mining land use options.

A five-class land suitability classification with suitability decreasing progressively from Class 1 to Class 5 was used for the evaluation of land in the Project area. The land is assessed on the basis of a specified land use that allows optimum production with minimal degradation to the land resource in the long-term (Land Resource Branch Staff, 1990).

Land is considered less suitable as the severity and number of limitations for a land use increase, reflecting either:

(a) Reduced potential for production;

(b) Increased inputs to achieve an acceptable level of production; and/or

(c) Increased inputs required to prevent land degradation.

The five land suitability classes are as follows:

- **Class 1: Suitable land with negligible limitations.** This is highly productive land requiring only simple management practices to maintain economic production;
- **Class 2: Suitable land with minor limitations** which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production;
- **Class 3: Suitable land with moderate limitations** which either further lower production or require more than those management practices of Class 2 land to maintain economic production;
- **Class 4: Marginal land, which is presently considered unsuitable due to severe limitations**. The long term significance of these limitations on the proposed land use is unknown. The use of this land is dependent upon undertaking additional studies to determine whether the effect of the limitation(s) can be reduced to achieve sustained economic production; and
- **Class 5: Unsuitable land with extreme limitations** that generally preclude its use for agricultural activities.

The first three classes (Classes 1, 2 and 3) are considered suitable for the specified land use (e.g. *Rainfed Broadacre Cropping, Beef Cattle Grazing, Irrigated Cropping,* etc*)*, as the benefits from using the land for that land use in the long term should outweigh the inputs required to initiate and maintain production. Decreasing land suitability within a region often reflects the need for increased inputs rather than decreased potential production.

Land Class 4 is considered presently unsuitable or is used to classify marginal land where it is doubtful that the inputs required to achieve and maintain production outweigh the benefits in the long term.

Additional studies are needed to determine whether the effect of the limitation(s) can be reduced to achieve sustained production.

Land Class 5 is considered unsuitable, having limitations that in aggregate are so severe that the benefits would not justify the inputs required to initiate and maintain production in the long term. Some Class 5 lands however, such as escarpments, will always remain unsuitable for agriculture.

4.1.1 Land Suitability Assessment Methodology

A desktop review of the available relevant information was undertaken to assess the land suitabilities currently documented for the region.

Based on the findings of the desktop review, the soil survey and laboratory soil analyses a land suitability assessment was conducted on the six Land Units identified. The assessment was undertaken for the two types of existing land uses identified (Section 2.2, Land Use) as either currently or previously occurring in the Collinsville area:

- Rainfed Broadacre Cropping; and
- Beef Cattle Grazing.

The suitability assessment criteria used to assess these two land uses was obtained from *Land Suitability Assessment Techniques* (DME, 1995) and is provided in Appendix E.

Each value of the relevant land quality was assigned a rating from Classes 1 to 5. The overall capability rating was determined by the most limiting factor or factors (i.e. the quality or qualities assigned the highest number). The rating did not change according to how many of the most limiting factors were present. For example, there was no difference in the overall rating for a land unit with a Class 4 rating due only to waterlogging compared with another land unit where Class 4 was due to waterlogging, salinity, flooding and water erosion hazard.

4.1.2 Initial Desktop Review

The land suitability study of the Collinsville-Nebo-Moranbah region (DPI, 1984) was reviewed to determine the cropping potential of the region. The review identified that the major crops grown in Central Queensland included grain sorghum and sunflower during the summer and safflower and wheat during the winter.

Rainfed Broadacre Cropping in the region is restricted to soils with a high plant available water capacity (PAWC). The majority of the rainfall (70%) occurs in the summer months when sorghum and sunflower are grown, however, rainfall variability is so high during this period that PAWC is a critical factor for successful cropping. In the winter months rainfall is negligible so any cropping of wheat and sunflower must rely almost entirely on stored soil moisture.

The only soils that were considered to have some potential for rainfed cropping were the cracking clays (Vertosols). Cracking clays on sedimentary rocks must be deeper than 60 cm to be suitable for cropping in the Collinsville-Nebo areas. The Vertosols with heavy clay subsoils below the self-mulching layer may be susceptible to hardpan development. Hardpans that develop immediately below the plough layer may severely restrict root and water penetration.

Gilgaied Vertosols with deep (40 to 100 mm) melon hole microrelief severely hinders cultivation and land levelling will bring the saline subsoils to the surface resulting in poor crop growth. They were considered unsuitable for rainfed cropping.

Vertosols occur on gently undulating plains and rises. They are moderately to highly erodible. Where they are present on slopes greater than 1%, soil conservation measures would be required to minimise soil losses.

The Sodosols were considered unsuitable for rainfed cropping due to low PAWC and deep hardsetting surface soils. However they were considered suitable for grazing. The sodic nature of the subsoils results in the soils having a high erodibility potential. Relatively flat areas with slopes less than 2% were deemed suitable for pasture improvement, but slopes greater than this are unsuitable for cultivation and should be grazed for native pastures only.

The Dermosols have low PAWC, very low fertility and are unsuitable for rainfed cropping. They tend to support eucalypt woodlands that would be expensive to clear and prone to woody regrowth and are more suited to native pasture grazing.

4.1.3 Land Suitability Results

The site-specific land suitability assessments for Rainfed Broadacre Cropping and Beef Cattle Grazing are presented in the following sections. The detailed results are presented in Appendix F and definitions of the qualities that have been assessed are included in Appendix G.

Land Suitability for Rainfed Broadacre Cropping

The outcomes of the land suitability assessment for each land unit for Rainfed Broadacre Cropping are presented in Table 20 while mapping of the land suitability is presented in Figure 11.

The *Vertosols on undulating terrain* (LU2) are suitable Class 3 land for Rainfed Broadacre Cropping with moderate limitations of water availability because of high salinity below 0.8 mBGS and presence of weathered rocks at depth. As in LU1, soil workability is also a limitation. LU2 has a higher agricultural potential than LU1 mainly because high salinity and sodicity only occur at low depth, below 0.8 mBGS

The *Sodosols on undulating low hills* (LU3) are classified as Class 5 land generally unsuitable for Rainfed Broadacre Cropping with extreme limitations due to limited water availability, which preclude the landuse for Broadacre Cropping. The strongly sodic nature of the subsoil inhibits the infiltration of water into the soil and limits the PAWC of the soil profile to 50 to 75 mm, which is insufficient for cropping. These *Sodosols on undulating low hills* (i.e. moderate slopes of up to 10%) are additionally considered unsuitable for Rainfed Broadacre Cropping as the slopes are considered to present a risk for accelerated erosion and would require the extensive construction of contour banks and other erosion control measures.

Sodosols on flood plains (LU4) are marginal Class 4 land for Rainfed Broadacre Cropping due to the presence of dissected gullies. Other limitations include low water availability and soil physical factors as the soils exhibited hard setting surfaces when dry.

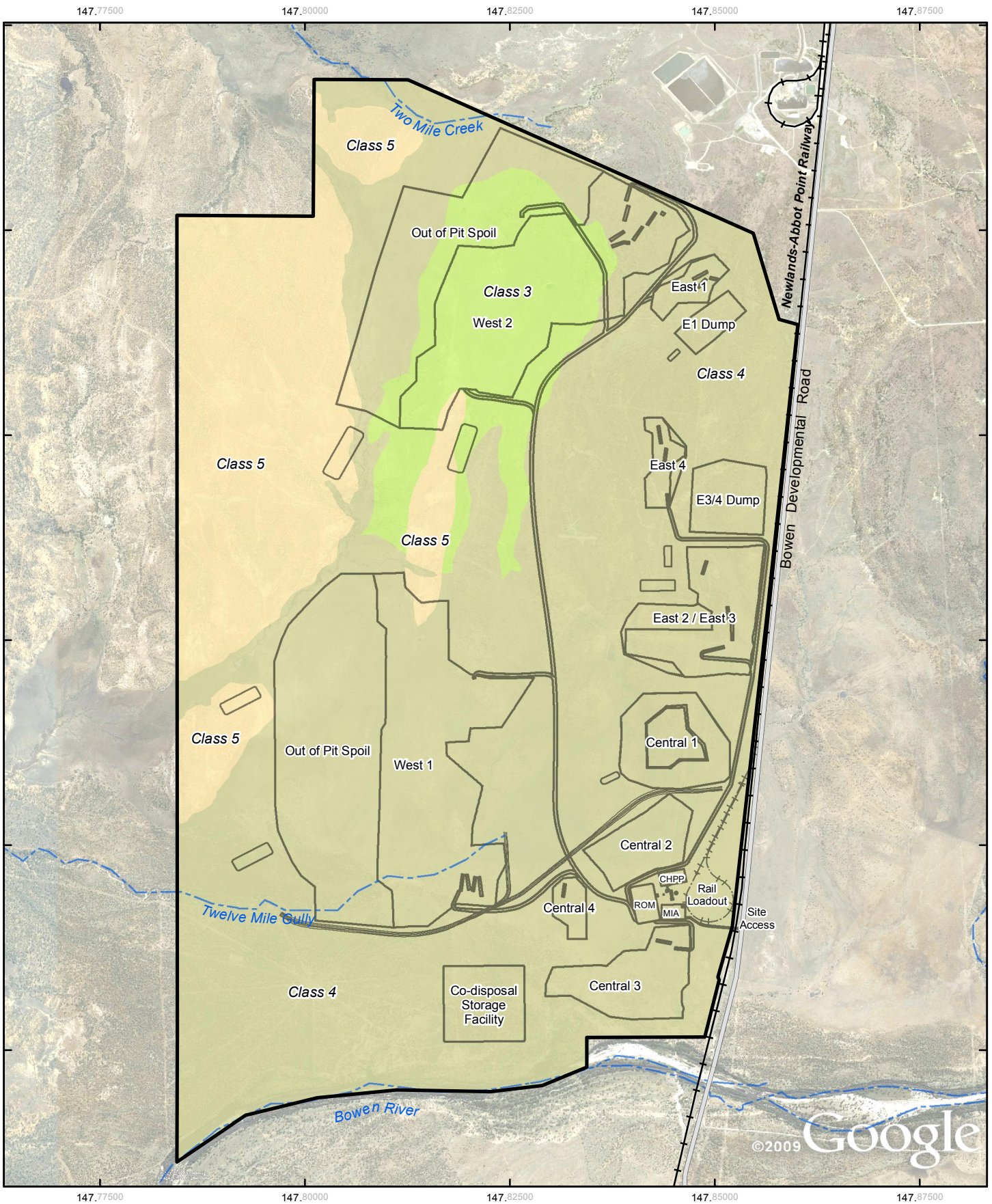
Table 20 Land Suitability Rating for Rainfed Broadacre Cropping

Land Unit	Land Suitability Rating Rainfed Broadacre Cropping	Most Limiting Factor/s
LU1 Vertosols on low lying areas.	Class 4 – marginal land with severe limitations.	Soil workability. Soil physical factors. Subsoil salinity.
LU2 Vertosols on undulating terrain.	Class 3 – suitable land with moderate limitations.	Water availability due to limited soil depth. Soil workability. Soil physical factors. Sodicity. Salinity.
LU3 Sodosols on undulating low hills.	Class 5 – unsuitable land with extreme limitations.	Water availability. Water erosion susceptibility and subsoil erodibility if exposed.
LU4 Sodosols on a flood plain.	Class 4 – unsuitable land with extreme limitations.	Water availability due to sodic subsoil. Soil physical factors. Topography.
LU5 Dermosols and **Vertosols** on undulating terrain.	Class 4 – marginal land with severe limitations.	Water availability due to saline and sodic subsoil. Water erosion susceptibility.
LU6 Tenosols and **Rudosols** adjacent to Intermittent or Permanent Watercourses.	Class 4 – marginal land with severe limitations.	Occasional flooding. Topography.

Dermosols and Vertosols on undulating terrain (LU5) are marginal Class 4 land for Rainfed Broadacre Cropping due to low water availability and water erosion limitations. The presence of weathered rock at approximately 0.8 mBGS restricts the volume of plant available water that can be stored in the soils profile resulting in an estimated plant available water holding capacity (PAWC) of 90 to 125 mm, which is low for most crops in the area. In addition, slopes of up to 10% are considered to present a risk for accelerated erosion once topsoil is exposed and would require the extensive construction of contour banks and other measures to minimise effects of overland flows of water on exposed soils.

The *Tenosols and Rudosols adjacent to intermittent or permanent watercourses* (LU6) were determined to be marginal Class 4 land for Rainfed Broadacre Cropping due to occasional flooding. In addition, the terraces within this land unit reduce the arable land area.

In summary only LU2 land is considered suitable Class 3 for Rainfed Broadacre Cropping in the Project. A combination of unfavourable physical and chemical soil characteristics, and topography renders all the other land units (LU1, LU3, LU4, LU5, LU6) marginal land and currently unsuitable for broadacre cropping.



LEGEND

- Major Road
- Existing Railway
- Drainage Feature
- Project Area
- Mine Layout

Land Suitability Assessment

- Class 3 - Suitable land with moderate limitations
- Class 4 - Marginal land with severe limitations
- Class 5 - Unsuitable land with extreme limitations

Based on or contains data provided by the State of QLD (DERM) [2011]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:70,000 (at A4)

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Land Suitability Assessment for Rainfed Broadacre Cropping

Figure 11

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Data source: GHD: Land Suitability Assessment (2012). DERM: Drainage (2010). QCOAL: Study Area/2011. GoogleEarthPro: Image (extracted 01062011). GA: 250K Topo Data/2009. Created by: TH

Land Suitability for Beef Cattle Grazing

A summary of the land suitability assessment for Beef Cattle Grazing on each land unit is presented in Table 21, and mapped in Figure 12.

Table 21 Land Suitability Rating for Beef Cattle Grazing

Land Unit	Land Suitability Rating Beef Cattle Grazing	Most Limiting Factor/s
LU1 Vertosols on low lying areas.	Class 3 – suitable land with moderate limitations.	Soil physical factors. Salinity. Subsoil salinity. pH.
LU2 Vertosols on undulating terrain.	Class 3 – suitable land with moderate limitations.	Water availability due to limited soil depth. Soil workability. Sodicity. Salinity.
LU3 Sodosols on undulating low hills.	Class 4 – marginal land with severe limitations.	Water availability. Nutrient deficiency. Water erosion susceptibility and subsoil erodibility if exposed.
LU4 Sodosols on a flood plain.	Class 3 – suitable with moderate limitations.	Water availability due to sodic subsoil. pH.
LU5 Dermosols and **Vertosols** on undulating terrain.	Class 3 – suitable with moderate limitations.	Water availability due to saline and sodic subsoil. Water erosion susceptibility.
LU6 Tenosols and **Rudosols** adjacent to intermittent or permanent watercourses.	Class 3 –suitable with moderate limitations.	Occasional flooding, topography.

The *Vertosols on low lying areas* (LU1) and *Vertosols on undulating terrain* (LU2) are suitable Class 3 land for Beef Cattle Grazing with moderate limitations due to soil workability, soil salinity and soil pH. The cracking clays with coarse self mulching peds (>20mm) provide a moderate limitation to pasture growth. The pH of the subsoil was recorded between 8.0 and 9.0, which is considered moderately to strongly alkaline and may lead to nutritional deficiencies in the rooting zone.

The *Sodosols on undulating low hills* (LU3) are marginal Class 4 land currently unsuitable for Beef Cattle Grazing, because of the low water availability. The strongly sodic nature of the subsoil inhibits the infiltration of water into the soil and PAWC of the soil profile is limited to 50 to 75 mm.

The *Sodosols on flood plains* (LU4) are suitable Class 3 land for Beef Cattle Grazing with moderate limitations associated with low water availability and an alkaline pH range within the root zone.

The *Dermosols and Vertosols on undulating terrain* (LU5) are considered suitable Class 3 land for Beef Cattle Grazing with moderate limitations due to water availability, nutritional deficiency and soil pH. The pH of the subsoil was recorded between 8.0 and 9.0 on the Vertosols, which is considered moderately to strongly alkaline and may lead to nutritional deficiencies in the rooting zone.

The *Tenosols and Rudosols adjacent to intermittent or permanent watercourses* (LU6) were considered suitable Class 3 land for Beef Cattle Grazing with limitations due to the topography of the terraces and the narrow areas within this land unit, which makes cultivation for sowing pastures somewhat restricted.

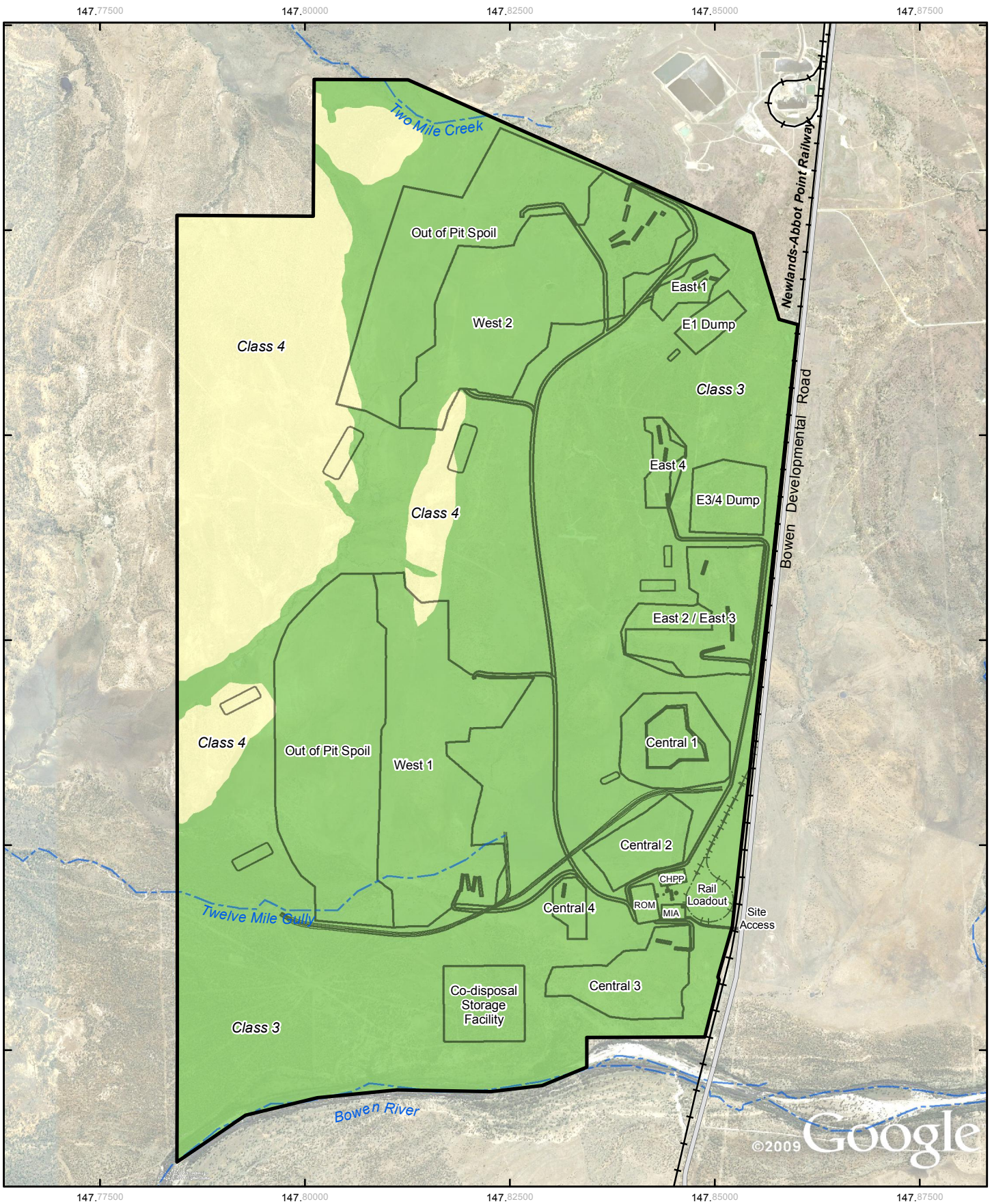
Land Suitability for Irrigation within 5km of Bowen River

The land located within 5 kilometres (km) of the Bowen River consists of LU1: Vertosols on low lying areas; LU3: Sodosols on undulating low hills; LU4: Sodosols on flood plain, with secondary Rudosols; LU5: Dermosols and Vertosols on undulating terrain and LU6: Tenosols and Rudosols adjacent to intermittent or permanent watercourses. These land units were assessed for irrigation suitability, using Section 4.3 of the *Fitzroy LWMP Reference Manual* (DERM, 2007). Most of the limitations that affect Broadacre Cropping would similarly apply to irrigated crops. However, water availability would no longer be a limitation for most of the soils except Sodosols where there is unavailability of water because of their physical properties.

- LU6 is comprised of narrow areas of small size, with terraces and drainage depressions. This topography makes it generally unsuitable for large scale irrigation;
- LU4 is made up of texture contrast soils with a sandy loam A horizon and a sandy clay or medium clay B horizon. Sandy soils generally have rapid water infiltration and deep drainage however, the LU4 soils were noted to have hard setting surface soils and sodic subsoils. The crusted surfaces and sodic clay subsoils result in poor water infiltration properties, poor drainage characteristics and a susceptibility to erosion that makes this land unit unsuitable for irrigation purposes;
- LU3 is made up of Sodosols on undulating low hills. These soils may exhibit poor permeability in their subsoils and hence are prone to lateral drainage through the A2 horizon which sits above an impermeable B2 horizon. The undulating terrain may exacerbate this feature of these soil types. Soil erosion is another limitation. Soils in LU3 are therefore unsuitable for any irrigated crops; and
- LU1 is composed of Vertosols and LU5 is comprised of Vertosols and Dermosols. The 'shrink swell' nature of the Vertosol soils result in rapid initial water infiltration through the cracks, but infiltration rates slow rapidly once the clays have swelled and sealed. It is then unlikely that any deep profile drainage would occur. This lack of deep drainage is confirmed by the presence of the sodic, saline and alkaline subsoils within this land unit (i.e. accumulation of salts and sodium cations). The Dermosols do not exhibit the same level of shrink swell as the Vertosols, although they are also comprised of medium to heavy clays with sodic, saline and alkaline subsoils. The low infiltration rates and the alkalinity, salinity, and sodicity of the subsoils may present significant soil chemical challenges to the establishment and growth of irrigated crops. Soils of these two land units may support a restricted range of irrigated crops. Trickle irrigation on these soils may be a possible irrigation method to reduce the soil salinity risk, if irrigation was required.

  In summary, LU2 is suitable for irrigated crops; however it is outside the 5 km reach of the Bowen River. The Vertosols and Dermosols of LU1 and LU5 should be suitable for a more restricted range of irrigated crops. Sodosols of LU3 and LU5 have inherent limitations that are not overcome by availability of water therefore they are considered unsuitable for irrigated crops. Tenosols and

Rudodols of LU6 are not suitable for irrigated crops because of the uneven, fragmented land surface topography.



LEGEND

- Major Road
- Existing Railway
- Drainage Feature
- Project Area
- Mine Layout

Land Suitability Assessment

- Class 3 - Suitable land with moderate limitations
- Class 4 - Marginal land with severe limitations

Based on or contains data provided by the State of QLD (DERM) [2011]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Land Suitability Assessment for Beef Cattle Grazing

Job Number 41-21894
Revision 1
Date 13 Mar 2012

Figure 12

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Data source: GHD: Land Suitability Assessment (2012). DERM: Drainage (2010). QCOAL: Study Area/2011. GoogleEarthPro: Image (extracted 01062011). GA: 250K Topo Data/2009. Created by: TH

4.2 Good Quality Agricultural Land (GQAL)

The Queensland Government recognises the importance of land that is capable of sustaining long-term agricultural practices for present and future agricultural commodities. Therefore, it is required that the location and extent of Good Quality Agricultural Land (GQAL) be identified and included in strategic plans, where present.

GQAL is defined as Agricultural Class A land, and in some areas includes Class B land and better quality Class C land where pastoral industries predominate (Planning Guidelines, DPI/DHLGP, 1993). GQAL is land that is capable of sustainable use for agriculture with a reasonable level of input and without causing degradation of land or other natural resources. There are four Agricultural Land Classes (A to D) defined for Queensland.

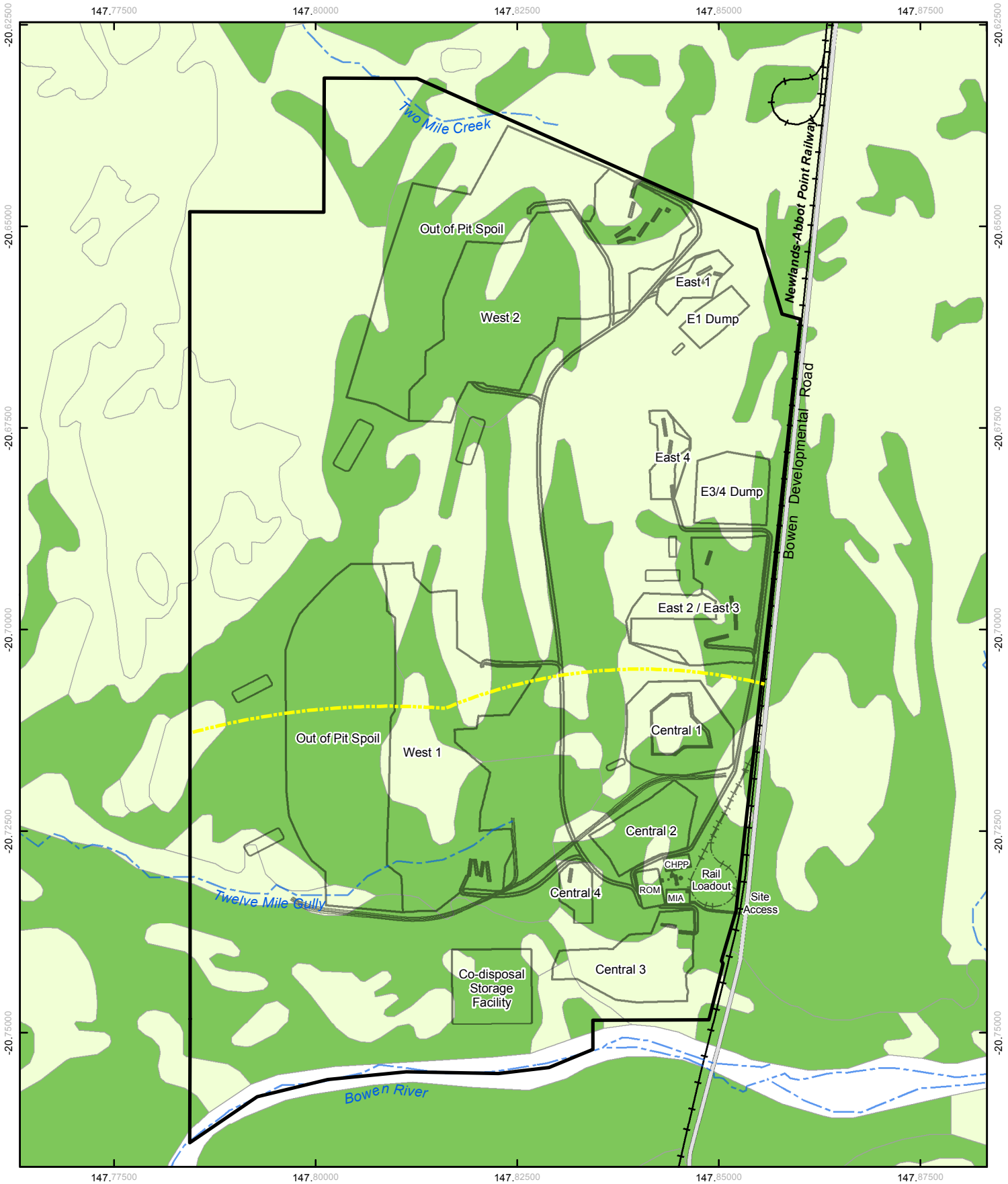
A search of the Bowen Shire Planning Scheme indicated that the Project area is located within a GQAL Special Management Area and that protection of the GQAL is part of the desired environmental outcomes for the Bowen Shire. These areas of GQAL are indicated in Figure 13.

The specific outcome for the GQAL in Bowen Shire is that good quality agricultural land is retained for rural purposes. This will be achieved by:

- Conducting other uses only if they are not irreversible and do not reduce the productive capacity of the land or alienate its use for rural purposes or result in land use conflicts with adjacent existing rural uses;
- Avoiding the use of identified land for other uses unless it can be proven that:
  - The land is not actually valuable agricultural land;
  - There is an overriding need in terms of public benefit for the proposal and the proposal cannot be located on alternative sites that are not identified as good quality agricultural land, including if:
    - The proposed location has features that make it desirable for the proposal; and
    - The features are not available in areas not identified as valuable agricultural land.

4.2.1 GQAL Methodology

To determine the presence of any GQAL within the Project area, the land suitability results were assessed against the agricultural land classes, as described in the *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI/DHLGP, 1993). The approximate correlation between land suitability for cropping (Land Resource Branch, 1990) and Agricultural Land Classes is provided in Table 22.



LEGEND

- Major Road
- Existing Railway
- Drainage Feature
- Irrigation within 5km of Bowen River
- Project Area
- Mine Layout

Collinsville Nebo Moranbah Land Suitability Study (Based on 1:250 000)

- Class A
- Class C

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1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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GQAL in the Vicinity of the Proposed Project Area (DPI, 1984) Figure 13

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Data source:DERM: Drainage/2010. QCOAL: Study Area/2011. GoogleEarthPro: Image (extracted 01062011). GA: 250K Topo Data/2009. DPI - CNM Land Suit Study (1984). Created by: TH

Table 22 Broadacre Cropping and Grazing Land Suitability Correlation to Agricultural Land Class

Land Suitability Class	Land Suitability Description	Agricultural Land Class Description*	Agricultural Land Class
1	Suitable land with negligible limitations.	Crop Land – land that is suitable for current and potential crops with limitations to production ranging from negligible to moderate levels. Land is considered to be good quality agricultural land (GQAL).	A
2	Suitable land minor limitations.		
3	Suitable land with moderate limitations.		
4	Marginal land, presently unsuitable due to severe limitations.	Limited Crop Land – Land marginal for current and potential crops due to severe limitations, and suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered suitable for cropping. Land is considered to be GQAL.	B
		Pasture Land – Land that is only suitable for improved or native pastures due to limitations which preclude continuous cultivation for crop production, but some areas may tolerate a short period of ground disturbance or pasture establishment.	C
5	Unsuitable land with extreme limitations.	Non-agricultural Land – Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/or catchment values or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage.	D

4.2.2 GQAL Results

The Agricultural Land Classes for each land unit in the Project area were assessed using calculated Land Suitability (Appendix F) and the correlations provided in Table 22. The subsequent land use suitability and agricultural land class of each land unit are shown in Table 26. Land Unit LU2 was considered to be Class A Agricultural Land which is suitable for potential crops with moderate limitations. Land Units LU1, LU3, LU4, LU5 and LU6 were considered to be Class C Agricultural Land. Class C land is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production; but some areas may tolerate a short period of ground disturbance for pasture establishment (Figure 14).

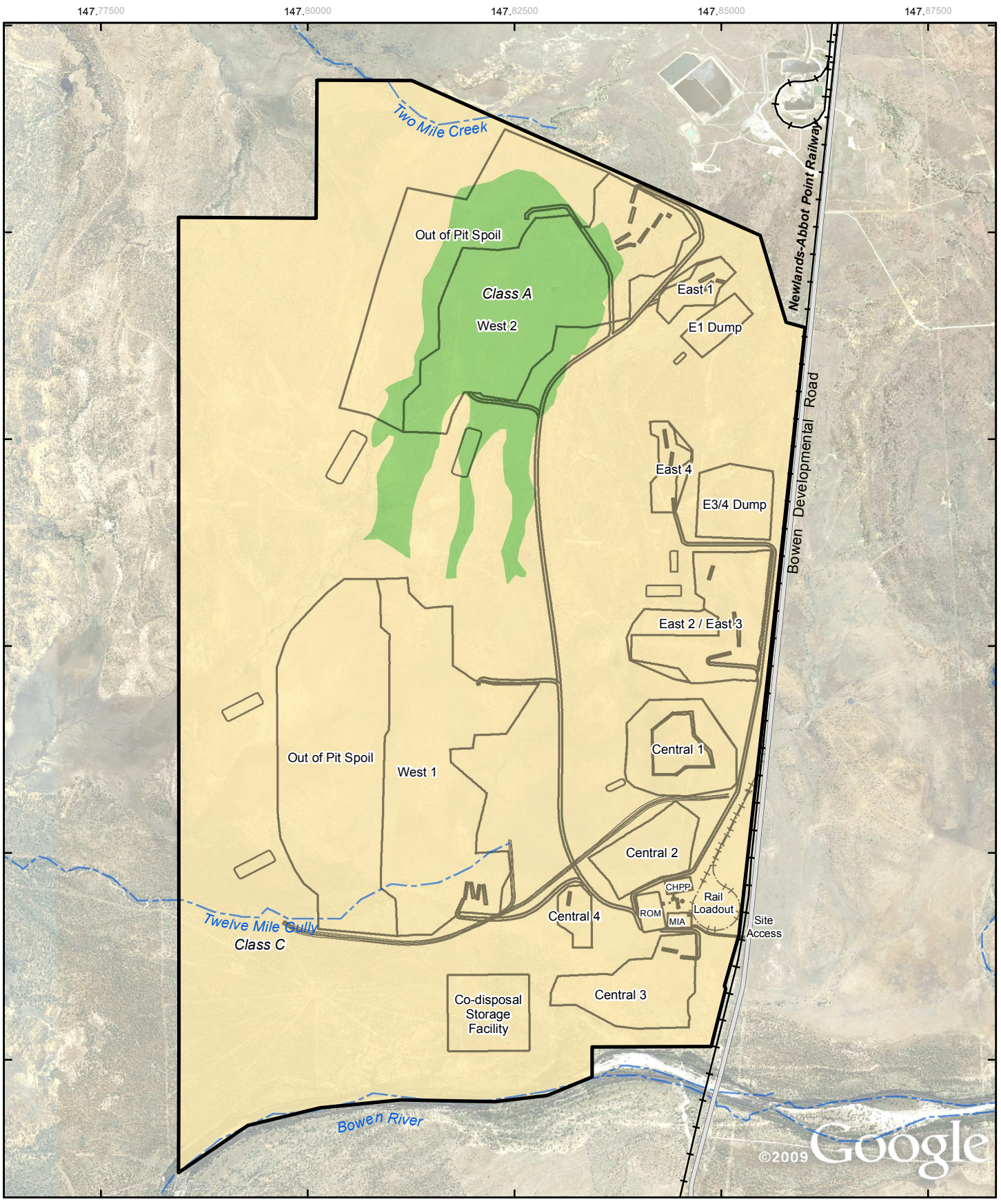
Table 23 Suitabilities of the Land Units for Cropping and their Agricultural Land Classes

Land Unit	Broadacre Crops		Grazing		Agricultural Land Class
	Suitability	Severe Limitation*	Suitability	Severe Limitation	
LU1	4	Workability and physical condition.	3	-	C
LU2	3	-	3	-	A
LU3	5	Extreme Water Availability.	4	Water Availability.	C
LU4	4	Dissected Topography.	3	-	C
LU5	4	Water Availability & Erosion.	3	-	C
LU6	4	Flooding.	3	-	C

A comparison of these results with the regional GQAL maps provided within the Bowen Shire Planning Scheme shows that the Class C land (LU1, LU3, LU4, LU5 and LU6) roughly correlates with the Planning Scheme, with the exception of the southern portion of the area. The Class A (Land Unit LU2) land correlates with the Planning Scheme in the northern portion of the area. However, the Planning Scheme indicates more extensive Class A. Within the remaining area, there are some differences between the findings of this field investigation and the Planning Scheme, and much of the additional Class A land shown on the Planning Scheme map approximately corresponds with the Land Unit LU1 area (Class C land). However, the GQAL results reported by GHD have been based on more intensive field observations within the proposed Project area.

4.3 Strategic Cropping Land

A Strategic Cropping Land Assessment was not conducted and is not required for this Project as the Terms of Reference were finalised in December 2010 and a certificate of application for mining leases were issued prior to the cut-off date of 31 May 2011.



LEGEND

- Major Road
- Existing Railway
- Drainage Feature
- Project Area
- Mine Layout

Agricultural Land Class(Based on 1:50000)

- Class A - Suitable land with negligible limitations
- Class C - Marginal land, presently unsuitable due to severe limitations

1:70,000 (at A4)

0 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia

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Agricultural Land Classes

Figure 14

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Data source: GHD: Ag Land Class/2012. DERM: Land Units/2009. QCOAL: Study Area/2011. GoogleEarthPro: Image (extracted 01062011). GA: 250K Topo Data/2009. Created by: TH/JVC

5. Conclusions

Six broad land units were defined within the Project area during the initial desktop review and soil survey.

The first of these Land Units (LU1) with mainly Vertosols was located in the central portion of the site in low lying areas. The second Land Unit (LU2) was also located centrally, appearing as Vertosols on undulating terrain. Land Unit 3 (LU3) consisted of Sodosols on the elevated western portion of the site, and these are considered highly prone to erosion. Land Unit 4 (LU4) also contained hard setting Sodosols, located in the low-lying flood plain adjacent to the Bowen River, in the southern portion of the site. The fifth land unit, LU5 was located on the higher ground on the eastern portion of the site, with open eucalypt woodland on Dermosols and Vertosols. Land Unit (LU6) was located adjacent to intermittent or permanent watercourses with marked terraces, levees and shallow drainage depressions. Proposed infrastructure and areas of disturbance associated with the Drake Coal Project are largely located in the central and western portions of the mining lease area, coinciding predominantly with Land Units (in decreasing order) LU1, LU5, LU2 and LU4. The other two Land Units (LU3 and LU6) are likely to be affected to a much smaller extent.

Based on the soil assessment results, topsoil stripping is recommended from three of the Land Units (LU1, LU2 and LU5) and possibly part of LU6. LU1, LU2 and LU5 cover approximately 62% of the Project area and coincide with the majority of proposed Project development. Surface soil from Sodosols of Land Units LU3 and LU4 is not considered suitable for stripping as its high erodibility and low water availability make the soil unsuitable for plant growth and use in rehabilitation activities. Very little project development is planned for these land units and disturbance is expected to be minimal, except in the vicinity of “Central 3” development.

The land suitability assessment results indicate that all land units in the Project area are better suited to Beef Cattle Grazing than for Rainfed Broadacre Cropping with the exception of LU2 which is suitable for both land uses. LU2 was assessed to be suitable for Broadacre Cropping and approximately 70% of this land unit is located within the development area. All land units, with the exception of LU3, were assessed as suitable for Beef Cattle Grazing and therefore, approximately 85% of the Project area is considered suitable for this land use. The above land units will have the most impact during development of the proposed Project. The remaining land unit (LU3), located on the eastern portion of the site, was considered to be marginal for Beef Cattle Grazing. Land Units within 5 km proximity to the Bowen River were also assessed for suitability for irrigation. The results indicate the soils are generally unsuitable for irrigation, based on either the shrink-swell properties of the Vertosols or the sodic subsoil and high erodibility potential of the Sodosols.

Class A Good Quality Agricultural Land was identified on the Project site on Land Unit LU2. The remaining land units were determined to be Class C agricultural land suitable only for grazing.

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Appendix A

Ground Observation Descriptions

Soil Survey Ground Observations - Drake Coal Project November - December 2011

Location (G#)	Observation Date	Photo No.	Location		Soil Type	Position & Slope (%)	Land Use	Vegetation	Erosion?	Comment
			Latitude	Longtitude						
1	30/11/11	596-600	-20,40,22.0728	147,51,3.0708	-	Alluvial Flat	Grazing	Melaleuca sp., Bauhinia, Mountain Coolibah, Buffel grass, Qld Blue grass, Bloodwood	Active Gully to 2m deep	Sandstone and mudstone rocks in gully. Layers of SCL with layers of gravelly LS. SCL light brown, gravelly LS lighter, yellowy brown. White clay at 1.4 m depth. Roots common down to 1.4 m.
1	30/11/11	601-603	-20,40,22.0728	147,51,3.0708	-	Upper slope3%	Grazing	Mountain Coolibah, Bloodwood, Buffel grass, Spear grass	-	Silty clay loam A1 horizon (black 7.5YR2.5/1). Light clay in B horizon with calcium carbonate nodules (light olive brown 2.5Y5/4)
1	30/11/12	604	-20,40,22.0728	147,51,3.0708	Black Vertosol	-	Grazing	Mountain Coolibah, Acacias, Buffel grass	Minor water sheeting	See Soil Survey Worksheet C1
2	30/11/11	611-613	-20,40,22.5372	147,51,0.162	-	Midslope 3%	Grazing	Bloodwood, Mountain Coolibah	Soft Scald	Crust on surface, overlying a dark grey angular blocky structure, heavy clay. Possibly sodic .
3	30/11/11	614	-20,40,21.6408	147,50,57.8652	Brown Dermosol (Shallow)	Ridge 1%	Grazing	Mountain Coolibah, Ironbark, Buffel grass	Water sheeting	See Soil Survey Worksheet Soil Survey Worksheet C2
4	30/11/11	620	-20,40,20.532	147,50,43.9692	Brown Dermosol (Shallow)	Broad Ridge	Grazing	Ironbark, Bloodwood, Buffel grass	Minor water sheeting	See Soil Survey Worksheet C3
5	30/11/11	628	-20,40,19.5168	147,50,33.684	Black Vertosol	Drainage line	Grazing	Ironbark, Bloodwood	-	Black Vertosol over weathering lithic felspathic sandstones. 1m depth of cracking clay over sandstone bed rock.
6	30/11/11	629-630	-20,40,17.9472	147,50,20.238	-	Ridge	Cell Grazing	Bloodwood, Ironbark	-	Rotational cell grazing. Silty topsoil.
7	30/11/11	631-633	586875.4861	7714040.101	Brown Vertosol	Midslope		Brigalow community	-	Brown Vertosol, wash off siltstone, cracks to 50 mm wide.
8	30/11/11	634	586841.6534	7714998.206	Red Dermosol (Shallow)	Ridge	Grazing	Prickly Acacia, Brigalow, Buffel grass	Minor sheet erosion	See Soil Survey Worksheet C4
9	30/11/11	640	-20,39,43.8732	147,50,2.7348	Black Vertosol (gilgai)	Ridge	Grazing	Prickly Acacia, Brigalow, Buffel grass	Nil	See Soil Survey Worksheet C5
9	30/11/11	660	-20,39,43.8732	147,50,2.7348	Brown Vertosol (gilgai)	Elevated Crest	Grazing	Prickly Acacia, Brigalow	-	Brown Vertosols, minor Gilgai.
10	30/11/11	643	-20,39,43.3152	147,49,46.2972	Black Vertosol (gilgai)	Elevated gentle slope	Grazing	Whitewood, Prickly Acacia, Buffel grass	Nil	See Soil Survey Worksheet C6
11	30/11/11	650	-20,39,38.1852	147,49,10.848	Black Vertosol (Shallow)	Gentle Slope 1%	Grazing	Whitewood, Prickly Acacia, Brigalow, Buffel grass	Nil	See Soil Survey Worksheet C7
12	30/11/11	655	-20,40,32.2068	147,48,23.1948	Alluvium overlying Black Vertosol	Deposition Zone, Flat	Grazing	Bauhinia, Brigaolw, Whitewood, Buffel grass	Nil	See Soil Survey Worksheet C8
15	2/12/11	661-662	-204218.8928	147,51,18.5508	Brown Dermosol	1%	Grazing	Bloodwood, Ironbark, Buffel grass	-	Lithic sandstone. Brown dermosol at railway line cutting.
16	2/12/11	663-664	-20,41,58.0992	147,51,7.4268	-	5%	Grazing	Brigalow, Buffel grass, *Carissa ovata,* Bauhinia, Bloodwood.	-	Lithic sandstone rock, outcrop.
17	2/12/11	665-666	-20,41,59.5752	147,50,46.4532	Brown Dermosol	-	Grazing	Bloodwood, Ironbark, Buffel grass	-	Brown Dermosol.
18	2/12/11	667-668	-20,41,52.6488	147,50,6.5688	Rudosol	Alluvial Flat 1%	Grazing	*Melaleuca* sp. , Moreton Bay Ash, Bauhinia, Buffel grass	Gullies to 2m deep	Stratic rudosol.
19	2/12/11	669-671	-20,41,44.1348	147,49,47.01	Red Dermosol (Shallow)	3-5%	Grazing	Brigalow, Bloodwood, Ironbark, Buffel grass	-	Sandstone, Red Dermosol (very shallow).
20	2/12/11	672-674	-20,41,37.4388	147,49,35.6952	Black Vertosol	1%		Brigalow, Buffel grass	Gully to 1.5m	Black Vertosol (becoming shallow on plain).
21	2/12/11	675-676	-20,41,27.33	147,49,16.536	Sodosol	-	Grazing	Ironbark, Bloodwood, Buffel grass	-	Sodosol.
22	2/12/11	677-678	-20,41,17.304	147,48,52.4448	-	5%		Whitewood, Buffel grass	-	lithic sandstone, sodic scald.
23	2/12/11	679-680	-20,41,8.2752	147,48,26.9568	Black Vertosol (Shallow)	Old flood plain	Grazing	*Owenia acidulata* , Brigalow, Buffel grass	-	Shallow Black Vertosol (less than 1 m deep).
24	2/12/11	681-683	-20,41,7.9008	147,48,22.554	Rudosol	Creek bed	-	Bauhinia, Brigalow, Moreton Bay Ash, Bloodwood, Buffel grass	-	Sandy creek. Stratic rudosol (layered). Layers of sandy loam. Creek running after 30mm of rain.
25	2/12/11	684-685	-20,41,4.3548	147,48,14.9112	-	Alluvial Flat	-	Box trees (open woodland), Buffel grass	-	Alluvial flat.
26	2/12/11	686	-20,40,5.79	147,47,13.47	Brown Sodosol	Crest	-	Box trees (open woodland), *Carissa ovata,* Buffel grass, Bauhinia	Minor	See Soil Survey Worksheet C9
27	2/12/11	693-694	582,277.092	7,714,008.662	Sodosol	3-5%	-	Box trees, Buffel grass	-	Quarry site, sodic shallow soil, 50 cm soil depth over sandstone, similar to Core 9.
28	2/12/11	695 -697	-20,40,36.4188	147,47,27.204	-	Midslope 3-5%	-	Box tree woodland, Buffel grass	Severe gully erosion	Severe gully erosion.
29	2/12/11	698	582,858.096	7,713,063.821	Yellow/Brown Sodosol	Upper slope (Gully)	-	Box woodland, Buffel grass	Severe gully erosion	See Soil Survey Worksheet C10
30	2/12/11	704	-20,40,59.0448	147,47,57.8832	Yellow/Brown Sodosol	Midslope 3-5%	-	*Carissa ovata,* Bloodwood, Ironbark, Buffel grass	Nil	See Soil Survey Worksheet C11
31	2/12/11	710	-20,40,57.414	147,47,10.1112	Brown Sodosol	Upper slope 2%	-	*Cassia brewsteri,* Box trees (open woodland), Buffel grass	Minor water erosion	See Soil Survey Worksheet C12
32	2/12/11	722-723	-20,40,57.1548	147,47,19.698	Red Sodosol	Gully	-	*Eucalyptus platyphylla,* Box tree, Buffel grass, *Cassia brewsteri*	Severe gully erosion	Severe gully erosion. Soil becomes redder as slope increases. Possibly Red Sodosol. Located adjacent to C13 but up the gully slope.
32	2/12/11	717	-20,40,57.1548	147,47,19.698	Sodic Brown Kandosol	Gully	-	*Eucalyptus platyphylla,* Box tree, Buffel grass, *Cassia brewsteri*	Severe gully erosion	See Soil Survey Worksheet C13
33	2/12/11	724-725	-20,40,57.1872	147,47,21.1632	Red Sodosol	Midslope 3-5%	-	*Cassia brewsteri* , Box woodland, Buffel grass	-	Red Sodosol.
34	2/12/11	726	-20,40,59.2932	147,47,35.9988	Brown Sodosol	Swale	-	Open box woodland, buffel grass	Nil	See Soil Survey Worksheet C14
36	2/12/11	732-733	-20,41,0.1392	147,47,53.484	Red Sodosol	Upper slope	-	Open box/ironbark woodland, buffel grass	-	Red Sodosol.
37	2/12/11	734-735	-20,41,1.1472	147,47,57.4512	Brown Sodosol	Midslope	-	Open box woodland, buffel grass	-	Sodic Brown Sodosol.
38	2/12/11	736-737	-20,41,2.9472	147,48,4.4172	Brown Sodosol	Lower slope	-	Open box woodland, buffel grass	-	Brown Sodosol.
39	2/12/11	738	-20,38,53.8332	147,48,22.6008	Black Vertosol	Flat	Grazing	Brigalow, Box, *Cassia brewsteri* , Bauhinia, Buffel grass	Nil	See Soil Survey Worksheet C15: Gypsum at 120cm
40	2/12/11	744	-20,38,43.836	147,48,5.166	Brown Sodosol	Swale	Grazing	Open Box woodland, Buffel grass	Minor water erosion	See Soil Survey Worksheet C16
41	2/12/11	749	-20,38,50.5068	147,48,10.17	Brown Sodosol	Midslope 2%	Grazing	Open Box woodland	Nil	See Soil Survey Worksheet C17
42	2/12/11	756	583729.177	7715347.045	Brown Sodosol	Elevated Ridge	-	Brigalow, Box woodland, *Cassia brewsteri, Carissa ovata* , Whitewood, Buffel grass	Minor water erosion	See Soil Survey Worksheet C18
43	2/12/11	762-763	-20,40,0.7932	147,48,6.912	-	Midslope	Grazing	Open Box woodland		Sandstone rock outcrop.
44	2/12/11	766-767	-20,40,7.1868	147,48,2.844	-	Gully	-	Open Box woodland	Severe gully erosion	Demonstrates hard surface setting characteristics.
44	2/12/11	764-765	-20,40,7.1868	147,48,2.844	Yellow/Brown Sodosol	Gully	-	Open Box woodland	Severe gully erosion	Yellow/Brown Sodosol.
45	2/12/11	768-769	-20,40,29.586	147,48,7.956	Sodosol	-	-	-	Tunnel erosion	Tunnel erosion through sodic soils. Gully is accelerating at an increasing rate up the hill.
46	2/12/11	770-771	-20,40,58.0152	147,48,10.2168	Rudosol	-	-	*E. platyphylla* , Box open woodland	Gully erosion	Soil profile exposed in gully, stratic Rudosol.
47	2/12/11	772	-20,41,1.7412	147,49,17.8572	Brown Dermosol (Shallow)	Midslope 2%	Grazing	Bloodwood, Ironbark	Nil	See Soil Survey Worksheet C19
48	2/12/11	778	-20,40,45.8472	147,49,14.34	Calcarosol	Midslope 1-2%	-	Ironbark, Bloodwood, Bauhinia, Buffel grass	Minor sheet erosion	See Soil Survey Worksheet C20
49	2/12/11	784	-20,40,39.756	147,49,9.9552	Dermosol	Midslope 1-2%	-	Ironbark, Bloodwood, Buffel grass	Minor sheet erosion	See Soil Survey Worksheet C21
50	2/12/11	790	-20,42,12.0168	147,48,47.124	Black Vertosol	Midslope 2%	-	Brigalow, Buffel grass	Minor water erosion	See Soil Survey Worksheet C22
52	2/12/11	795-796	-20,42,22.3632	147,48,45.6372	-	Drainage line	-	Brigalow, Sand paper fig, *Owenia acidulata*	-	Rounded drainage line, series of drainage lines running south with interfluves.
53	2/12/11	797	-20,42,41.9508	147,48,45.2808	Red Dermosol	Lower slope 1%	Grazing	Whitewood, regrowth Brigalow, open Buffel grassland	Minor sheet erosion	See Soil Survey Worksheet C23
55	2/12/11	802	-20,43,18.6672	147,48,38.3688	Black Vertosol	Lower Slope 1%	-	Whitewood, Buffel grasslands	Minor sheet erosion	See Soil Survey Worksheet C24
56	2/12/11	808	-20,44,23.5968	147,48,18.81	Brown Sodosol	Flat	Cell grazing	*Eucalyptus platyphylla,* Ironbark, Bloodwood	Nil	See Soil Survey Worksheet C25
57	2/12/11	815-816	-20,44,12.8472	147,50,10.23	Black Vertosol	Flat	Grazing	Grasslands	-	Change from sodic plains to a Black Vertosol flat.
60	2/12/11	817-818	-20,42,11.5308	147,50,53.3868	-	Ridge	Grazing	Regrowth trees	-	Conglomerate rock. Tertiary silcrete.
60	2/12/11	835	-204211.5308	147,50,53.3868	Red Dermosol (Shallow)	Ridge 1%	-	Ironbark, Bloodwood, Buffel grass	Nil	See Soil Survey Worksheet C28
61	2/12/11	841	-20,42,46.6992	147,50,48.1272	Brown Dermosol	Upper slope	-	Bloodwood, Brigalow, Bauhinia, Buffel grass	Nil	See Soil Survey Worksheet C29
62	2/12/11	829-834	-20436.582	147,50,44.6568	Red Dermosol (Shallow)	Upper slope 1-2%	Grazing	Bloodwood, Ironbark, Buffel grass	Minor sheet erosion	See Soil Survey Worksheet C27
63	3/12/11	846-847	-20,43,18.948	147,50,42.8208	-	-	-	-	-	Change of slope on flat.
64	3/12/11	848	-20,43,26.3172	147,50,41.7948	Black Vertosol	-	-	-	-	Channel 10 m wide, 1.5 m deep. Black Vertosol.
64	3/12/11	824-828	-20,43,26.3172	147,50,41.7948	Brown Vertosol	Flat	-	Brigalow, Bauhinia, Sesbania, Buffel grass	Minor water erosion	See Soil Survey Worksheet C26
65	3/12/11	849-850	-20,43,34.788	147,50,40.5348	-	-	-	-	-	Edge of flood plain.
66	3/12/11	851	-20,43,37.974	147,50,39.624	Brown Dermosol (Deep)	Upper slope	-	Brigalow, *Owenia acidulata,* Buffel grass, Whitewood	Nil	See Soil Survey Worksheet C30
67	3/12/11	857	-20,43,46.362	147,50,38.544	Red Dermosol	Midslope 3%	-	Bauhinia, Brigalow, Native Orange, *Carissa ovata,* Buffel grass	Nil	See Soil Survey Worksheet C31
68	3/12/11	863	-20,43,49.9188	147,50,38.292	-	-	-	-	-	Change of slope and vegetation.
69	3/12/11	863	-20,43,55.452	147,50,36.8988	Red Dermosol	Ridge	-	Bloodwood, Box woodland, Ironbark, Bauhinia, Buffel grass	Minor	See Soil Survey Worksheet C32
70	3/12/11	870	-20,44,5.8488	147,50,21.012	Black Vertosol	Midslope 2-3%	-	Brigalow, *Owenia acidulata,* Bauhinia, Buffel grass	Nil	See Soil Survey Worksheet C33
71	3/12/11	876	-20,44,10.9788	147,50,11.7852	Black Vertosol	Lower slope	-	Bloodwood, Brigalow, Buffel grass	Nil	See Soil Survey Worksheet C34

Location (G#)	Observation Date	Photo No.	Location		Soil Type	Position & Slope (%)	Land Use	Vegetation	Erosion?	Comment
			Latitude	Longtitude						
72	3/12/11	882	-20,44,13.8552	147,49,48.63	Red Chromosol	Upper slope 1%	-	Ironbark, Bloodwood, Buffel grass	Minor water sheeting erosion	See Soil Survey Worksheet C35
73	3/12/11	888	-20,44,9.348	147,49,14.5848	Tenosol	Flat River Terrace	Grazing	Scattered Bloodwood, *Eucalyptus platyphylla* , grassland	Nil	See Soil Survey Worksheet C36
74	3/12/11	894	585447.5698	7706860.572	-	-	-	-	-	Depression.
75	3/12/11	895-896	-20,44,9.024	147,49,20.262	-	-	-	-	-	Sandy splay.
76	3/12/11	897-898	-20,44,9.4308	147,49,22.3752	-	-	-	-	-	Soil type change.
77	3/12/11	899	-20,44,9.3228	147,49,24.3048	Brown Sodosol	High River Terrace	-	Open woodland, large bloodwoods, large *Eucalyptus playtphylla,* native grasses	Nil	See Soil Survey Worksheet C37
78	3/12/11	905	-20,44,4.5348	147,49,6.87	Brown Sodosol	Open depression	-	Bloodwood, Moreton Bay Ash, *Eucalyptus platyphylla* , Buffel grass	Nil	See Soil Survey Worksheet C38
79	3/12/11	911	-20,44,4.1028	147,49,4.5192	-	-	-	-	-	Compacted soil from stock movement.
80	3/12/11	912	-20,44,5.7912	147,48,59.8788	-	River Terrace	-	-	-	First terrace.
81	3/12/11	913	-20,44,18.6828	147,47,9.7188	Red Sodosol	Plain	-	Open woodland (Box and *E. platyphylla*), 80% grass cover	Minor water erosion	See Soil Survey Worksheet C39
82	3/12/11	919	-20,44,19.7628	147,47,18.8412	-	-	-			Soil change (transition to cracking soils).
83	3/12/11	920	-20,44,23.5032	147,47,32.514	Brown Sodosol	Flat	-	Open woodland (Box and *E. platyphylla*), Eremophila, Buffel grass, Qld Blue grass	Nil	See Soil Survey Worksheet C40
84	3/12/11	927	-20,45,15.2532	147,48,7.6608	Tenosol	Flat River Terrace	-	*E. tereticornis, E. platyphylla* , Bloodwood, Buffel grass	Nil	See Soil Survey Worksheet C41
85	3/12/11	933	-20,45,18.1368	147,48,8.8272	-	River	-	-	-	Bowen river.
85	3/12/11	934			-	Flat River Terrace	-	-	-	Bowen river, lower terrace.
86	3/12/11	935	-20,45,5.9688	147,48,14.3028	-	-	-	-	Gully erosion	Gully erosion.
87	3/12/11	936	-20,45,1.6992	147,48,18.7452	-	-	-	-	Gully erosion	Gully erosion.
88	3/12/11	937	-20,44,54.1788	147,48,30.744	-	-	-	-	Gully erosion	Gully erosion.
89	3/12/11	938-940	-20,44,56.1588	147,48,36.576	-	-	-	-	Gully erosion	Gully erosion.
90	3/12/11	941	-20,44,52.6632	147,48,35.784	Brown Sodosol	Flat	-	Open woodland (Box, Bloodwood), grassland	Minor sheet erosion	See Soil Survey Worksheet C42
91	3/12/11	946	-20,44,43.2672	147,48,22.6152	Sodosol	-	-	*Eremophila* sp.	-	Possible presence of sodic soil.
92	3/12/11	947	-20,44,38.5368	147,48,15.8112	Brown Sodosol	-	-	-	-	Brown Sodosol in tree roots.
93	3/12/11	948	-20,44,36.096	147,48,11.1168	Brown Sodosol	Flat	-	Bauhinia, Eremophila, 50% grass cover	Minor sheet erosion	See Soil Survey Worksheet C43
95	3/12/11	954	-20,43,46.326	147,48,34.704	-	-	-	-	Gully erosion	Gully erosion (20 m wide, 3 m deep).
95	3/12/11	955			-	-	-	-	-	Erodible soils.
97	3/12/11	956	-20,43,37.632	147,48,35.982	Black Vertosol	Midslope 3%	-	Brigalow, Open buffel grassland	Minor sheet erosion	See Soil Survey Worksheet C44
99	3/12/11	962	-20,43,0.8148	147,48,41.3748	Black Vertosol	Lower slope	Cell Grazing	-	-	Gully in Black Vertosol, on lower slope near cell grazing water centre.
100	3/12/11	963	-20,42,55.404	147,48,42.4008	-	Dam	-	-	Eroded	Erosion at dam.
101	3/12/11	964	-20,41,46.734	147,48,49.7052	Brown Sodosol	-	-	-	-	Similar to Core-45.
102	3/12/11	965	-20,41,42.8928	147,48,49.842	Brown Sodosol	Midslope 4%	-	Bloodwood, Bauhinia, Ironbark, Open Buffel grassland	Moderate gully erosion and sheet erosion	See Soil Survey Worksheet C45
104	3/12/11	971	-20,41,29.0652	147,48,51.9588	-	-	-	-	-	Surface sandstone rock.
105	3/12/11	974	-20,41,27.8772	147,48,51.9732	-	Waterway	-	-	-	Broad waterway (30 m wide).
106	3/12/11	975	-20,40,34.2372	147,49,5.7792	-	Gully	-	-	-	Gully - drainage line between flat and ridge.
107	3/12/11	976	-20,40,29.8668	147,49,1.9668	Red Sodosol	Midslope	-	Ironbark, Bloodwood, Bauhinia, Buffel grass	Severe sheet erosion	See Soil Survey Worksheet C46
109	3/12/11	982	-20,39,49.4892	147,49,4.4832	Black Vertosol	Hill Crest	-	-	Badly scalded	Badly scalded area, crest of hill, bare Black Vertosols.
110	3/12/11	983	-20,39,23.5188	147,49,7.5972	-	Gully	-	-	-	Shallow rounded gully.
111	3/12/11	984	-20,39,18.396	147,49,7.9248	Black Vertosol	Lower slope	-	Open Buffel grassland, small Whitewood	Minor gully erosion	See Soil Survey Worksheet C47
115	3/12/11	990	-20,39,7.0308	147,49,9.948	Black Vertosol	Rise	-	-		Black Vertosol on rise.
116	3/12/11	991	-20,38,54.0708	147,49,27.3828	Brown Vertosol	Crest rise		Box, Brigalow, *Owenia acidulata* , Buffel grass	Minor sheet erosion	See Soil Survey Worksheet C48
117	3/12/11	997	-20,39,4.212	147,49,58.6092	Tenosol	Midslope 2-3%		Bloodwood, Buffel grassland	Moderate sheet erosion	See Soil Survey Worksheet C49
118	3/12/11	1005	-20,39,13.7448	147,50,15.684	-	-	-	-	-	Transition in soil type.
119	3/12/11	1006	-20,39,22.824	147,50,27.2832	Brown Vertosol	Upper slope		Open Buffel grassland, mountain Coolibah, Whitewood, Brigalow	Moderate gully erosion	See Soil Survey Worksheet C50
120	3/12/11	1012	-20,39,29.772	147,50,35.88	Dermosol	-	-	-	-	Dermosol in fallen tree root.
121	3/12/11	1013	-20,39,32.202	147,50,39.0192	-	-	-	-	-	Scattered rock on surface.
122	3/12/11	1014	-20,39,52.1172	147,50,51.4212	-	-	-	-	Gully	Erosion Gully.
123	3/12/11	1015	-20,40,14.6748	147,50,54.6612	-	-	-	-	-	Sandstone rock.
124	3/12/11	1016	-20,40,38.91	147,50,51.6408	-	Ridge			-	Top of ridge, shallow crusted soils.
126	4/12/11	1017	-20,41,6.2772	147,48,9.0288	-	-		Urochloa Grass, Box woodland	-	Sandy soil.
127	4/12/11	1018-1021	-20,41,14.19	147,48,10.206	-	-		Salt bush	-	Salt bush.
128	4/12/11	1022	-20,41,25.2708	147,48,3.402	Vertosol	-		Parthenium	-	Parthenium weed on Vertosol.
129	4/12/11	1023-1024	-20,41,49.4772	147,47,46.1688	-	-	-	-	Gully	Erosion gully.
131	4/12/11	1025-1026	-20,42,1.782	147,47,38.1912	-	-	-	-	Gully	Gully 2m wide and 1.5 m deep, levee on edge of gully.
132	4/12/11	1032-1033	-20,42,6.516	147,47,31.4772	-	Dam		-	-	Dam.
132	4/12/11	1027-1031	-20,42,6.516	147,47,31.4772	Brown Vertosol	Alluvial Fan		-	-	Brown Vertosol (alluvial fan).
133	4/12/11	1034-1035	-20,42,15.2568	147,47,27.5568	Black Vertosol	-		-	-	10YR4/2 Black Vertosol.
134	4/12/11	1037-1038	-20,42,19.17	147,47,27.8052	-	-	-	-	-	Brown loam soil on black clay in gully (5 m wide and 1.5 m depth).
134	4/12/11	1036	-20,42,19.17	147,47,27.8052	Black Vertosol	-	Grazing	-	-	Cattle on Black Vertosol.
135	4/12/11	1039	-20,42,23.8248	147,47,24.0288	-	-		-	-	Sandy loam to at least 40 cm deep.
135	4/12/11	1040	-20,42,23.8248	147,47,24.0288	-	-	Grazing	Box woodland	-	Cattle in open Box woodland.
136	4/12/11	1041-1042	-20,42,30.942	147,47,15.6588	-	30-50%	-	-	-	Steep scarp, rocky, (30-50% slope)
137	4/12/11	1043-1044	-20,42,31.4892	147,47,13.1928	Rudosol	Ridge	-	-	-	Sandy lithic Rudosol (hard ridge).
138	4/12/11	1045-1046	-20,42,33.336	147,47,7.188	-	Ridge	-	-	-	Loose sand below ridge.
139	4/12/11	1047-1048	-20,43,24.8988	147,47,6.648	-	Ridge	-	-	-	Sandy soil, below small stony ridge.
140	4/12/11	1049-1051	-20,43,26.7492	147,47,18.2508	-	-	-	*E. platyphylla*	-	Loamy sand soil opening up to the north with more heavy soil east of the ridge line.
141	4/12/11	1052-1053	-20,43,25.392	147,47,31.5312	-	-	-	-	-	Fine sandy loam (grey).
142	4/12/11	1054	582522.1998	7708498.828	Black Vertosol	-	-	-	-	Carbonate nodules on surface of Black Vertosol.
142	4/12/11	1055-1056	582522.1998	7708498.828	Black Vertosol	-	-	-	-	Gilgai puff. Black soil, pH 9.5, A1 light clay.
143	4/12/11	1057-1058	-20,43,15.9708	147,47,33.342	Black Vertosol	-	-	Cane grass	-	Melon hole country medium clay at the top (pH 6) graduating to heavy clay (B horizon). Black Vertosol.
144	4/12/11	1059-1061	-20,42,51.9588	147,47,38.5728	Black Vertosol	-	-	Mitchell grass	-	Mitchell grass on Black Vertosol.
145	4/12/11	1062-1064	-20,42,38.3112	147,47,42.0612	Brown Sodosol	-	-	-	-	Brown Sodosol.
146	4/12/11	1065-1066	-20,42,30.0528	147,47,43.8468	Brown Sodosol	-	-	-	-	Scald on Sodosol.
147	4/12/11	1067	-20,42,25.4628	147,47,48.2892	-	-	-	-	-	Sodic crust.
148	4/12/11	1068-1069	-20,42,24.858	147,47,50.2728	Brown Sodosol	-	-	-	Sheet erosion	Brown Sodosol affected by sheet erosion.
149	4/12/11	1070-1072	-20,42,21.564	147,47,56.1768	-	-	-	-	Sheet erosion	Soft scald with sheet erosion.
150	4/12/11	1073-1074	-20,42,16.4952	147,48,7.6392	Vertosol	-	-	-	-	10YR3/3 brown cracking Vertosol.
151	4/12/11	1075-1078	-20,42,14.508	147,48,11.592	Brown Sodosol	-	-	-	-	Brown Sodosol.
153	4/12/11	1079-1080	-20,42,9.8532	147,48,21.6108	Vertosol	3%	-	-	-	Cracking Vertosol clay.
154	4/12/11	1081-1082	-20,42,6.4188	147,48,30.8808	Black Vertosol	-	-	-	-	Black Vertosol.
155	4/12/11		-20,40.14800	147,47.22300	Brown Sodosol	VG, F	Grazing in remnant woodland on partially improved pastures	*Eucalyptus populnea* open woodland on light brown sandy clays, ground stratum of tussock grasses *(Pennisetum*, Urochloa** and *Bothriochloa*)	Small scalds in places	Low rolling hills to west of property on landzone 9. Likely brown sodosols. Mixed native and introduced pastures. Remnant vegetation. Minor erosion in drainage depressions. Occasional small scalds.
156	4/12/11		-20,40.78100	147,47.62200	Brown Sodosol		Grazing in remnant woodland on partially improved pastures	*Eucalyptus populnea* open woodland on light brown sandy clays, ground stratum of tussock grasses *(Pennisetum*, Urochloa** and *Bothriochloa*)	Minor gully erosion in drainagel depressions	Low rolling hills to west of property on landzone 9. Likely brown sodosols. Mixed native and introduced pastures. Remnant vegetation. Minor erosion in drainage depressions. Occasional small scalds.
157	4/12/11		-20,44.84400	147,49.40700	Brown Tensols and Rudosols		Grazing in remnant woodland on partially improved pastures	Mixed open woodland (*E. populnea, C. tessellaris, C. platyphylla, C. dallachiana*) on alluvial flats. Tussock ground stratum both native and introduced.	nil	Alluvial flats. Likely alluvial rudosols and tenosols. Remnant vegetation with mixed native and introduced pastures. No obvious erosion.
158	4/12/11		-20,44.82300	147,49.70900	Brown Tensols and Rudosols		Grazing in remnant woodland on partially improved pastures	Mixed open woodland (*E. tessellaris, C. platyphylla, C. dallachiana, E. crebra*) on alluvial flats. Tussock ground stratum both native and introduced.	nil	Alluvial flats. Likely alluvial rudosols and tenosols. Remnant vegetation with mixed native and introduced pastures. No obvious erosion.

Notes
"-"indicates no information was recorded

Ground Observation Location: GO#1





Australian Soil Classification	Vertosol
Date / Time	17 November 2009 / 1220
Slope	1%
Aspect	300^{o}
Elevation	153 m
Eastings / Northings	5837265 / 7718175
Depth to Free Water	None

Vegetation

Pasture with isolated trees. Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 90%.

Geology	Fine-grained sedimentary rocks
Landform	Flat
Surface Soil Condition	Periodic cracking
Runoff	Slow
Permeability	High
Drainage	Well drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Extensive clearing
Type of Observation	Auger boring

Soil Description

Topsoil: Light Clay, brown (10 YR 5/3 dry), dry, moderate pedality, 5-10 mm, subangular blocky, rough, moderate strength. High plasticity (normal), moderately sticky. Roots common. Depth ~0.18 m.

Comments

Stable surface, gilgai micro relief, macropores 10-20 mm wide.

Ground Observation Location: GO#2





Australian Soil Classification Vertosol

Site Details

Date / Time	17 November 2009 / 1320
Slope	1%
Aspect	30^{o}
Elevation	161 m
Eastings / Northings	584809 / 7717179
Depth to Free Water	None

Vegetation

Pasture with isolated trees. Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 90%.

Geology Fine-grained sedimentary rocks

Land surface

Landform	Mid slope
Surface Soil Condition	Periodic cracking
Runoff	Moderately rapid
Permeability	High
Drainage	Well drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Extensive clearing
Type of Observation	Existing vertical exposure

Soil Description

Not described

Comments

Stable surface, macropores 20-50 mm wide.

Ground Observation Location: GO#3 (TP2)





Australian Soil Classification Vertosol

Site Details

Date / Time	17 November 2009 / 1351
Slope	1%
Aspect	270^{o}
Elevation	173 m
Eastings / Northings	585379 / 7716309
Depth to Free Water	None

Vegetation

Pasture with isolated trees. Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 70%.

Geology Fine-grained sedimentary rocks

Land surface

Landform	Flat
Surface Soil Condition	Periodic cracking
Runoff	Moderately rapid
Permeability	High
Drainage	Well drained
Rock Outcrop	None
Erosion Activity	Partially stabilised
Wind Erosion	None
Water Erosion	Minor sheet
Gully Erosion Depth	None
Disturbance of Site	Extensive clearing
Type of Observation	Auger boring

Soil Description

Medium Clay, very dary grey (5Y 3/1 dry), dry, strong pedality, 10-20 mm, subangular blocky, rough, moderately firm strength. High plasticity (normal), moderately sticky. Trace manganese nodules < 5 mm. Field pH 7.0. Many roots. Depth ~0.1 m.

Comments

Stable surface, macropores 10-20 mm wide.

Ground Observation Location: GO#4





Australian Soil Classification Sodosols

Site Details

Date / Time	17 November 2009 / 1045
Slope	3%
Aspect	90^{o}
Elevation	165 m
Eastings / Northings	582985 / 7714343
Depth to Free Water	None

Vegetation

Dichanthium spp . and *Astrebla spp.* grassland; *Eucalyptus populnea* and *Acacia harpophylla* open forest; and *Eucalyptus crebra* woodland.

Geology Fine-grained sedimentary rocks

Land surface

Landform	Lower slope and gully drainage line
Surface Soil Condition	Hard setting
Runoff	Rapid
Permeability	Slow
Drainage	Poorly drained
Rock Outcrop	None
Erosion Activity	Active
Wind Erosion	None
Water Erosion	Severe sheet, rill, and gully
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Existing vertical exposure

Soil Description

Not described

Comments

Severe scalding present and loss of topsoil. Tunnel erosion of subsoil is evident. There are a lot of dead lot of dead trees along the drainage line.

Ground Observation Location: GO#5 / TP1





Australian Soil Classification	Dermosol
Date / Time	19 November 2009 / 0820
Slope	2%
Aspect	250^{o}
Elevation	187 m
Eastings / Northings	589376 / 7713518
Depth to Free Water	None

Vegetation

Eucalyptus populnea and *Acacia harpophylla* open forest; *Eucalyptus crebra* woodland; *Eucalyptus melanophloia* +/- *E. orgadophila* woodland . Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 90%.

Geology	Fine-grained sedimentary rocks
Land surface	
Landform	Crest
Surface Soil Condition	Firm
Runoff	Moderately rapid
Permeability	Moderate
Drainage	Well drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Auger boring

Topsoil Description

Sandy Clay Loam, dark brown (7.5YR 4/3 dry), dry, moderate pedality 10-20 mm, sub angular blocky, rough fabric, moderately weak strength, fine grained sand fraction. Non plastic, non sticky. Field pH 6.5. Estimated depth 0.16m.

Comments

Periodic surface cracking < 5mm.

Ground Observation Location: GO#6





Australian Soil Classification Sodosol

Site Details

Date / Time	18 November 2009 / 1630
Slope	4%
Aspect	100°
Elevation	135 m
Eastings / Northings	582183 / 7710705
Depth to Free Water	None

Vegetation

Dichanthium spp. and *Astrebla spp.* grassland; *Eucalyptus populnea* and *Acacia harpophylla* open forest; and *Eucalyptus crebra* woodland. Groundcover is approximately 95%.

Geology Fine-grained sedimentary rocks

Land surface

Landform	Mid slope
Surface Soil Condition	Soft
Runoff	Rapid
Permeability	Slow
Drainage	Poorly drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	Minor sheet
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Auger boring

Soil Description

Topsoil: Clayey Sand, yellowish brown (10YR 5/4 dry), dry, weak pedality 2-5 mm, angular blocky, sandy fabric, moderately weak strength, fine grained, subangular. Non plastic, non sticky. Roots common. Field pH 5.5. Depth ~0.2 m.

Subsoil: Light Clay, brown with red mottle (7.5YR 5/4; 10R 4/8; dry) , dry, very strong strength, moderate plasticity, moderately sticky. Few roots. Field pH 5.5.

Comments

Stable surface.

Ground Observation Location: GO#7





Australian Soil Classification	Dermosol
Date / Time	17 November 2009 / 1500
Slope	2%
Aspect	280^{o}
Elevation	170 m
Eastings / Northings	583284 / 7711988
Depth to Free Water	None

Vegetation

Eucalyptus populnea and *Acacia harpophylla* open forest; *Eucalyptus crebra* woodland; *Eucalyptus melanophloia* +/- *E. orgadophila* woodland . Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 90%.

Geology	Fine-grained sedimentary rocks
Land surface	
Landform	Crest
Surface Soil Condition	Firm
Runoff	Moderately rapid
Permeability	Moderate
Drainage	Moderately well drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Auger boring

Topsoil Description

Light Clay, dark brown (10YR 3/3 dry), dry, moderate pedality 2-5 mm, sub angular blocky, rough fabric, moderately form strength, fine grained sand fraction. Moderate-high plasticity (normal), very sticky. Field pH 6.5

Comments

Periodic surface cracking < 5mm. Coarse fragments across surface < 2 % abundance, 200-600 mm diameter, subrounded.

Ground Observation Location: GO#8





Australian Soil Classification Vertosol

Site Details

Date / Time	17 November 2009 / 1440
Slope	1%
Aspect	20 ^{o}
Elevation	149 m
Eastings / Northings	586914 / 7711095
Depth to Free Water	None

Vegetation

Pasture with isolated trees. Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 90%.

Geology Fine-grained sedimentary rocks

Land surface

Landform	Flat
Surface Soil Condition	Periodic cracking
Runoff	Moderately rapid
Permeability	High
Drainage	Well drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Extensive clearing
Type of Observation	Existing vertical exposure

Topsoil Description

Not described

Comments

Stable surface, macropores 20-50 mm wide. Adacant drainage line is partially stabilised with some minor streambank erosion.

Ground Observation Location: GO#9





Australian Soil Classification	Dermosol
Date / Time	17 November 2009 / 1620
Slope	2%
Aspect	270^{o}
Elevation	179 m
Eastings / Northings	589015 / 7712098
Depth to Free Water	None

Vegetation

Eucalyptus populnea and *Acacia harpophylla* open forest; *Eucalyptus crebra* woodland; *Eucalyptus melanophloia* +/- *E. orgadophila* woodland . Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 85%.

Geology	Fine-grained sedimentary rocks
Land surface	
Landform	Crest
Surface Soil Condition	Firm
Runoff	Moderately rapid
Permeability	Moderate
Drainage	Well drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Auger boring

Soil Description

Topsoil: Light Clay, dark brown (10YR 3/3 dry), dry, moderate pedality 5-10 mm, sub angular blocky, rough fabric, moderately firm strength, fine grained sand fraction. Moderate plasticity (normal), slightly sticky. Field pH 6.5. Depth ~0.15 m. Common roots.

Comments

Periodic surface cracking < 5mm.

Ground Observation Location: GO#10





Australian Soil Classification Vertosol

Site Details

Date / Time	18 November 2009 / 1530
Slope	1%
Aspect	290^{o}
Elevation	134 m
Eastings / Northings	583512 / 7709876
Depth to Free Water	None

Vegetation

Pasture with isolated trees. Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 80%.

Geology Fine-grained sedimentary rocks

Land surface

Landform	Flat
Surface Soil Condition	Periodic cracking
Runoff	Moderately rapid
Permeability	High
Drainage	Well drained
Rock Outcrop	None
Erosion Activity	Partially stabilised
Wind Erosion	None
Water Erosion	Minor sheet
Gully Erosion Depth	None
Disturbance of Site	Extensive clearing
Type of Observation	Auger boring

Soil Description

Topsoil: Light Medium Clay, dark brown (7.5Y 4/2 dry), dry, strong pedality, 10-20mm, subangular blocky, rough, moderately firm strength. High plasticty (normal), moderately sticky. Field pH 6.5. Many roots. Depth ~ 0.1m.

Comments

Stable surface with cracks 10-20 mm wide.

Ground Observation Location: GO#11





Australian Soil Classification Rudosol

Site Details

Date / Time	18 November 2009 / 1320
Slope	1%
Aspect	200°
Elevation	138 m
Eastings / Northings	585268 / 7707026
Depth to Free Water	None

Vegetation

Eucalyptus crebra and *Corymbia dallachiana* woodland; *Eucalyptus platyphylla* and *Corymbia spp.* woodland; *Eucalyptus tereticornis* and/or *Eucalyptus spp.* tall woodland. Groundcover is approximately 95%.

Geology Floodplain complexes on Cainozoic alluvial plains.

Land surface

Landform	Flat
Surface Soil Condition	Loose
Runoff	Slow
Permeability	High
Drainage	Rapidly drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Auger boring

Soil Description

Topsoil: Sand, dark brown (10YR 3/3 dry), dry, weak pedality 2-5 mm, angular blocky, sandy fabric, fine to coarse grained, poorly sorted. Trace fine gravel, subrounded. Common roots. Field pH 6.5. Depth ~0.3 m.

Subsoil: Sand, light yellowish brown (10YR 6/4 dry), dry, apedal single, fine to coarse grained, poorly sorted. Trace fine gravel, subrounded. Common roots. Field pH 6.5. Depth >0.9 m.

Comments Stable surface.

Ground Observation Location: GO#12





Australian Soil Classification Dermosol

Date / Time	18 November 2009 / 0830
Slope	1%
Aspect	300°
Elevation	159 m
Eastings / Northings	588574 / 7706673
Depth to Free Water	None

Vegetation

Eucalyptus populnea and *Acacia harpophylla* open forest; *Eucalyptus crebra* woodland; *Eucalyptus melanophloia* +/- *E. orgadophila* woodland . Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 85%.

Geology Fine-grained sedimentary rocks

Land surface

Landform	Upper slope
Surface Soil Condition	Firm
Runoff	Moderately rapid
Permeability	Moderate
Drainage	Well drained
Rock Outcrop	None
Erosion Activity	Partially stabilised
Wind Erosion	None
Water Erosion	Moderate sheet
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Auger boring

Soil Description

Topsoil: Sandy Clay Loam, dark brown (7.5YR 4/3 dry), dry, moderate pedality 10-20 mm, subangular blocky, rough fabric, moderately firm strength, fine grained sand fraction. Low plasticity (normal), slightly sticky. Field pH 6.5.

Comments

Coarse fragments across surface < 2-10 % abundance, 5-200 mm diameter, subrounded.

Ground Observation Location: GO#13





Australian Soil Classification Sodosol

Site Details

Date / Time	18 November 2009 / 1420
Slope	1%
Aspect	60^{o}
Elevation	133 m
Eastings / Northings	582197 / 7705287
Depth to Free Water	None

Vegetation

Eucalyptus crebra and *Corymbia dallachiana* woodland; *Eucalyptus platyphylla* and *Corymbia spp* . woodland; *Eucalyptus tereticornis* and/or *Eucalyptus spp.* tall woodland. Groundcover is approximately 95%.

Geology Floodplain complexes on Cainozoic alluvial plains.

Land surface

Landform	Flat
Surface Soil Condition	Firm
Runoff	Moderately rapid
Permeability	Slow
Drainage	Poorly drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Auger boring

Soil Description

Topsoil: Sandy Loam, dark brown (7.5YR 4/2 dry), dry, moderate weak pedality 10-20 mm, subangular blocky, sandy fabric, moderately weak strength, fine grained sand. Non plastic, very sticky. Many roots. Field pH 6.5. Depth ~0.25m.

Subsoil: Light Clay, yellowish brown (10YR 5/4 dry), dry, apedal massive, moderate plasticity (normal), very sticky. Few roots. Field pH 6.5.

Comments

Stable surface.

Ground Observation Location: GO#14 (TP3)





Australian Soil Classification Sodosol

Site Details

Date / Time	19 November 2009 / 1330
Slope	1%
Aspect	230°
Elevation	174 m
Eastings / Northings	582266 / 7713721
Depth to Free Water	None

Vegetation

Eucalyptus populnea and *Acacia harpophylla* open forest; and *Eucalyptus crebra* woodland. Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 85%.

Geology Fine-grained sedimentary rocks

Land surface

Landform	Upper slope
Surface Soil Condition	Loose
Runoff	Moderately rapid
Permeability	Slow
Drainage	Imperfectly drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Soil pit

Topsoil Description

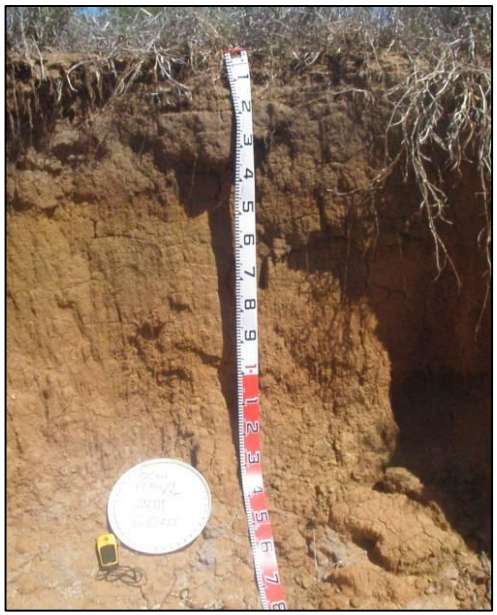
Loamy Sand, light yellowish brown (10YR 6/4 dry), dry, weak pedality 10-20 mm, angular blocky, sandy fabric, moderately weak strength, fine grained sand, non plastic. Field pH 6.0. Depth ~0.35 m.

Comments

Stable surface in the observation area; however there was evidance of severe rill and gully erosion at lower portions of the slope.

Ground Observation Location: GO#15





Australian Soil Classification	Sodosols
Date / Time	17 November 2009 / 0940
Slope	2%
Aspect	120^{o}
Elevation	162 m
Eastings / Northings	583450 / 7714297
Depth to Free Water	None

Vegetation

Eucalyptus populnea and *Acacia harpophylla* open forest; and *Eucalyptus crebra* woodland. Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 90%.

Geology	Fine-grained sedimentary rocks
Land surface	
Landform	Mid slope
Surface Soil Condition	Hard setting
Runoff	Moderately rapid
Permeability	Slow
Drainage	Poorly drained
Rock Outcrop	None
Erosion Activity	Active
Wind Erosion	None
Water Erosion	Severe sheet, rill, and gully
Gully Erosion Depth	1.5-3.0 m
Disturbance of Site	Limited clearing
Type of Observation	Existing vertical exposure

Soil Description

Topsoil: Sandy Clay Loam, yellowish brown (10YR 5/4 dry), dry, weak pedality 10-20 mm, subangular blocky, sandy fabric, fine grained, subangular. Moderately firm strength, low plasticity. Common roots. Field pH 6.5. Depth 0.19m.

Subsoil: Light Clay, brownish yellow and red mottle (10YR 6/6, 10R 5/6, dry), dry, apedal massive,earthy fabric. Few roots.

Comments

Gully development continues down to the underlying siltstone/mudstone at ~2.0m. Erosion is partially stabilised.

Ground Observation Location: GO#16





Australian Soil Classification Sodosols

Site Details

Date / Time	17 November 2009 / 1120
Slope	2%
Aspect	160°
Elevation	168 m
Eastings / Northings	583193 / 7714380
Depth to Free Water	None

Vegetation

Eucalyptus populnea and *Acacia harpophylla* open forest; and *Eucalyptus crebra* woodland. Groundcover is tussocking grass, predominately buffel (*Cenchrus ciliaris*), with an estimated coverage of 90%.

Geology Fine-grained sedimentary rocks

Land surface

Landform	Mid slope
Surface Soil Condition	Soft
Runoff	Moderately rapid
Permeability	Slow
Drainage	Imperfectly drained
Rock Outcrop	None
Erosion Activity	Stabilised
Wind Erosion	None
Water Erosion	None
Gully Erosion Depth	None
Disturbance of Site	Limited clearing
Type of Observation	Auger boring

Soil Description

Topsoil: Loamy Sand, brown (10YR 5/3 dry), dry, weak pedality 5-10 mm, angular blocky, sandy fabric, fine grained, subangular. Field pH 6.0. Depth ~0.32m.

Comments

Stable surface.

Appendix B

Soil Profile Descriptions

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

Soil Survey Worksheet

Location:	(P604 – 610) G2	Date:	30/11/2011
Assessors:	BOLM HANR LAWS	Site Number:	C1

Location Characteristics

Geology and Topography Observations	Greatly inclined upper reaches of land open depression
Landuse and Vegetation Observations	Scattered trees (Mountain Coolibah, Acacia) Buffel grass → Grazing

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Black Vertisol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Friable with Cracks.			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor Water Sheeting			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine + abundant in A1 / few to 120 CM			
Horizon Layer (Layers in Profile)	1 A1	2 A2	3 B1	4 B2
Horizon Depth CM (eg 0.00 to 0.15m)	0-15	15-45	45-80	80-120.
Sample Depth Range (m) CM (eg 0.05 to 0.10m)	0-15	(15-25)(25-35)	(35-55)(55-65)	((65-80)(80-120))
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Dry	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	7.5 YR 3/1 BL	BL	Dark grey	Dark greyish brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Poor	Poor	Poor
Field Texture Grade (sand/silt/clay)	MC	HC	HC	HC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	50-100	100-200	100-200	100-200
Structure Ped Shape (platy, prismatic, blocky, round, etc)	AB.	PR	PR	AB.
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	5% Scattered Mudstone to 200MM	10% Isolated Ironstone	20% Weathered Siltstone	20% Weathered Siltstone
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	C	C
Boundary Shape (even, wavy, irregular, broken)	W	W	W	I

Field Comments

Weathered Siltstone at 1.2 M. Roots present to Weathered rock. Scattered stones on surface.
A1 = pH 8.5 B1 = pH 8.0
A2 = pH 9.0 B2 = pH 7.5.

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Soil Survey Worksheet

Location:	614 – 619 G4.	Date:	30/11/2011
Assessors:	BOLM HANR LAWJ	Site Number:	C2.

Location Characteristics

Geology and Topography Observations	Ridge 1% slope Weathered mudstone at 55 cm.
Landuse and Vegetation Observations	Mountain Coolibah, Ironbark, Buffel grass – grazing

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Shallow Brown Dermosol.			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Surface crust (vesicular)			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Water sheeting			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Roots to 55 CM			
Horizon Layer (Layers in Profile)	A1-A2 [1]	[2] B21	B22 [3]	Weathered Rock
Horizon Depth (eg 0.00 to 0.15m) CM	0-5	5-25	25-55	55-
Sample Depth Range (m) (eg 0.05 to 0.10m) CM	0-5	5-25	25-55	55-65
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Dry	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Brown 7.5YR4/2	Brown 7.5YR4/4	Strong Brown 7.5YR5/6	–
Mottle Characteristics (% & Colour)	–	–	–	–
Drainage (Poor, Moderate, Well, Rapid)	Poor	Poor	Moderate	–
Field Texture Grade (sand/silt/clay)	SCL	ZC.	LC.	–
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	W	–
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20	20-50	2-5	–
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL.	AB.	PO.	–
Consistence Force (weak, moderate, strong)	Moderate	Strong	Moderate	–
Seggregations (Type and amount %)	–	–	–	–
Stones - Type & Amount (Type and amount %)	–	–	–	–
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	–
Boundary Shape (even, wavy, irregular, broken)	W	C	I	–

Field Comments

A1-A2 = 6.5 pH.
B21 = 7.0 pH.
B22 = 8.5 pH.

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Soil Survey Worksheet

Location:	620 – 627. G5.	Date:	30/11/2011
Assessors:	BCM, HANR, LAWJ.	Site Number:	C3.

Location Characteristics

Geology and Topography Observations	Broad ridge – Weathered sandstone over Siltstone
Landuse and Vegetation Observations	Ironbark, Bloodwood, Buffelgrass grazing.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Lithic Tenosol or very Shallow Brown Dermosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Surface Crust (vesicular)			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor water sheeting			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Medium roots to 30cm / Fine roots to 60cm			
Horizon Layer (Layers in Profile)	A1 [1]	B21 [2]	B22. [3]	[4]
Horizon Depth (eg 0.00 to 0.15m) CM	0-10	10-20	20-30	
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	10-20	25-35	
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Dry	Dry	Dry	
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown 7.5 YR 3/2	Dark Brown 7.5 YR 3/3	Brown with orange mottles 30%	
Mottle Characteristics (% & Colour)	–	–	ORANGE Mottles 30%.	
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Poor	Poor.	
Field Texture Grade (sand/silt/clay)	ZCL	ZC	SCL.	
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	
Structure Ped Size (mm) (eg 10 to 20 mm)	20-50.	50-100	10-20.	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	AB	AB.	
Consistence Force (weak, moderate, strong)	Strong	Strong	Moderate	
Seggregations (Type and amount %)	–	–	Ca_2CO_3 (30%)	
Stones - Type & Amount (Type and amount %)	–	–	–	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	C	C.	
Boundary Shape (even, wavy, irregular, broken)	E	E	E.	

Field Comments

Weathered sandstone beyond 30 CM.

1 CM Cracks in surface of soil.

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Soil Survey Worksheet

Location: 634-39 G9.	Date: 30/11/2011
Assessors: BaM HANK LANJ.	Site Number: C4.

Location Characteristics

Geology and Topography Observations	Scattered stones on surface, namely Sandstone, petrified wood. · Elevated ridge
Landuse and Vegetation Observations	Prickly Acacia, Brigalow Buffel grass - Grazing.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Red Dermosol (Shallow)		
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		Friable		
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		Minor Sheet erosion		
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		Roots to 60 cm		
Horizon Layer (Layers in Profile)	1 A1	2 B2	B/C 3	Weathered Sandstone
Horizon Depth CM (eg 0.00 to 0.15m)	0-10	10-25	25-40	40-
Sample Depth Range (m) CM (eg 0.05 to 0.10m)	0-10	10-25	25-35	-
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Dry	Dry	Dry	-
Field Colour (brown, red, yellow, yellowish brown)	Brown 7.5YR 4/3	Reddish Brown 5YR 4/3	Strong Brown 7.5YR 4/6.	-
Mottle Characteristics (% & Colour)	-	-	-	-
Drainage (Poor, Moderate, Well, Rapid)	Well	Well	Well	-
Field Texture Grade (sand/silt/clay)	Sandy Clay	MC	Sandy Clay	-
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	M	-
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20	10-20.	5-10.	-
Structure Ped Shape (platy, prismatic, blocky, round, etc)	SB	AB	PO.	-
Consistence Force (weak, moderate, strong)	Strong	Strong	Moderate	-
Seggregations (Type and amount %)	-	-	<5% Manganese nodules	-
Stones - Type & Amount (Type and amount %)	-	-	-	-
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	C	C	-
Boundary Shape (even, wavy, irregular, broken)	E	E	W.	-

Field Comments

A1 = pH 7.0
B2 = pH 7.0.
B/C = pH 7.0.

Weathered Rock pH. 8.5

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Soil Survey Worksheet

Location:	640 - 642. C10.	Date:	30/11/2011
Assessors:	BdM, HANR, LANR.	Site Number:	C5

Location Characteristics

Geology and Topography Observations	Minor gilgai (Melon hole) on an elevated ridge. Calcareous Silt Stone.
Landuse and Vegetation Observations	Brigalow, Prickly Acacia, Buffel grass - grazing.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Black vertosol		
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		Friable and Cracking		
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		Nil		
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		fine roots to 100cm		
Horizon Layer (Layers in Profile)	A1 1	B1 2	B21 3	B22 4
Horizon Depth CM (eg 0.00 to 0.15m)	0-25	25-65	65-80	80-95
Sample Depth Range (m) CM (eg 0.05 to 0.10m)	0-25	(25-35)(35-55)	(65-80)(55-65)	80-95
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Dry	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown 7.5YR 3/3	Dark Brown 7.5YR 3/2.	Very Dark Grey 7.5YR 3/1	Dark Reddish Brown 5YR 3/4
Mottle Characteristics (% & Colour)	—	20% Red Mottle	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Poor	Poor	Poor.
Field Texture Grade (sand/silt/clay)	MC.	MHC.	HC	MC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	M
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20	20-50	20-50	10-20.
Structure Ped Shape (platy, prismatic, blocky, round, etc)	AB	AB	AB	Po.
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	Strong.
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	G	C	C
Boundary Shape (even, wavy, irregular, broken)	W	W	E	E

Field Comments

Scattered Sandstone Rocks (100-300 mm) on Soil Surface.

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Soil Survey Worksheet

Location:	643- 649 G11	Date:	30/11/2011
Assessors:	BCM, HANR, LANJ	Site Number:	C6.

Location Characteristics

Geology and Topography Observations	Elevated, gentle slope. Calcereous Siltstone.
Landuse and Vegetation Observations	Whitewood, Prickly Acacia, Buffel grass. grazing! (Crabhole country - J. Lawrie)

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Black Vertosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Friable, Cracking			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil.			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Coarse roots to 60cm, fine roots to 85cm			
Horizon Layer (Layers in Profile)	1 A1	B11 2	B12 3	B2 4
Horizon Depth (eg 0.00 to 0.15m) CM	0-10	10-35	35-65	65-85
Sample Depth Range (m) (eg 0.05 to 0.10m) CM	0-10	(10-25)(25-35)	(35-55)(55-65)	(65-85)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Dry	Moist	Moist	Moist
Field Colour (brown, red, yellow, yellowish brown)	Brown 7.5 YR 4/2	7.5YR 4/2	7.5 YR 4/2	Dark greyish brown 10YR 4/2.
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Poor	Poor.
Field Texture Grade (sand/silt/clay)	MC	HC	HC	HC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20	20-50	20-50	10-20.
Structure Ped Shape (platy, prismatic, blocky, round, etc)	AB	AB	AB	PO.
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	Iron stone 10%.	Ironstone 10%.
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	G	C
Boundary Shape (even, wavy, irregular, broken)	W	W	W	W

Field Comments

Weathered rock beyond 85 cm.

0-25 = pH 7
25-35 = pH 8-5
35-55 = pH 8
55-65 = pH 8.

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Soil Survey Worksheet

Location:	650 - 654 G12	Date:	30/11/2011
Assessors:	BOLM, HANR, LANJ	Site Number:	C7

Location Characteristics

Geology and Topography Observations	Slope-Gentle (1%), rolling
Landuse and Vegetation Observations	Brigalow, Whitewood. Prickly Acacia, Buffel grass - grazing.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Shallow Black Vertosol		
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		Friable, Cracking		
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		Nil		
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		Fine roots to 60cm		
Horizon Layer (Layers in Profile)	A1 1	B11 2	B12 3	4
Horizon Depth (eg 0.00 to 0.15m) CM	0-10	10-25	25-65	
Sample Depth Range (m) (eg 0.05 to 0.10m) CM	0-10	(10-25) (25-35) (35-55) (55-65)		
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Dry	Dry	Mod. Moist	
Field Colour (brown, red, yellow, yellowish brown)	Dark greyish Brown 10YR 4/2	10YR 4/2	10YR 4/2.	
Mottle Characteristics (% & Colour)	-	-	-	
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Poor	Poor.	
Field Texture Grade (sand/silt/clay)	MC	HC	HC.	
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20	10-20	20-50	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	AB	PR	PR.	
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	
Seggregations (Type and amount %)	-	-	-	
Stones - Type & Amount (Type and amount %)	-	-	-	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	G	D.	
Boundary Shape (even, wavy, irregular, broken)	E	W	I.	

Field Comments

Weathered Siltstone > 65 cm

0-10 = pH 7.5 35-55 = pH 8.0.
10-25 = pH 8.0. 55-65 = pH 9.0.
25-35 = pH 8.0.

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Soil Survey Worksheet

Location:	655 - 659 G 13.	Date:	30/11/2011
Assessors:	BoLM, HANK, LANJ.	Site Number:	CK.

Location Characteristics

Geology and Topography Observations	Flat, interfluve Deposition zone (layer 1+2 deposited over last 100 years)
Landuse and Vegetation Observations	Bunhinia, Brigalow, Whitewood Buffel grass - grazing.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Recent Alluvium - Overlying Black Vertosol				
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Crusted				
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil				
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Fine roots to 70cm				
Horizon Layer (Layers in Profile)	Layer 1[1]	Layer 2[2]	A1 [3]	B1 [4]	B2.
Horizon Depth (eg 0.00 to 0.15m) CM	0-15	15-35	35-65	65-85	85-130
Sample Depth Range (m) (eg 0.05 to 0.10m) CM	0-10	(10-25)	(25-35)	(35-55) (55-65)	(65-85) (85-130)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Dry	Dry	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Brown 7.5YR 4/2	Brown 7.5YR 4/3	Very dark Brown 7.5YR 2.5/2	Dark Brown 7.5YR 3/2	Brown 7.5YR 4/2
Mottle Characteristics (% & Colour)	—	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Poor	Poor	Poor	Poor	Poor
Field Texture Grade (sand/silt/clay)	ZCL.	LC	MC	HC	MHC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	5-10	10-20.	20-50	10-20	10-20
Structure Ped Shape (platy, prismatic, blocky, round, etc)	AB	AB	AB	AB	AB
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	C	C	C
Boundary Shape (even, wavy, irregular, broken)	W	I	E	E	E

Field Comments
0-10 = pH 8
10-25 = pH 8
25-35 = pH 7.5
35-65 = pH 7.5
65-85 = pH 8.0
85-130 = pH 8.0

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Soil Survey Worksheet

Location:	686-692 G25	Date:	2/12/11
Assessors:	BoLM, HANR, LAWJ	Site Number:	C9

Location Characteristics

Geology and Topography Observations	Crest
Landuse and Vegetation Observations	Box tree open woodland, currant bush Buffel Grass, Bauhinia

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Soft			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Roots to 65cm			
Horizon Layer (Layers in Profile)	A1	B21	B22	4
Horizon Depth (eg 0.00 to 0.15m)	0-25	25-50	50-65	
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-25	25-35	(35-55)(55-65)	
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown (7.5YR3/4)	Brown (7.5YR5/4)	Brown	
Mottle Characteristics (% & Colour)	—	—	—	
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Poor	Poor	
Field Texture Grade (sand/silt/clay)	LS	Sandy Clay	Clay	
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	S	S	
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5mm	20-50mm	20-50mm	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	SB	SB	
Consistence Force (weak, moderate, strong)	weak	Strong	Strong	
Seggregations (Type and amount %)	—	—	—	
Stones - Type & Amount (Type and amount %)	—	—	—	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	A	A	A	
Boundary Shape (oven, wavy, irregular, broken)	W	W	W	

Field Comments: Duplex soil
Weathered sandstone (red) below 65cm

A1 = pH 6
B21, B22 = pH 6.5

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Soil Survey Worksheet

Location:	698-703 G29	Date:	2/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C 10

Location Characteristics

Geology and Topography Observations	Upper Slope Gully
Landuse and Vegetation Observations	Box woodland Buffel grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Yellow/brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Severe gully erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 60cm			
Horizon Layer (Layers in Profile)	A1	A2	B21	B22
Horizon Depth (eg 0.00 to 0.15m)	0-22	22-35	35-55	55-85
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-22	22-35	35-55	(55-65)(65-80)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Brown (7.5YR4/3)	7.5YR7/3	10YR4/4	10YR4/4
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Poor	Poor
Field Texture Grade (sand/silt/clay)	SCL	SL	Clay	Clay
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	W	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5mm	2-5	200-500mm	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PL	AB	AB
Consistence Force (weak, moderate, strong)	weak	weak	strong	strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

Highly erodible Soil Sodicity present.

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Soil Survey Worksheet

Location:	704 - 709 G30	Date:	2/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C11

Location Characteristics

Geology and Topography Observations	Midslope 3-5%.
Landuse and Vegetation Observations	Currant bush Bloodwood, Ironbark Buffelgrass.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Yellow/brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 80cm			
Horizon Layer (Layers in Profile)	A1	A2	B21	B22
Horizon Depth (eg 0.00 to 0.15m)	0-20	20-50	50-70	70-85
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-20	25-35	35-55 (55-65)	65-80
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	7.5YR 4/3	7.5YR 7/3	10YR 4/4	10YR 4/4
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Poor	Poor
Field Texture Grade (sand/silt/clay)	SCL	SL	Clay	clay
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5mm	20-50mm	20-50mm	20-50mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	AB	AB	AB
Consistence Force (weak, moderate, strong)	weak	strong	strong	strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

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Soil Survey Worksheet

Location: 710 - 716 G31	Date: 2/12/11
Assessors: BOLM, HANR, LAWJ	Site Number: C12

Location Characteristics

Geology and Topography Observations	Upper Slope of ridge (2% slope)
Landuse and Vegetation Observations	Cassia brewsteri Open Box woodland Buggel Grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	minor water erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 80cm			
Horizon Layer (Layers in Profile)	A1	A2	B21	B22
Horizon Depth (eg 0.00 to 0.15m)	0-13	13-25	25-45	45-65
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-13	13-25	(25-35)(35-55)	55-65
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Moist	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	7.5YR4/3	7.5YR5/4(dry)	Brown	Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Poor	Poor
Field Texture Grade (sand/silt/clay)	LS	SL	Clay	Clay
Structure Pedality Grade (Apedal or weak/moderate/strong)	weak	weak	strong	strong
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5mm	2-5mm	20-50mm	20-50mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PL	AB	AB
Consistence Force (weak, moderate, strong)	weak	weak	strong	strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	C	C
Boundary Shape (even, wavy, irregular, broken)	W	W	E	E

Field Comments

Weather rock at 65cm

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Soil Survey Worksheet

Location: 717 - 721 G32	Date: 2/12/11
Assessors: BOLM, HANR, LAWJ	Site Number: C13

Location Characteristics

Geology and Topography Observations	Eroded Gully
Landuse and Vegetation Observations	Eucalyptus platyphylla, Box Buffel grass, Cassia brewsteri

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Sodic Brown Kandosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Severe gully erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	large roots to 110cm			
Horizon Layer (Layers in Profile)	A1	A2	B2	4
Horizon Depth (eg 0.00 to 0.15m)	0-13	13-45	45-110	
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-13	(13-25)(25-35)	(55-65)(65-110)	
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Moist	Dry	
Field Colour (brown, red, yellow, yellowish brown)	redish Brown	Lighter redish brown	Yellow brown 10YR 4/6	
Mottle Characteristics (% & Colour)	—	—	—	
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Poor	
Field Texture Grade (sand/silt/clay)	LS	SL	LS	
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	M	S	
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5mm	20-50mm	200-500mm	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	SB	SB	
Consistence Force (weak, moderate, strong)	Weak	Moderate	strong	
Seggregations (Type and amount %)	—	—	—	
Stones - Type & Amount (Type and amount %)	—	—	—	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	
Boundary Shape (even, wavy, irregular, broken)	E	E	E	

Field Comments

weatted rock at 110cm

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Soil Survey Worksheet

Location: 726 - 731 G35	Date: 2/12/11
Assessors: BOLM, HANR, LAUT	Site Number: C14

Location Characteristics

Geology and Topography Observations	Swale
Landuse and Vegetation Observations	Open Box woodland Buffel Grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Roots to 80 cm			
Horizon Layer (Layers in Profile)	A1	A2	B21	B22
Horizon Depth (eg 0.00 to 0.15m)	0-12	12-25	25-35	35-90
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-12	12-25	(25-35)(35-55)	(55-90)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Moist	Moist	Moist
Field Colour (brown, red, yellow, yellowish brown)	Brown	light Brown	Dark Brown	Yellow brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Well	Poor	Poor
Field Texture Grade (sand/silt/clay)	LS	S	MC	MC
Structure Pedality Grade (Apedal or weak/moderate/strong)	Apedal-loose	Apedal-loose	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	—	—	20-50mm	20-50mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	—	—	SB	SB
Consistence Force (weak, moderate, strong)	weak	weak	strong	strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	some sandstone
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	C	C
Boundary Shape (even, wavy, irregular, broken)	W	W	E	E

Field Comments: Bottom 20cm (70-90cm) has red Weathered sandstone

Weathered sandstone beyond 90cm

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Soil Survey Worksheet

Location: 736 - 763. G 39	Date: 2/12/2011
Assessors: BOLM & HARR & SLAWJ	Site Number: C15.

Location Characteristics

Geology and Topography Observations	Flat
Landuse and Vegetation Observations	Brigalow, Box, Cassia brewsteri, Bauhinia, Buffel grass, grazing

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Black Vertosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		Friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		Roots to 90CM			
Horizon Layer (Layers in Profile)	A1 1	A2. 2	B1 3	B2.1 4	B22
Horizon Depth CM (eg 0.00 to 0.15m)	0-15	15-35	35-65	65-90.	90-140.
Sample Depth Range (m) CM (eg 0.05 to 0.10m)	0-15	(15-35)(25-35)	(35-55)(55-65)	65-90	90-140
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	Moist	Moist
Field Colour (brown, red, yellow, yellowish brown)	Black	Dark Grey	Dark Brown	Brown	Brown ORANGE 60%.
Mottle Characteristics (% & Colour)	—	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Poor	Poor	Poor	Poor
Field Texture Grade (sand/silt/clay)	LMC	HC	HC	HC	HC.
Structure Pedality Grade (Apedal or weak/moderate/strong)	M	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20	10-20.	20-50	20-50	20-50.
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PR	PR	PR	PR	PR.
Consistence Force (weak, moderate, strong)	Moderate	Strong	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—	gypsum 10%
Stones - Type & Amount (Type and amount %)	—	ferricrete gravel 10%	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	W	W	W	W	W.

Field Comments

Gypsum (Calcium Sulphate) at 120CM.

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Soil Survey Worksheet

Location:	744 - 748 G40	Date:	2/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C16

Location Characteristics

Geology and Topography Observations	Swale
Landuse and Vegetation Observations	Open Box woodland Grazing, Buffel Grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	minor water erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 100cm			
Horizon Layer (Layers in Profile)	A1	A2	B21	B22
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-30	30-60	60-100
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	(10-25) (25-35)	(35-55) (55-65)	(65-100)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Dark Brown	Dark Brown	Strong Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	well	Poor	Poor
Field Texture Grade (sand/silt/clay)	LS	SL	MC	MC
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	W	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	5-10mm	5-10mm	20-50mm	20-50mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PL	SB	SB
Consistence Force (weak, moderate, strong)	weak	weak	strong	strong
Seggregations (Type and amount %)	—	—	—	carbonates 10%
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	C	C
Boundary Shape (even, wavy, irregular, broken)	I	I	E	E

Field Comments

Weathered sandstone at 100cm

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Soil Survey Worksheet

Location:	749 - 755 G41	Date:	2/12/2011
Assessors:		Site Number:	C17.

Location Characteristics

Geology and Topography Observations	Mid slope 2%.
Landuse and Vegetation Observations	Open Box Woodland, Grazing

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	roots to 65cm			
Horizon Layer (Layers in Profile)	A1 1	A2 2	B21 3	B22 4
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-30	30-45	45-65.
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	10-30	30-45	45-65
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Moist	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Dark Brown	Dark Brown	Yellowish Brown
Mottle Characteristics (% & Colour)	—	—	10% Orange	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Well	Poor	Poor
Field Texture Grade (sand/silt/clay)	loamy sand	loamy sand	Sandy Clay	Sandy Clay.
Structure Pedality Grade (Apedal or weak/moderate/strong)	weak	weak.	Strong	Strong.
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5	2-5.	20-50	20-50.
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PL	AB	AB.
Consistence Force (weak, moderate, strong)	Weak	Weak	Strong	Strong.
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	C	C.
Boundary Shape (even, wavy, irregular, broken)	W	W	E	E

Field Comments

- Weathered red lithic rock >65cm
- Duplex Soil.

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Soil Survey Worksheet

Location:	756 - 761 G42	Date:	2/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C18

Location Characteristics

Geology and Topography Observations	Elevated Ridge
Landuse and Vegetation Observations	Box woodland, Currant Bush, whitewood, Brigalow, Cassia brewsteri, Buffel grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	minor water erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Fine roots to 70cm			
Horizon Layer (Layers in Profile)	A1	B21	B22	4
Horizon Depth (eg 0.00 to 0.15m)	0-25	25-55	55-75	
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-25	(25-35)(35-55)	(55-65)(65-75)	
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	
Field Colour (brown, red, yellow, yellowish brown)	Brown	Dark Brown	Orangey brown	
Mottle Characteristics (% & Colour)	—	—	—	
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Poor	Poor	
Field Texture Grade (sand/silt/clay)	LS	Sandy Clay	Sandy Clay	
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	S	S	
Structure Ped Size (mm) (eg 10 to 20 mm)	5-10mm	20-50mm	20-50mm	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	SB	SB	
Consistence Force (weak, moderate, strong)	weak	strong	strong	
Seggregations (Type and amount %)	—	—	carbonate 10%	
Stones - Type & Amount (Type and amount %)	—	—	—	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	C	C	
Boundary Shape (even, wavy, irregular, broken)	W	E	E	

Field Comments

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Soil Survey Worksheet

Location:	772-777 G47	Date:	2/12/2011
Assessors:		Site Number:	C19

Location Characteristics

Geology and Topography Observations	Mid Slope 2%.
Landuse and Vegetation Observations	Bloodwood, Ironbark. Grazing

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Shallow Brown Dermosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Crusted			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Fine roots to 60cm			
Horizon Layer (Layers in Profile)	A1 1	B21 2	B22 3	4
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-35	35-70.	
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	(10-25)(25-35)	35-70.	
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Moist.	Dry	
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Dark Reddish Brown	Pale Brown	
Mottle Characteristics (% & Colour)	—	—	—	
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Poor	Poor	
Field Texture Grade (sand/silt/clay)	Sandy Clay M	MC S	Sandy Clay. V	
Structure Pedality Grade (Apedal or weak/moderate/strong)				
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5	10-20	—	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	SB.	—	
Consistence Force (weak, moderate, strong)	Weak	Strong	Moderate	
Seggregations (Type and amount %)	—	Carbonate 30%	—	
Stones - Type & Amount (Type and amount %)	—	—	—	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	
Boundary Shape (even, wavy, irregular, broken)	E	E	E	

Field Comments

Weathered rock beyond 70 cm

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Soil Survey Worksheet

Location: 778 - 783 G48	Date: 2/12/2011
Assessors: BOLM, HANR, LAWJ	Site Number: C20

Location Characteristics

Geology and Topography Observations	Midslope (1-2% slope)
Landuse and Vegetation Observations	Ironbark, Bloodwood, Bauhinia, Buffel grass.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Calcarosol (CA)			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Crusted			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor sheet erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 60cm			
Horizon Layer (Layers in Profile)	A1	B11	B12	4
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-25	25-65	
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	(10-25)(25-35)	(35-55)(55-65)	
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Light Brown	Cream	
Mottle Characteristics (% & Colour)	—	—	—	
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	
Field Texture Grade (sand/silt/clay)	Sandy Clay	SCL	SCL	
Structure Pedality Grade (Apedal or weak/moderate/strong)	M	M	M	
Structure Ped Size (mm) (eg 10 to 20 mm)	50-100mm	50-100mm	50-100mm	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	SB	SB	
Consistence Force (weak, moderate, strong)	Moderate	Moderate	Moderate	
Seggregations (Type and amount %)	—	—	—	
Stones - Type & Amount (Type and amount %)	—	—	—	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	A	C	C	
Boundary Shape (even, wavy, irregular, broken)	E	E	E	

Field Comments

A1 = pH 8
B11 = pH 8.5
B12 = pH 8.5

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Soil Survey Worksheet

Location:	784 - 789 C649	Date:	2/12/2011
Assessors:		Site Number:	C21.

Location Characteristics

Geology and Topography Observations	Mod slope (1-2%).
Landuse and Vegetation Observations	Ironbark, Bloodwood, Buffel grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Dermosol.			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Crusted			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor water sheet erosion.			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	roots to 65cm.			
Horizon Layer (Layers in Profile)	A1 1	B1 2	B2 3	B/C horizon
Horizon Depth (eg 0.00 to 0.15m)	0-15	15-40	40-65	65-85
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-15	(15-25) (25-35)	35-55	65-85
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Moist.	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Dark Reddish Brown	Brown	Cream
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	M	M	M	M
Field Texture Grade (sand/silt/clay)	MC	MC	MC.	Sandy Clay.
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	V
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5	10-20	10-20	—
Structure Ped Shape (platy, prismatic, blocky, round, etc)	SB	SB	SB	—
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	Strong.
Seggregations (Type and amount %)	—	—	—	20% Calcium Carbonate
Stones - Type & Amount (Type and amount %)	Ferricrete and fossilised wood 5%.	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

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Soil Survey Worksheet

Location:	790 - 794 GSO	Date:	2/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C22

Location Characteristics

Geology and Topography Observations	2% slope
Landuse and Vegetation Observations	Brigalow, Buffel grass.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Black vertosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor water erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 100cm			
Horizon Layer (Layers in Profile)	A1	B11	B12	B13
Horizon Depth (eg 0.00 to 0.15m)	0-15	15-60	60-100	100-130
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-15	(15-25)(25-35)	(35-55)(65-100)	(100-130)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Dry	Moist	Moist	Moist
Field Colour (brown, red, yellow, yellowish brown)	Black	Black	Dark grey	Brownish Black
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	Moderate
Field Texture Grade (sand/silt/clay)	MC	HC	HC	HC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	50 - 100mm	100 - 200mm	100 - 200mm	100 - 200mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	SA	SA	SA	SA
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	20% Carbonate nodules
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

Weathered Rock Beyond 130cm.

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Soil Survey Worksheet

Location: 797 -801 G52	Date: 2/12/11
Assessors: BOLM, HANR, LAWJ	Site Number: C23

Location Characteristics

Geology and Topography Observations	Lower slope (1% slope)
Landuse and Vegetation Observations	Whitewood regrowth, Brigalow, Buffel Grass, oper grass lault grazing

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Red dermosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor sheet erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 80cm.			
Horizon Layer (Layers in Profile)	A1	B21	B22	B23
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-25	25-40	40-80
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	10-25	(25-35) (35-55)	(55-65) (65-80)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark brown	Dark Brown	Dark Red	Red.
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	Moderate.
Field Texture Grade (sand/silt/clay)	Sandy Clay	MC	MC	MC
Structure Pedality Grade (Apedal or weak/moderate/strong)	M	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	50-100mm	50-100mm	50-100mm	50-100mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	SB	SB	SB
Consistence Force (weak, moderate, strong)	Moderate	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	Carbonate nodu (5%
Stones - Type & Amount (Type and amount %)	ferricrete(10%)	ferricrete(20%)		
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

Silcrete on surface.

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Soil Survey Worksheet

Location: 802 - 807 G53	Date: 2/12/11
Assessors: BOLM, HANR, LAWJ	Site Number: C24

Location Characteristics

Geology and Topography Observations	1% Slope
Landuse and Vegetation Observations	Seathered shrubs (whitewood) Buffel grasslands

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Black vertosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor sheet erosion.			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine Roots to 100cm			
Horizon Layer (Layers in Profile)	A1	B1	B21	B22
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-35	35-65	65-95
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	(10-25) (25-35)	(35-55) (55-65)	(65-95)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Black	Black	Black	Black
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Poor	Poor	Poor
Field Texture Grade (sand/silt/clay)	MC	HC	HC	HC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20mm	20-50mm	50-100mm	50-100mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	SB	AB	AB	AB
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	Red stone 70%
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

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Soil Survey Worksheet

Location:	808-814 C054	Date:	2/12/2011
Assessors:	BOLM, NAMR, LAWJ.	Site Number:	C25

Location Characteristics

Geology and Topography Observations	Flat terrain.
Landuse and Vegetation Observations	Euc. platyphylla, Bloodwood, Ironbark Cell grazing

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol (Depending on chemical analysis - ESP)			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Soft			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 150CM			
Horizon Layer (Layers in Profile)	A1 1	A2 2	B21 3	B22 4
Horizon Depth (eg 0.00 to 0.15m)	0-15	15-30	30-80	80-150.
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-15	(15-25) (25-35)	(35-55) (55-65)	(65-80) (80-150)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Light Brown	Orange brown	Light Orange brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Moderate	Moderate	Moderate
Field Texture Grade (sand/silt/clay)	L	SL	MC with Sand	Sandy Clay
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	M	S	V
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5	2-5.	20-50	—
Structure Ped Shape (platy, prismatic, blocky, round, etc)	Round	Round	PL	—
Consistence Force (weak, moderate, strong)	Weak	Moderate	Strong	Strong.
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

A1 = pH 6
A2 = pH 6
B21 = pH 6.5
B22 = pH 9.0
>80CM = pH 8.0.

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Soil Survey Worksheet

Location:	824-828 G63	Date:	2/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C26

Location Characteristics

Geology and Topography Observations	Plat terrain
Landuse and Vegetation Observations	Brigalow, Bauhinia Sesbania, Buffel grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown vertosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor water erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 20cm			
Horizon Layer (Layers in Profile)	A1	B21	B22	4
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-60	60-130	
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-10)	(10-25) (25-35)	(35-55) (55-65)	(65-130)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Moist	Moist	
Field Colour (brown, red, yellow, yellowish brown)	Brown	Dark Brown	Dark Brown	
Mottle Characteristics (% & Colour)	—	—	—	
Drainage (Poor, Moderate, Well, Rapid)	Poor	Poor	Poor	
Field Texture Grade (sand/silt/clay)	MC	HC	HC	
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	
Structure Ped Size (mm) (eg 10 to 20 mm)	5-10mm	100-200mm	100-200mm	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PR	PR	PR	
Consistence Force (weak, moderate, strong)	Moderate	Strong	Strong	
Seggregations (Type and amount %)	—	—	—	
Stones - Type & Amount (Type and amount %)	—	—	—	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	D	D	
Boundary Shape (even, wavy, irregular, broken)	E	I	I	

Field Comments

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Soil Survey Worksheet

Location:	Ridgelands Cameron (Confirm: Gelac)	Date:	2/12/2011
Assessors:	829 - 834	Site Number:	C27

Location Characteristics

Geology and Topography Observations	Upper Slope (1-2%)
Landuse and Vegetation Observations	Bloodwood, Ironbark, Bullockgrass - grazing.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Shallow Red Dermosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor water sheet erosion.			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Fine roots to 80cm			
Horizon Layer (Layers in Profile)	A1 [1]	A2 [2]	B1 [3]	B2 [4]
Horizon Depth (eg 0.00 to 0.15m)	0-12	12-25	25-45	45-75
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-12	(12-25)(25-35)	35-55	55-65
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Mod. Moist	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Brown	Reddish Brown	Pale Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Well	Well	Well.
Field Texture Grade (sand/silt/clay)	LC (With Sand)	LMC	MC	Sandy Clay
Structure Pedality Grade (Apedal or weak/moderate/strong)	M	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	20-50	20-50	20-50	20-50
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PO	PO	PO.
Consistence Force (weak, moderate, strong)	Moderate	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

- Scattered Sandstone rock on surface.
- Weathered lithic sandstone > 75 cm

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Soil Survey Worksheet

Location:	835-840 G60 Synchronised	Date:	3/12/11
Assessors:		Site Number:	C28

Location Characteristics

Geology and Topography Observations	Top of ridge (1% slope)
Landuse and Vegetation Observations	Ironbark, Bloodwood, Buffel grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Shallow Red Dermosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 50cm			
Horizon Layer (Layers in Profile)	A1	B21	B22	BC
Horizon Depth (eg 0.00 to 0.15m)	0-15	15-25	25-50	50-60
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-15	15-25	25-55	55-65
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod. Moist.	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Dark Brown	Redish Brown	Pale Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Moderate	Moderate	Moderate
Field Texture Grade (sand/silt/clay)	Sandy Clay	Sandy Clay	MC	weathered Rock.
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	50-100mm	50-100mm	10-20mm	10-20mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PL	Round	Round
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

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Soil Survey Worksheet

Location:	841-845 G61	Date:	3/12/2011
Assessors:		Site Number:	C29

Location Characteristics

Geology and Topography Observations	Upper Slope
Landuse and Vegetation Observations	Bloodwood, Brigalow, Bauhinia, Buffel grass.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Dermosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Fine roots to 60cm			
Horizon Layer (Layers in Profile)	A1 1	B21 2	B22 3	Weathered Sandstone
Horizon Depth (eg 0.00 to 0.15m)	0-15	15-45	45-80	80-100
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-15	(15-25) (25-35)	35-55	(55-65)(65-80)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Brown	Brown	Cream
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	Moderate
Field Texture Grade (sand/silt/clay)	Silty Clay	MC	MC	—
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	—
Structure Ped Size (mm) (eg 10 to 20 mm)	5-10	10-20.	20-50.	—
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PO	PO.	—
Consistence Force (weak, moderate, strong)	Moderate	Strong	Strong	—
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	Sandstone 5% 5-100mm	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	—
Boundary Shape (even, wavy, irregular, broken)	E	E	E	—

Field Comments

Sparse Sandstone rock on Surface

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Soil Survey Worksheet

Location:	851-856 G66	Date:	3/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C30

Location Characteristics

Geology and Topography Observations	Upper slope
Landuse and Vegetation Observations	Brigalow, Owenia acidulata, Buffel grass, whitewood.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Deep Brown Dermosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 100cm			
Horizon Layer (Layers in Profile)	A1	A2	B21	4
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-35	35-140	
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-10)	(10-25)(25-35)	(35-55)(55-65)(65-140)	
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	mod moist	mod moist	
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Brown	Brown	
Mottle Characteristics (% & Colour)	—	—	—	
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	
Field Texture Grade (sand/silt/clay)	Silty Clay	MC	MC	
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	S	S	
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20mm	50-100mm	100-200mm	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PR	PR	
Consistence Force (weak, moderate, strong)	weak	Strong	Strong	
Seggregations (Type and amount %)	—	—	—	
Stones - Type & Amount (Type and amount %)	—	—	—	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	
Boundary Shape (even, wavy, irregular, broken)	E	E	E	

Field Comments

Some vertical cracking.

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Soil Survey Worksheet

Location:	857 - 862, G67	Date:	3/12/2011
Assessors:	BoLM, HANR, LAWJ.	Site Number:	C31

Location Characteristics

Geology and Topography Observations	Mid Slope 3%.
Landuse and Vegetation Observations	Bauhinia, Bricalow, Native Orange, Currant Bush, Buffel Grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Red Dermosol		
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		Crusted		
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		Nil.		
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		Roots to 50CM		
Horizon Layer (Layers in Profile)	A1 1	B21 2	B22 3	Weathered Rock
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-35	35-50	50 - 100
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	(10-25) (25-35)	(35-55) (55-65)	(65-100) (100-150)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Moist	Moist	Dry
Field Colour (brown, red, yellow, yellowish brown)	Brown	Reddish Brown	Reddish Brown	-
Mottle Characteristics (% & Colour)	-	-	-	-
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	-
Field Texture Grade (sand/silt/clay)	Silty Clay M	MC	MC.	-
Structure Pedality Grade (Apedal or weak/moderate/strong)		S	S	-
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20.	50-100	50-100	-
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	SB	SB	-
Consistence Force (weak, moderate, strong)	Moderate	Strong	Strong	-
Seggregations (Type and amount %)	-	-	-	-
Stones - Type & Amount (Type and amount %)	1% ferricrete	-	-	-
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	-
Boundary Shape (even, wavy, irregular, broken)	E	E	E	-

Field Comments

- Decomposed rock to 150 cm.
- Ferricrete on surface (upto 20mm)

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Soil Survey Worksheet

Location:	863-869 G69	Date:	3/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C32

Location Characteristics

Geology and Topography Observations	Top of Ridge
Landuse and Vegetation Observations	Bloodwood, Box, Ironbark Bauhinia, Buffel grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Red Dermosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	firm crust.			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	minor			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 10cm			
Horizon Layer (Layers in Profile)	A1	A2	B2	70-100
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-30	30-70	weathered Rock
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	(10-25)(25-35)	(35-55)(55-65)	
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Moist	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Brown	Reddish Brown	Dark Red (2.5YR 3/6)	
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	well	well	well
Field Texture Grade (sand/silt/clay)	Sandy Clay	LC	MC	
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	M	M	
Structure Ped Size (mm) (eg 10 to 20 mm)	50-100mm	50-100mm	50-100mm	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	SB	SB	
Consistence Force (weak, moderate, strong)	weak	moderate	moderate	
Seggregations (Type and amount %)	—	—	—	
Stones - Type & Amount (Type and amount %)	—	—	—	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	
Boundary Shape (even, wavy, irregular, broken)	E	E	E	

Field Comments

Weathered sandstone rock (to 150mm) & ferricrete on surface.

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Soil Survey Worksheet

Location:	870-875 G70.	Date:	3/12/2011
Assessors:	BAM, HANA, LAWJ.	Site Number:	C33.

Location Characteristics

Geology and Topography Observations	Mid Slope (2-3%)
Landuse and Vegetation Observations	Brigalow, Queensland acidulata, Bauhinia, Buffel grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Black Vertosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine to coarse roots to 90CM.			
Horizon Layer (Layers in Profile)	A1 1	B1 2	B21 3	B/C 4
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-70	70-95	95-130.
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	(10-25)(25-35)	(35-55)(55-65)	(70-95)(95-130)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Mod Moist	Mod Moist	—
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	10YR3/2 Dark greyish brown	10YR 3/2	—
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	—
Field Texture Grade (sand/silt/clay)	MC	HC	HC	—
Structure Pedality Grade (Apedal or weak/moderate/strong)	M	S	S	—
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20.	200-500	200-500	—
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	AB	AB.	—
Consistence Force (weak, moderate, strong)	Moderate	Strong	Strong	—
Seggregations (Type and amount %)	—	—	5% Carbonate	—
Stones - Type & Amount (Type and amount %)	5% ferricrete/ silcrete	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	G	C	—
Boundary Shape (even, wavy, irregular, broken)	E	I	E.	—

Field Comments

Sandstone rocks on surface.

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Soil Survey Worksheet

Location:	876 - 881 G 71	Date:	3/12/2011
Assessors:	BCLM, HANR, LAWJ.	Site Number:	C34

Location Characteristics

Geology and Topography Observations	Lower Slope
Landuse and Vegetation Observations	Bloodwood / Brigalow, Buffel grass.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Black. Vertosol.			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil.			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 100 CM			
Horizon Layer (Layers in Profile)	A1 1	B1 2	B2 3	B/C 4
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-85	85-120	120-150
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	(10-25)(25-35)(35-55)(55-65)	(65-120)	(120-150)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Mod Moist	Mod Moist	Mod Moist
Field Colour (brown, red, yellow, yellowish brown)	Black	Black 7.5 YR 2.5/1	Black	Black into Weathered sandstone
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Moderate	Poor	Poor
Field Texture Grade (sand/silt/clay)	MC	HC	HC	HC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	50-100	200-500	200-500	100-200.
Structure Ped Shape (platy, prismatic, blocky, round, etc)	AB	AB	AB	AB
Consistence Force (weak, moderate, strong)	S	S	S	S
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	Sil crete/ferricrete 5%	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	G	G
Boundary Shape (even, wavy, irregular, broken)	I	I	I	I

Field Comments

Silcrete + ferricrete observed on soil surface

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Soil Survey Worksheet

Location:	82 - 87 G72.	Date:	3/12/2011
Assessors:	BOLM, HANR, LAWJ	Site Number:	C35.

Location Characteristics

Geology and Topography Observations	Upper Slope, low rise 1% slope
Landuse and Vegetation Observations	Ironbark, Bloodwood, Buffel Grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Red Chromosol		
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		Seasonally Herd Setting.		
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		Minor water sheeting erosion		
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		Medium roots to 80CM		
Horizon Layer (Layers in Profile)	A1 1	A2 2	B21 3	B22 4
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-20	20-45	45-85
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-10)	(10-25) (25-35)	(35-55)	(55-65) (65-90)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Mod Moist	Mod Moist	Mod Moist
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Reddish Brown	Dark Reddish Brown	Dark Reddish Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Well	Well	Moderate
Field Texture Grade (sand/silt/clay)	(fine) SL	SCL	LMC (Subplastic)	MC
Structure Pedality Grade (Apedal or weak/moderate/strong)	M	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5	10-20	100-200	100-200
Structure Ped Shape (platy, prismatic, blocky, round, etc)	Round	SB	SB	SB
Consistence Force (weak, moderate, strong)	Moderate	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	Silcrete 60%
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	G	G
Boundary Shape (even, wavy, irregular, broken)	I	I	I	I

Field Comments

A1 = pH 6.5
A2 = pH 6.0
B21 = pH 7.0
B22 pH 7.0.

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Soil Survey Worksheet

Location:	888 - 893 G 73	Date:	3/12/2011
Assessors:		Site Number:	C36.

Location Characteristics

Geology and Topography Observations	Level Terrace
Landuse and Vegetation Observations	Scattered Bloodwood, Euc. platyphylla, Grassland - grazing.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Tenosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Firm			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil.			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Roots to 50CM			
Horizon Layer (Layers in Profile)	A1 1	A2 2	B11 3	B12 4
Horizon Depth (eg 0.00 to 0.15m)	0-25	25-60	60-85	85-140
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-10)(10-25)	(25-35)	(35-55)	(55-65)(65-100)(100-140)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Brown	Cream	Pale Orange	light orange
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Well	Well	Well.
Field Texture Grade (sand/silt/clay)	Coarse Sand	Coarse Sand	Coarse Sand	Coarse Sand
Structure Pedality Grade (Apedal or weak/moderate/strong)	Apedal	Apedal	Apedal	Apedal
Structure Ped Size (mm) (eg 10 to 20 mm)	—	—	—	—
Structure Ped Shape (platy, prismatic, blocky, round, etc)	—	—	—	—
Consistence Force (weak, moderate, strong)	Weak	Weak	Weak	weak
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	-	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	G	G
Boundary Shape (even, wavy, irregular, broken)	W	W	W	W

Field Comments

Old flood deposit

Splay deposit

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Soil Survey Worksheet

Location:	899-904 G77	Date:	3/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C37

Location Characteristics

Geology and Topography Observations	Higher Terrace
Landuse and Vegetation Observations	Openwoodland, large bloodwood, large Euc. platyphylla, native grasses

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 120cm			
Horizon Layer (Layers in Profile)	A1	A2	B21	B22
Horizon Depth (eg 0.00 to 0.15m)	1-25	25-55	55-100	100-140
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-10)(10-25)	(25-35)(35-55)	(55-65)(65-100)	(100-140)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	7.5YR 6/2 (light brown dry)	7.5YR 4/6 strong brown	Pale orange/brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	well	moderater	Well
Field Texture Grade (sand/silt/clay)	SL	SL	Sandy Clay	SCL
Structure Pedality Grade (Apedal or weak/moderate/strong)	Apedal	Apedal	S	M
Structure Ped Size (mm) (eg 10 to 20 mm)	—	—	50-100mm	50-100mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	—	—	SB	V
Consistence Force (weak, moderate, strong)	weak	weak	strong	moderate
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	G	G
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

A2 (not bleached).

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Soil Survey Worksheet

Location:	905-910 G78	Date:	3/12/2011
Assessors:		Site Number:	C38

Location Characteristics

Geology and Topography Observations	Open depression.
Landuse and Vegetation Observations	Scattered Bloodwood, Moreton Bay Ash, Euc. platyphylla, Buffel grass.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Roots to 70CM			
Horizon Layer (Layers in Profile)	A1 1	A2 2	B21 3	B22 4
Horizon Depth (eg 0.00 to 0.15m)	0-7	7-30	30-70	70-100
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-7	(7-25), (25-35)	(35-55)	(55-65) (65-100)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Grey	Pale Grey	Yellowish Brown 10YR 5/6	ORANGE (BROWN)
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	Moderate	Moderate	Moderate
Field Texture Grade (sand/silt/clay)	SC	LS	Sandy Clay.	SCL.
Structure Pedality Grade (Apedal or weak/moderate/strong)	Apedal	Apedal	Weak	(V) Massive
Structure Ped Size (mm) (eg 10 to 20 mm)	—	—	20-50 MM	—
Structure Ped Shape (platy, prismatic, blocky, round, etc)	—	—	SB	—
Consistence Force (weak, moderate, strong)	—	—	Weak	—
Seggregations (Type and amount %)	—	—	—	
Stones - Type & Amount (Type and amount %)	—	—	10% Sandstone	30% Sandstone
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	Clear	Clear	G	G
Boundary Shape (even, wavy, irregular, broken)	Wavy	Wavy	W	W

Field Comments

A2 sporadically bleached

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Soil Survey Worksheet

Location: 913-918 G81	Date: 3/12/11
Assessors: BOLM, HANR, LAWJ	Site Number: C39

Location Characteristics

Geology and Topography Observations	Level Plain
Landuse and Vegetation Observations	Open woodland - Box, Euc. platyphylla 80% grass ground cover

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Red sodosol		
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		seasonably hard setting		
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		minor water erosion		
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		fine roots to 120 cm		
Horizon Layer (Layers in Profile)	A1	A2	B21	B22
Horizon Depth (eg 0.00 to 0.15m)	0-25	25-37	37-90	90-150
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-25	(25-35)(35-55)	(55-65)(65-90)	(90-150)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Brown	5YR 4/6 yellow red	yellowish red	Yellow red
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	Moderate
Field Texture Grade (sand/silt/clay)	fine Sandy loam	Fine SL	MC	SCL
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	W	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20mm	10-20mm	50-100mm	50-100mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PL	SB	SB
Consistence Force (weak, moderate, strong)	weak	weak	strong	strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	G
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

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Soil Survey Worksheet

Location:	920 – 925. C83	Date:	3/12/2011
Assessors:	BM, HANR, LANJ	Site Number:	C40.

Location Characteristics

Geology and Topography Observations	Mainly flat, Sloping gently to the west
Landuse and Vegetation Observations	Open woodland – Box, Euc. Platyphylla, Eremophila, Buffel grass, Rice Blue Grass

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		Loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		fine roots to 100 CM			
Horizon Layer (Layers in Profile)	A1 1	A2 2	B21 3	B22.	B23
Horizon Depth (eg 0.00 to 0.15m)	0-15	15-30	30-55	55-80	80-150.
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-15	(15-25.)(25-35)	(35-55)(55-65)	(65-80)	80-140
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Mod Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Pale Brown	Brown	Light Reddish Br	Yellowish Brown.
Mottle Characteristics (% & Colour)	–	–	–	–	–
Drainage (Poor, Moderate, Well, Rapid)	Well	Well	Moderate	Mod	Mod
Field Texture Grade (sand/silt/clay)	ZL	L	MC	MC	Sandy Clay
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	M	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5	20-50	50-100	50-100	50-100
Structure Ped Shape (platy, prismatic, blocky, round, etc)	round	SB	SB	SB	SB
Consistence Force (weak, moderate, strong)	Weak	Moderate	Strong	Strong	Strong
Seggregations (Type and amount %)	–	–	–	Carbonate 10%	–
Stones - Type & Amount (Type and amount %)	–	–	Silcrete 3%	–	–
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E	E

Field Comments

Seasonally herd setting.

Carbonate nodules at 55-80 CM

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Soil Survey Worksheet

Location:	927-932 G84	Date:	3/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C41

Location Characteristics

Geology and Topography Observations	2nd terrace on Bowen River
Landuse and Vegetation Observations	Enc. platyphylla, Bloodwood, Buffelgrass River terrace, Euc tereticornis

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Stratic Tenosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Nil			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Roots to 150cm			
Horizon Layer (Layers in Profile)	A1	A2	B1	B2
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-65	65-100	100-150
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10 (10-25)	(25-35) (35-55)	(55-65) (65-100)	(100-140)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Moist	Mod Moist	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Grey	Grey	Pale Brown	Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	well	well	well
Field Texture Grade (sand/silt/clay)	SL	LS	LS	LS
Structure Pedality Grade (Apedal or weak/moderate/strong)	Apedal	Apedal	Apedal	Apedal
Structure Ped Size (mm) (eg 10 to 20 mm)	—	—	—	—
Structure Ped Shape (platy, prismatic, blocky, round, etc)	—	—	—	—
Consistence Force (weak, moderate, strong)	weak	weak	weak	weak
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

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Soil Survey Worksheet

Location:	941-945 G90	Date:	3/12/11
Assessors:	BOLM, HANM, LAWT	Site Number:	C42

Location Characteristics

Geology and Topography Observations	Mainly flat terrain
Landuse and Vegetation Observations	Open woodland, Box, Bloodwood, grassland.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	minor sheet erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine root to 100cm			
Horizon Layer (Layers in Profile)	A1	A2-1	A22	B2
Horizon Depth (eg 0.00 to 0.15m)	0-17	17-40	40-55	55-130
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-17	(17-25)(25-35)	(35-55)	(55-65)(65-130)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Brown	Pale Brown	Pale Brown	orange brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Well	well	well	moderate
Field Texture Grade (sand/silt/clay)	SL	SL	SL	MC (with sand
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	W	W	S
Structure Ped Size (mm) (eg 10 to 20 mm)	20-50mm	20-50mm	20-50mm	50-100mm.
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	PL	PL	SB
Consistence Force (weak, moderate, strong)	weak	weak	weak	strong
Seggregations (Type and amount %)	—	—	—	manganese 10%
Stones - Type & Amount (Type and amount %)	—	—	—	silcrete 10%
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

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Soil Survey Worksheet

Location:	948-953 G93	Date:	3/12/2011
Assessors:	BOLM, HANR, LAWJ.	Site Number:	C43.

Location Characteristics

Geology and Topography Observations	Flat terrain.
Landuse and Vegetation Observations	Bauhinia Eremophila, 50% grass cover

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Brown Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Crusted (Sodic)			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Minor Water Sheet erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Fine roots to 100 CM			
Horizon Layer (Layers in Profile)	A1 1	A2 2	B21 3	B22 4
Horizon Depth (eg 0.00 to 0.15m)	0-10	10-35	35-60	60-140.
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-10	(10-25)(25-35)	(35-55)(55-65)	(65-100)(100-140
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Mod Moist	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Dark Brown	Yellowish Brown	Yellowish Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Poor	Poor
Field Texture Grade (sand/silt/clay)	L	SCL	MC	MC
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	M	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	10-20.	20-50	20-50	50-100
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	Round	SB	SB
Consistence Force (weak, moderate, strong)	Weak	Moderate	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	Silcrete 5%
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	G
Boundary Shape (even, wavy, irregular, broken)	E	E	W	W

Field Comments

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Soil Survey Worksheet

Location:	956-961 G97 (Re-synchronised with Gtac)	Date:	3/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C44

Location Characteristics

Geology and Topography Observations	Mid Slope (3%)
Landuse and Vegetation Observations	Scattered Brigalow, Open Buffel grassland.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Black vertosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	(water) minor sheet erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine & medium roots to 110cm			
Horizon Layer (Layers in Profile)	A1	B21	B22	B23
Horizon Depth (eg 0.00 to 0.15m)	0-13	13-80	80-110	110-150
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-13)(13-25)	(25-35)(35-55)	(55-65)(65-110)	(110-150)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	very dark greyish Brown	Dark brown	Dark brown	Grey clay
Mottle Characteristics (% & Colour)	—	—	—	Brown mottels (10%)
Drainage (Poor, Moderate, Well, Rapid)	well	moderate	Poor	Poor
Field Texture Grade (sand/silt/clay)	MC	HC	HC	HC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	50-100mm	200-500mm	200-500mm	200-500mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	AB	AB	AB	AB
Consistence Force (weak, moderate, strong)	strong	strong	strong	strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	Iron stone (5%)	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	G	G	G
Boundary Shape (even, wavy, irregular, broken)	E	W	W	W

Field Comments

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Soil Survey Worksheet

Location: 965 - 970 C102	Date: 3/12/2011
Assessors: BCM, HANR, LAMJ	Site Number: C45

Location Characteristics

Geology and Topography Observations	Mid Slope 4% Slope Rolling topography.
Landuse and Vegetation Observations	Bloodwood, Banhinia, Ironbark, Open Buffel grassland.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Brown Sodosol		
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		Crusted		
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		Moderate gully erosion		
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		fine roots to 40cm		
Horizon Layer (Layers in Profile)	A1 1	B21 2	B22 3	B/C 4
Horizon Depth (eg 0.00 to 0.15m)	0-11	11-40	40-60	60-100
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-11	(11-25) (25-35)	(35-55)	(55-65) (65-80)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dk Brown	Light brown	Pale Brown	Cream
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	Moderate
Field Texture Grade (sand/silt/clay)	SCL.	Sandy Clay	CS	LS.
Structure Pedality Grade (Apedal or weak/moderate/strong)	Moderate	Moderate	Apedal	Apedal
Structure Ped Size (mm) (eg 10 to 20 mm)	20-50.	20-50	—	—
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	Round	—	—
Consistence Force (weak, moderate, strong)	Moderate	Moderate	Weak	weak.
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	C	C
Boundary Shape (even, wavy, irregular, broken)	W	W	W	W.

Field Comments

Much of the original topsoil had been washed away due to sheet erosion.

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Soil Survey Worksheet

Location: 976-981 G107		Date:	3/12/11
Assessors: BOLM, HANR, LAWJ		Site Number:	C46

Location Characteristics

Geology and Topography Observations	Mod Slope %
Landuse and Vegetation Observations	Scatter, Ironbark, Bloodwood, Bauhinia, Buffel grassland.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Red Sodosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	loose			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Severe water sheet erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 80cm			
Horizon Layer (Layers in Profile)	A1	B21	B22	B3/C
Horizon Depth (eg 0.00 to 0.15m)	0-22	22-55	55-75	75-140
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-22)(22-35)	(35-55)	(55-65)(65-90)	(90-120)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Brown	Yellowish Red 5YR4/6	Orange Brown	Cream
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	moderate	moderate
Field Texture Grade (sand/silt/clay)	SL	MC	MC	Sandy Clay
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	S	S	M
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5mm	20-50mm	50-100mm	50-100mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	Round	SB	SB	SB
Consistence Force (weak, moderate, strong)	weak	strong	strong	moderate
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	—	—
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	C	C	C
Boundary Shape (even, wavy, irregular, broken)	E	E	E	E

Field Comments

Severly eroded slope.

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Soil Survey Worksheet

Location: 984-989 G111	Date: 3/12/11
Assessors: BOLM, HANR, LAWJ	Site Number: C47

Location Characteristics

Geology and Topography Observations	Botton of slope
Landuse and Vegetation Observations	Open Buffel grassland Scatter small white wood

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Black vertosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	friable, cracking			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	minor gully erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 140cm			
Horizon Layer (Layers in Profile)	A1	B21	B22	B23
Horizon Depth (eg 0.00 to 0.15m)	0-12	12-35	35-65	65-150
Sample Depth Range (m) (eg 0.05 to 0.10m)	0-12	(12-25)(25-35)	(35-55)(55-65)	(65-90)(90-120)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Black	Dark Brown 7.5YR 3/2	Dark Brown	Dark Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	moderate	moderate	moderate
Field Texture Grade (sand/silt/clay)	HC	HC	HC	HC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	200-500mm	200-500mm	200-500mm	200-500mm
Structure Ped Shape (platy, prismatic, blocky, round, etc)	AB	AB	AB	AB
Consistence Force (weak, moderate, strong)	strong	strong	strong	strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	ferricrete 30%	ferricrete 30%
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	G	G
Boundary Shape (even, wavy, irregular, broken)	W	W	W	W

Field Comments

- very dense soil (possible hard pan from stock traffic)
- ferricrete on soil surface

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

Soil Survey Worksheet

Location:	991-996 G116	Date:	3/12/2011
Assessors:	BALM, HANK, LAWJ	Site Number:	C48.

Location Characteristics

Geology and Topography Observations	Lower side of crest.
Landuse and Vegetation Observations	Box, Brigalow, Avena acidulater, Buffel grass.

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)		Brown Vertosol		
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)		Friable		
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)		Minor water sheet erosion		
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)		Fine roots to 80cm		
Horizon Layer (Layers in Profile)	A1	B1 2	B2 3	B3 4
Horizon Depth (eg 0.00 to 0.15m)	0-13	13-50	50-80	80-130
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-13)	(13-25) (25-35) (35-55) (55-65) (65-90) (90-130)		
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	DARK BROWN 7.5 YR 3/2	7.5YR 3/3	Dark Brown	Dark Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	Moderate
Field Texture Grade (sand/silt/clay)	MC	HC	HC	HC
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	20-50.	200-500	200-500	200-500
Structure Ped Shape (platy, prismatic, blocky, round, etc)	AB	AB	AB	AB
Consistence Force (weak, moderate, strong)	Strong	Strong	Strong	Strong
Seggregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	—	—	ferricrete 5%	ferricrete 5%.
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	G	G	G
Boundary Shape (even, wavy, irregular, broken)	E	W	W	W

Field Comments

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

Soil Survey Worksheet

Location:	997-1004 G117	Date:	3/12/11
Assessors:	BOLM, HANR, LAWJ	Site Number:	C49

Location Characteristics

Geology and Topography Observations	Midslope (2-3% slope)
Landuse and Vegetation Observations	Scattered Bloodwood Buffel grassland

Soil Profile Properties

Soil Type Field Name (Australian Soil Classification)	Lithic Tenosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Crusted			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Moderate sheet erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	fine roots to 85cm			
Horizon Layer (Layers in Profile)	A1	B21	B22	4
Horizon Depth (eg 0.00 to 0.15m)	0-25	25-55	55-60	
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-25)	(25-35)(35-55)	(55-65)	
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Dry	Dry	
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	Cream	pale cream	
Mottle Characteristics (% & Colour)	—	—	—	
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	
Field Texture Grade (sand/silt/clay)	LC (with sand)	SCL	SCL	
Structure Pedality Grade (Apedal or weak/moderate/strong)	W	W	W	
Structure Ped Size (mm) (eg 10 to 20 mm)	2-5mm	20-50mm	2-5mm	
Structure Ped Shape (platy, prismatic, blocky, round, etc)	PL	SB	round	
Consistence Force (weak, moderate, strong)	weak	weak	weak	
Seggregations (Type and amount %)	—	—	—	
Stones - Type & Amount (Type and amount %)	—	—	—	
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	G	G	G	
Boundary Shape (even, wavy, irregular, broken)	W	W	W	

Field Comments

dry weathered sandstone beyond 60cm

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Soil Survey Worksheet

Location:	1006-1011 C-119	Date:	3/12/2011
Assessors:	BAM, HANR, LAWJ.	Site Number:	C50.

Location Characteristics

Geology and Topography Observations	Upper Slope on undulating landform
Landuse and Vegetation Observations	Open Buffel grassland. Scattered Mountain Coolibah, Whitewood, Bugalow.

Soil Profile Properties

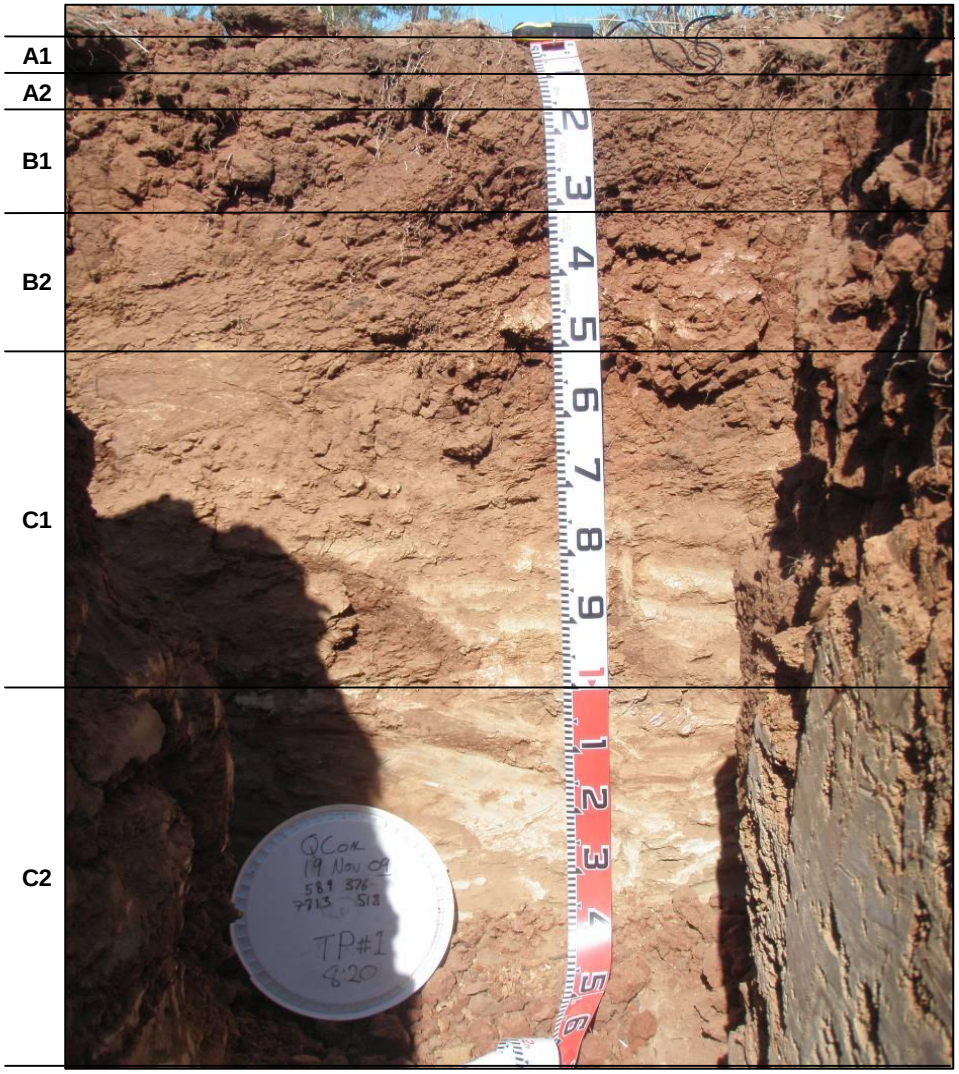
Soil Type Field Name (Australian Soil Classification)	Brown Vertosol			
Surface Condition (crusted, mulched, soft, firm, gravelly, loose, trampled, cultivated)	Friable			
Erosion Type, Severity & Present Condition (rill, sheet, wind - minor, moderate, severe - stabilised, active)	Moderate gully erosion			
Root Depth, Type & Amount (eg 0.30m, fine/medium/coarse, few/common/many/abundant)	Medium to fine roots to 100CM			
Horizon Layer (Layers in Profile)	A1 1	B11 2	B12 3	B13 4
Horizon Depth (eg 0.00 to 0.15m)	0-22	22-40	40-90	90-130
Sample Depth Range (m) (eg 0.05 to 0.10m)	(0-22)(22-35)	(35-55)	(55-65)(65-90)	(90-130)
Field Moisture (Dry, Moist, Moderately Moist, Wet)	Mod Moist	Dry	Dry	Dry
Field Colour (brown, red, yellow, yellowish brown)	Dark Brown	10YR4/3 Brown	Brown	Brown
Mottle Characteristics (% & Colour)	—	—	—	—
Drainage (Poor, Moderate, Well, Rapid)	Moderate	Moderate	Moderate	Moderate
Field Texture Grade (sand/silt/clay)	MC	HC	HC	LMC.
Structure Pedality Grade (Apedal or weak/moderate/strong)	S	S	S	S
Structure Ped Size (mm) (eg 10 to 20 mm)	50-100	200-500	200-500	50-100.
Structure Ped Shape (platy, prismatic, blocky, round, etc)	Round	AB	AB	AB
Consistence Force (weak, moderate, strong)	Moderate	Strong	Strong	Moderate
Segregations (Type and amount %)	—	—	—	—
Stones - Type & Amount (Type and amount %)	ferricrete 5%	—	—	Sand Stone/ Mud Stone 5%
Boundary Distinctness (sharp, abrupt, clear, gradual, diffuse)	C	G	G	G
Boundary Shape (even, wavy, irregular, broken)	E	W	W	W

Field Comments

- Moderate Gully Erosion
- Some Calcium Carbonate nodules on Soil Surface

Soil Profile Description: TP1 - Dermosol

Associated Ground Observation GO#5



Description

A1: 0.0 - 0.08 m
Sandy Clay Loam, dark brown (7.5YR 4/3 dry), dry, moderate pedality 10-20 mm, sub angular blocky, rough fabric, moderately weak strength, macropore cracks <5 mm, fine grained sand fraction. Non plastic, non sticky. Field pH 6.5. Many roots. Sharp smooth change to:

A2: 0.08 - 0.16 m
Sandy Clay Loam, dark brown (7.5YR 4/4 dry), dry, moderate pedality 10-20 mm, sub angular blocky, rough fabric, moderately weak strength, macropore cracks <5 mm, fine grained sand fraction. Non plastic, non sticky. Field pH 6.5. Many roots. Abrupt smooth change to:

B1: 0.16 - 0.31 m
Light Clay, weak red (10R 4/3 dry), dry, strong pedality 20-50 mm, sub angular blocky, rough fabric, moderately firm strength, macropore cracks <5 mm, fine grained sand fraction. Very plastic, moderately sticky. Field pH 6.0. Common roots. Clear smooth change to:

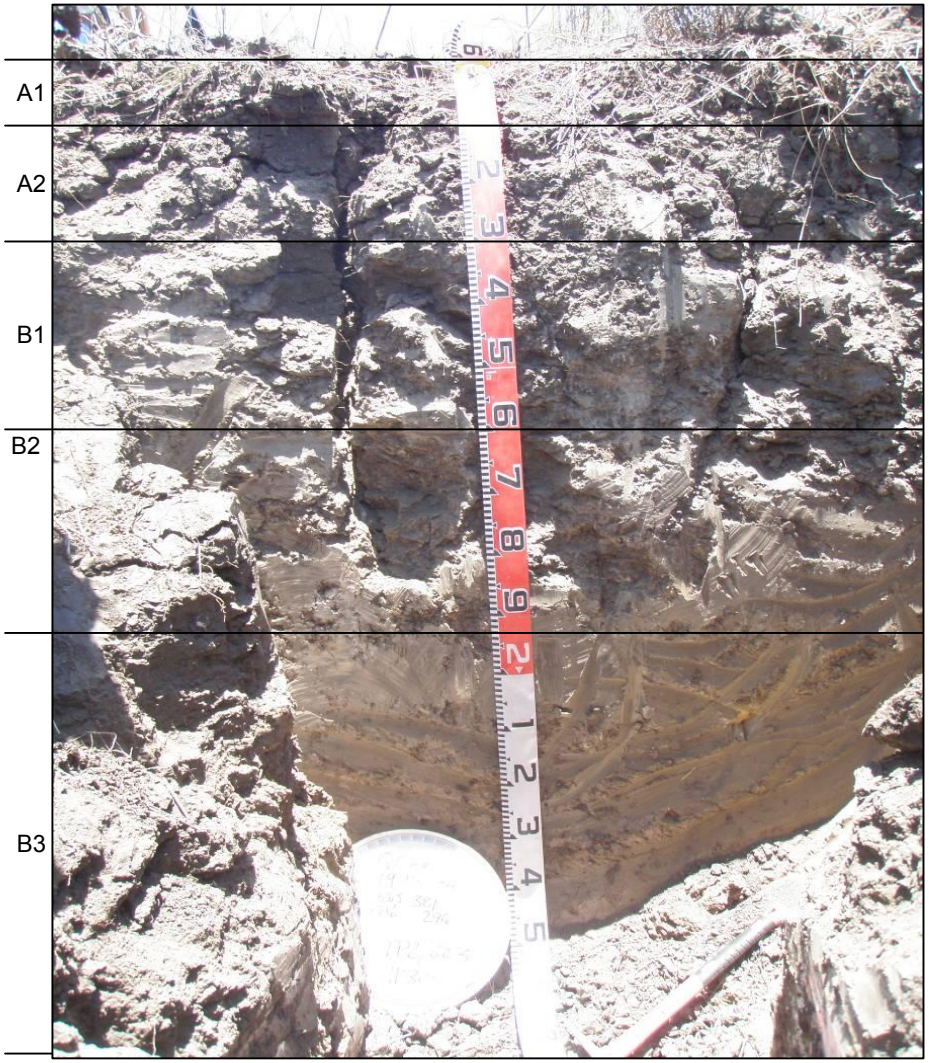
B2: 0.31 - 0.51 m
Light Clay, weak red and pale yellow mottle (10R 4/4 dry), dry, strong pedality 20-50 mm, sub angular blocky, rough fabric, moderately firm strength, macropore cracks <5 mm, fine grained sand fraction. Very plastic, moderately sticky. Field pH 6.0. Common roots. Clear wavy change to:

C1: 0.51 - 1.0 m
Weathered sandstone, reddish yellow. No roots.

C2: 1.0 - 1.4 m
Weathered sandstone, mottled light grey, pale yellow, and dark orange. No roots.

Soil Profile Description: TP2 - Vertosol

Associated Ground Observation GO#3



A1: 0.0 - 0.1 m
Medium Clay, very dark grey (5Y 3/1 dry), dry, strong pedality, 10-20 mm, subangular blocky, rough, moderately firm strength, macropore cracks 10-20 mm. High plasticity (normal), moderately sticky. Trace manganese nodules < 5 mm. Field pH 7.0. Many roots. Gradual smooth change to:

A2: 0.1 - 0.3 m
Medium Clay, dark grey (5Y 4/1 dry), dry, strong pedality, 20-50mm, subangular blocky, rough, very strong strength, macropore cracks 10-20 mm. High plasticity (normal), moderately sticky. Trace manganese nodules < 5 mm. Field pH 7.0. Many roots. Gradual smooth change to:

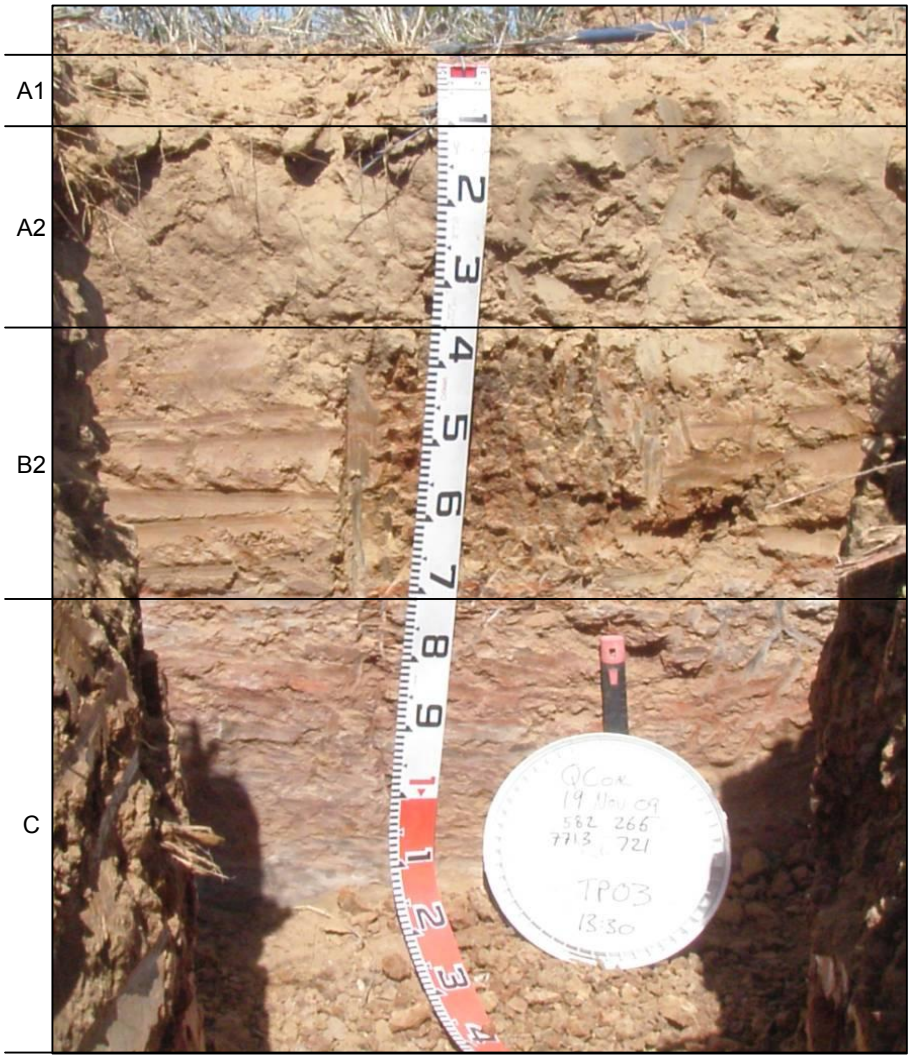
B1: 0.3 - 0.6 m
Medium Clay, dark grey (5Y 5/2 dry), dry, strong pedality, 20-50mm, subangular blocky, rough, very strong strength, macropore cracks 10-20 mm. High plasticity (normal), moderately sticky. Field pH 7.0. Roots common. Gradual smooth change to:

B2: 0.6 - 0.93 m
Medium Clay, dark grey and orange mottle (5Y 6/2 dry), slightly moist, strong pedality, 20-50mm, subangular blocky, rough, very strong strength, macropore cracks 10-20 mm. High plasticity (normal), moderately sticky. Field pH 7.0. Few roots. Clear smooth change to:

B3: 0.93 - 1.5 m
Medium Clay, dark grey (5Y 4/2 dry), slightly moist, strong pedality, 20-50mm, subangular blocky, rough, very strong strength, macropore cracks 10-20 mm. High plasticity (normal), moderately sticky. Field pH 7.0. No roots.

Soil Profile Description: TP3 - Sodosol

Associated Ground Observation GO#14



A1: 0.0 - 0.1 m
Loamy Sand, light yellowish brown (10YR 6/4 dry), dry, weak pedality 10-20 mm, angular blocky, sandy fabric, moderately weak strength, fine grained sand, non plastic. Field pH 6.0. Many roots. Abrupt smooth change to:

A2: 0.1 - 0.35 m
Loamy Sand, very pale brown (10YR 7/3 dry), dry, weak pedality 10-20 mm, angular blocky, sandy fabric, moderately weak strength, fine grained sand, non plastic. Field pH 6.0. Many roots. Abrupt smooth change to:

B2: 0.35 - 0.71 m
Sandy Clay Loam, dark brown (7.5YR 3/4 dry), dry, moderate pedality 20-50 mm, sub angular blocky, rough fabric, moderately firm strength, macropore cracks <5 mm, fine grained sand fraction. Moderate plasticity, slightly sticky. Field pH 6.0. Few roots. Sharp smooth change to:

C: 0.71 - 1.2 m
Weathered sandstone, reddish and dark grey. No roots.

Appendix C

Laboratory Certificates of Analysis

Nutrient Advantage®

Nutrient Advantage Advice® Nutrient Report

GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001777
Paddock Name: 02-12-2011
Sample Name: SITE 12
Sample Depth (cm): 25 **To** 35

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		8.00
pH (1:5 CaCl2)		6.80
Nitrate Nitrogen (NO3)	mg/kg	<1.0
Available Potassium	mg/kg	90
Chloride	mg/kg	27.0
Electrical Conductivity	dS/m	0.10
Cation Exchange Capacity	meq/100g	14.80
Calcium (Amm-acet.)	%	41.000
Calcium (Amm-acet.)	meq/100g	6.000
Magnesium (Amm-acet.)	%	49.000
Magnesium (Amm-acet.)	meq/100g	7.200
Sodium (Amm-acet.)	%	9.500
Sodium (Amm-acet.)	meq/100g	1.400
Potassium (Amm-acet.)	%	1.600
Potassium (Amm-acet.)	meq/100g	0.230
Calcium/Magnesium Ratio		0.8
Potassium to Magnesium Ratio		0.0
% Clay	%	40
% Sand (Fine)	%	47
% Sand (Coarse)	%	2
% Silt	%	11
Sansilclay Texture		Sandy Clay

Analyses conducted by **Nutrient Advantage Laboratory Services**
8 South Road, Werribee VIC 3030
NATA Accreditation No: 11958
Tel: 1800 803 453
Certificate of Analysis is available upon request.
Email: lab.feedback@incitecpivot.com.au

Nutrient Advantage®

Nutrient Advantage Advice® Nutrient Report

Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001777	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 12	**Sampling Date:**	
Sample Depth (cm):	25 **To** 35		

The results reported pertain only to the sample submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
* One or more components of this test are below their detection limit. The value used is indicative only.

Disclaimer: *Laboratory analyses and fertiliser recommendations are made in good faith, based on the best technical information available as at the date of this report. Incitec Pivot Limited, its officers, employees, consultants, Agents and Dealers do not accept any liability whatsoever arising from or in connection with the analytical results, interpretations and recommendations provided, and the client takes the analytical results, interpretations and recommendations on these terms. In respect of liability which cannot be excluded by law, Incitec Pivot's liability is restricted to the re-supply of the laboratory analysis or the cost of having the analysis re-supplied.*

Nutrient Advantage®

Nutrient Advantage Advice® Nutrient Report

GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001778
Paddock Name: 02-12-2011
Sample Name: SITE 12
Sample Depth (cm): 55 **To** 65

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		8.60
pH (1:5 CaCl2)		7.50
Nitrate Nitrogen (NO3)	mg/kg	<1.0
Available Potassium	mg/kg	58
Chloride	mg/kg	210.0
Electrical Conductivity	dS/m	0.23
Cation Exchange Capacity	meq/100g	12.20
Calcium (Amm-acet.)	%	23.000
Calcium (Amm-acet.)	meq/100g	2.800
Magnesium (Amm-acet.)	%	52.000
Magnesium (Amm-acet.)	meq/100g	6.300
Sodium (Amm-acet.)	%	25.000
Sodium (Amm-acet.)	meq/100g	3.000
Potassium (Amm-acet.)	%	1.200
Potassium (Amm-acet.)	meq/100g	0.150
Calcium/Magnesium Ratio		0.4
Potassium to Magnesium Ratio		0.0
% Clay	%	21
% Sand (Fine)	%	64
% Sand (Coarse)	%	5
% Silt	%	10
Sansilclay Texture		Sandy Clay Loam

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Nutrient Advantage Advice® Nutrient Report

Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001778	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 12	**Sampling Date:**	
Sample Depth (cm):	55 **To** 65		

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Nutrient Advantage®

Nutrient Advantage Advice® Nutrient Report

GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001779
Paddock Name: 02-12-2011
Sample Name: SITE 13
Sample Depth (cm): 0 **To** 13

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		6.60
pH (1:5 CaCl2)		5.70
Organic Carbon (OC)	%	0.29
Total Nitrogen	%	<0.04
Phosphorus (Colwell)	mg/kg	<5
Phosphorus (BSES)	mg/kg	9
Potassium (Nitric K)	meq/100g	1.70
Sulphate Sulphur (MCP)	mg/kg	2.2
Zinc (DTPA)	mg/kg	0.24
Copper (DTPA)	mg/kg	0.21
Iron (DTPA)	mg/kg	13.0
Manganese (DTPA)	mg/kg	4.70
Boron (Hot CaCl2)	mg/kg	0.14
Electrical Conductivity	dS/m	0.03
Silicon (BSES)	mg/kg	96
Organic Matter	%	0.5

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Nutrient Advantage Advice® Nutrient Report

GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001780
Paddock Name: 02-12-2011
Sample Name: SITE 13
Sample Depth (cm): 25 **To** 35

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		5.70
pH (1:5 CaCl2)		4.80
Aluminium Saturation	%	1.7
Nitrate Nitrogen (NO3)	mg/kg	<1.0
Available Potassium	mg/kg	41
Chloride	mg/kg	490.0
Electrical Conductivity	dS/m	0.30
Cation Exchange Capacity	meq/100g	5.91
Aluminium (KCl)	mg/kg	<9.00
Aluminium (KCl)	meq/100g	0.10
Calcium (Amm-acet.)	meq/100g	2.200
Calcium (Amm-acet.)	%	37.000
Magnesium (Amm-acet.)	meq/100g	2.000
Magnesium (Amm-acet.)	%	34.000
Sodium (Amm-acet.)	meq/100g	1.500
Sodium % of Cations (ESP)	%	25.000
Potassium (Amm-acet.)	meq/100g	0.110
Potassium (Amm-acet.)	%	1.900
Calcium/Magnesium Ratio		1.1
Potassium to Magnesium Ratio		0.1
% Clay	%	10
% Sand (Fine)	%	62

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Nutrient Advantage Advice® Nutrient Report

Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001780	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 13	**Sampling Date:**	
Sample Depth (cm):	25 **To** 35		

Analyte / Assay	Units	Value
% Sand (Coarse)	%	15
% Silt	%	14
Sansilclay Texture		Sandy Loam

The results reported pertain only to the sample submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
* One or more components of this test are below their detection limit. The value used is indicative only.

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Nutrient Advantage Advice® Nutrient Report

GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001781
Paddock Name: 02-12-2011
Sample Name: SITE 13
Sample Depth (cm): 55 **To** 65

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		5.70
pH (1:5 CaCl2)		5.00
Aluminium Saturation	%	2.5
Nitrate Nitrogen (NO3)	mg/kg	1.0
Available Potassium	mg/kg	21
Chloride	mg/kg	640.0
Electrical Conductivity	dS/m	0.47
Cation Exchange Capacity	meq/100g	4.00
Aluminium (KCl)	mg/kg	<9.00
Aluminium (KCl)	meq/100g	0.10
Calcium (Amm-acet.)	meq/100g	0.650
Calcium (Amm-acet.)	%	16.000
Magnesium (Amm-acet.)	meq/100g	1.100
Magnesium (Amm-acet.)	%	28.000
Sodium (Amm-acet.)	meq/100g	2.100
Sodium % of Cations (ESP)	%	53.000
Potassium (Amm-acet.)	meq/100g	0.053
Potassium (Amm-acet.)	%	1.300
Calcium/Magnesium Ratio		0.6
Potassium to Magnesium Ratio		0.0
% Clay	%	6
% Sand (Fine)	%	69

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Nutrient Advantage Advice® Nutrient Report

Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001781	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 13	**Sampling Date:**	
Sample Depth (cm):	55 **To** 65		

Analyte / Assay	Units	Value
% Sand (Coarse)	%	23
% Silt	%	3
Sansilclay Texture		Sand

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Nutrient Advantage Advice® Nutrient Report

GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001782
Paddock Name: 02-12-2011
Sample Name: SITE 14
Sample Depth (cm): 0 **To** 12

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		5.60
pH (1:5 CaCl2)		4.70
Organic Carbon (OC)	%	1.30
Total Nitrogen	%	0.10
Phosphorus (Colwell)	mg/kg	15
Phosphorus (BSES)	mg/kg	14
Potassium (Nitric K)	meq/100g	1.90
Sulphate Sulphur (MCP)	mg/kg	11.0
Zinc (DTPA)	mg/kg	1.30
Copper (DTPA)	mg/kg	0.32
Iron (DTPA)	mg/kg	210.0
Manganese (DTPA)	mg/kg	12.00
Boron (Hot CaCl2)	mg/kg	0.25
Electrical Conductivity	dS/m	0.15
Silicon (BSES)	mg/kg	140
Organic Matter	%	2.2

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Analyses conducted by **Nutrient Advantage Laboratory Services**
8 South Road, Werribee VIC 3030
NATA Accreditation No: 11958
Tel: 1800 803 453
Certificate of Analysis is available upon request.
Email: lab.feedback@incitecpivot.com.au

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GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001819
Paddock Name: 02-12-2011
Sample Name: SITE 31
Sample Depth (cm): 100 **To** 150

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		8.80
pH (1:5 CaCl2)		8.00
Nitrate Nitrogen (NO3)	mg/kg	<1.0
Available Potassium	mg/kg	53
Chloride	mg/kg	<10.0
Electrical Conductivity	dS/m	0.11
Cation Exchange Capacity	meq/100g	38.50
Calcium (Amm-acet.)	%	94.000
Calcium (Amm-acet.)	meq/100g	36.000
Magnesium (Amm-acet.)	%	5.500
Magnesium (Amm-acet.)	meq/100g	2.100
Sodium (Amm-acet.)	%	0.620
Sodium (Amm-acet.)	meq/100g	0.240
Potassium (Amm-acet.)	%	0.360
Potassium (Amm-acet.)	meq/100g	0.140
Calcium/Magnesium Ratio		17.0
Potassium to Magnesium Ratio		0.1
% Clay	%	11
% Sand (Fine)	%	63
% Sand (Coarse)	%	8
% Silt	%	18
Sansilclay Texture		Sandy Loam

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Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001819	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 31	**Sampling Date:**	
Sample Depth (cm):	100 **To** 150		

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GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001820
Paddock Name: 02-12-2011
Sample Name: SITE 32
Sample Depth (cm): 0 **To** 10

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		6.50
pH (1:5 CaCl2)		6.00
Organic Carbon (OC)	%	1.20
Total Nitrogen	%	0.08
Phosphorus (Colwell)	mg/kg	14
Phosphorus (BSES)	mg/kg	32
Potassium (Nitric K)	meq/100g	2.80
Sulphate Sulphur (MCP)	mg/kg	7.3
Zinc (DTPA)	mg/kg	1.40
Copper (DTPA)	mg/kg	0.65
Iron (DTPA)	mg/kg	14.0
Manganese (DTPA)	mg/kg	29.00
Boron (Hot CaCl2)	mg/kg	0.53
Electrical Conductivity	dS/m	0.07
Silicon (BSES)	mg/kg	320
Organic Matter	%	2.1

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GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001821
Paddock Name: 02-12-2011
Sample Name: SITE 32
Sample Depth (cm): 55 **To** 65

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		7.50
pH (1:5 CaCl2)		6.80
Nitrate Nitrogen (NO3)	mg/kg	<1.0
Available Potassium	mg/kg	220
Chloride	mg/kg	12.0
Electrical Conductivity	dS/m	0.06
Cation Exchange Capacity	meq/100g	12.40
Calcium (Amm-acet.)	%	81.000
Calcium (Amm-acet.)	meq/100g	10.000
Magnesium (Amm-acet.)	%	15.000
Magnesium (Amm-acet.)	meq/100g	1.800
Sodium (Amm-acet.)	%	0.670
Sodium (Amm-acet.)	meq/100g	0.083
Potassium (Amm-acet.)	%	4.400
Potassium (Amm-acet.)	meq/100g	0.550
Calcium/Magnesium Ratio		5.6
Potassium to Magnesium Ratio		0.3
% Clay	%	50
% Sand (Fine)	%	29
% Sand (Coarse)	%	16
% Silt	%	5
Sansilclay Texture		Clay

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Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001821	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 32	**Sampling Date:**	
Sample Depth (cm):	55 **To** 65		

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GHD PTY LTD

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BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001822
Paddock Name: 02-12-2011
Sample Name: SITE 33
Sample Depth (cm): 35 **To** 55

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		8.80
pH (1:5 CaCl2)		8.00
Nitrate Nitrogen (NO3)	mg/kg	<1.0
Available Potassium	mg/kg	110
Chloride	mg/kg	<10.0
Electrical Conductivity	dS/m	0.17
Cation Exchange Capacity	meq/100g	45.40
Calcium (Amm-acet.)	%	81.000
Calcium (Amm-acet.)	meq/100g	37.000
Magnesium (Amm-acet.)	%	16.000
Magnesium (Amm-acet.)	meq/100g	7.100
Sodium (Amm-acet.)	%	2.200
Sodium (Amm-acet.)	meq/100g	1.000
Potassium (Amm-acet.)	%	0.620
Potassium (Amm-acet.)	meq/100g	0.280
Calcium/Magnesium Ratio		5.2
Potassium to Magnesium Ratio		0.0
% Clay	%	45
% Sand (Fine)	%	25
% Sand (Coarse)	%	19
% Silt	%	11
Sansilclay Texture		Clay

ASPAC

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Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001822	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 33	**Sampling Date:**	
Sample Depth (cm):	35 **To** 55		

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GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
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Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001823
Paddock Name: 02-12-2011
Sample Name: SITE 34
Sample Depth (cm): 0 **To** 10

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		8.50
pH (1:5 CaCl2)		7.80
Organic Carbon (OC)	%	1.10
Total Nitrogen	%	0.07
Phosphorus (Colwell)	mg/kg	10
Phosphorus (BSES)	mg/kg	39
Potassium (Nitric K)	meq/100g	3.10
Sulphate Sulphur (MCP)	mg/kg	3.4
Zinc (DTPA)	mg/kg	0.14
Copper (DTPA)	mg/kg	0.56
Iron (DTPA)	mg/kg	6.7
Manganese (DTPA)	mg/kg	3.40
Boron (Hot CaCl2)	mg/kg	0.55
Electrical Conductivity	dS/m	0.16
Silicon (BSES)	mg/kg	1400
Organic Matter	%	1.9

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Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001861
Paddock Name: 02-12-2011
Sample Name: SITE 16
Sample Depth (cm): 0 **To** 10

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		5.50
pH (1:5 CaCl2)		4.50
Organic Carbon (OC)	%	1.20
Total Nitrogen	%	0.10
Phosphorus (Colwell)	mg/kg	8
Phosphorus (BSES)	mg/kg	14
Potassium (Nitric K)	meq/100g	2.00
Sulphate Sulphur (MCP)	mg/kg	5.6
Zinc (DTPA)	mg/kg	1.40
Copper (DTPA)	mg/kg	0.82
Iron (DTPA)	mg/kg	150.0
Manganese (DTPA)	mg/kg	35.00
Boron (Hot CaCl2)	mg/kg	0.28
Electrical Conductivity	dS/m	0.07
Silicon (BSES)	mg/kg	180
Organic Matter	%	2.1

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Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001862
Paddock Name: 02-12-2011
Sample Name: SITE 16
Sample Depth (cm): 35 **To** 55

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		6.50
pH (1:5 CaCl2)		5.20
Aluminium Saturation	%	1.0
Nitrate Nitrogen (NO3)	mg/kg	<1.0
Available Potassium	mg/kg	50
Chloride	mg/kg	240.0
Electrical Conductivity	dS/m	0.20
Cation Exchange Capacity	meq/100g	10.20
Aluminium (KCl)	mg/kg	<9.00
Aluminium (KCl)	meq/100g	0.10
Calcium (Amm-acet.)	meq/100g	3.000
Calcium (Amm-acet.)	%	29.000
Magnesium (Amm-acet.)	meq/100g	4.200
Magnesium (Amm-acet.)	%	41.000
Sodium (Amm-acet.)	meq/100g	2.800
Sodium % of Cations (ESP)	%	27.000
Potassium (Amm-acet.)	meq/100g	0.130
Potassium (Amm-acet.)	%	1.300
Calcium/Magnesium Ratio		0.7
Potassium to Magnesium Ratio		0.0
% Clay	%	24
% Sand (Fine)	%	52

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Nutrient Advantage Advice® Nutrient Report

Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001862	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 16	**Sampling Date:**	
Sample Depth (cm):	35 **To** 55		

Analyte / Assay	Units	Value
% Sand (Coarse)	%	9
% Silt	%	15
Sansilclay Texture		Sandy Clay Loam

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GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001863
Paddock Name: 02-12-2011
Sample Name: SITE 16
Sample Depth (cm): 65 **To** 100

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		9.60
pH (1:5 CaCl2)		8.80
Nitrate Nitrogen (NO3)	mg/kg	<1.0
Available Potassium	mg/kg	64
Chloride	mg/kg	470.0
Electrical Conductivity	dS/m	0.78
Cation Exchange Capacity	meq/100g	17.20
Calcium (Amm-acet.)	%	38.000
Calcium (Amm-acet.)	meq/100g	6.500
Magnesium (Amm-acet.)	%	23.000
Magnesium (Amm-acet.)	meq/100g	4.000
Sodium (Amm-acet.)	%	38.000
Sodium (Amm-acet.)	meq/100g	6.500
Potassium (Amm-acet.)	%	0.930
Potassium (Amm-acet.)	meq/100g	0.160
Calcium/Magnesium Ratio		1.6
Potassium to Magnesium Ratio		0.0
% Clay	%	20
% Sand (Fine)	%	66
% Sand (Coarse)	%	10
% Silt	%	4
Sansilclay Texture		Sandy Clay Loam

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Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001863	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 16	**Sampling Date:**	
Sample Depth (cm):	65 **To** 100		

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Report Print Date: 31/01/2012
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Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001864
Paddock Name: 02-12-2011
Sample Name: SITE 17
Sample Depth (cm): 0 **To** 10

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		6.10
pH (1:5 CaCl2)		5.10
Organic Carbon (OC)	%	0.64
Total Nitrogen	%	0.06
Phosphorus (Colwell)	mg/kg	8
Phosphorus (BSES)	mg/kg	12
Potassium (Nitric K)	meq/100g	1.50
Sulphate Sulphur (MCP)	mg/kg	3.2
Zinc (DTPA)	mg/kg	0.36
Copper (DTPA)	mg/kg	0.10
Iron (DTPA)	mg/kg	100.0
Manganese (DTPA)	mg/kg	6.20
Boron (Hot CaCl2)	mg/kg	0.36
Electrical Conductivity	dS/m	0.05
Silicon (BSES)	mg/kg	83
Organic Matter	%	1.1

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Report Print Date: 31/01/2012
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Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001865
Paddock Name: 02-12-2011
Sample Name: SITE 17
Sample Depth (cm): 30 **To** 45

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		8.00
pH (1:5 CaCl2)		6.90
Nitrate Nitrogen (NO3)	mg/kg	<1.0
Available Potassium	mg/kg	110
Chloride	mg/kg	350.0
Electrical Conductivity	dS/m	0.29
Cation Exchange Capacity	meq/100g	14.20
Calcium (Amm-acet.)	%	22.000
Calcium (Amm-acet.)	meq/100g	3.100
Magnesium (Amm-acet.)	%	50.000
Magnesium (Amm-acet.)	meq/100g	7.100
Sodium (Amm-acet.)	%	26.000
Sodium (Amm-acet.)	meq/100g	3.700
Potassium (Amm-acet.)	%	2.000
Potassium (Amm-acet.)	meq/100g	0.290
Calcium/Magnesium Ratio		0.4
Potassium to Magnesium Ratio		0.0
% Clay	%	36
% Sand (Fine)	%	57
% Sand (Coarse)	%	3
% Silt	%	4
Sansilclay Texture		Sandy Clay

Analyses conducted by **Nutrient Advantage Laboratory Services**
8 South Road, Werribee VIC 3030
NATA Accreditation No: 11958
Tel: 1800 803 453
Certificate of Analysis is available upon request.
Email: lab.feedback@incitecpivot.com.au

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Nutrient Advantage Advice® Nutrient Report

Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001865	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 17	**Sampling Date:**	
Sample Depth (cm):	30 **To** 45		

The results reported pertain only to the sample submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
* One or more components of this test are below their detection limit. The value used is indicative only.

Disclaimer: *Laboratory analyses and fertiliser recommendations are made in good faith, based on the best technical information available as at the date of this report. Incitec Pivot Limited, its officers, employees, consultants, Agents and Dealers do not accept any liability whatsoever arising from or in connection with the analytical results, interpretations and recommendations provided, and the client takes the analytical results, interpretations and recommendations on these terms. In respect of liability which cannot be excluded by law, Incitec Pivot's liability is restricted to the re-supply of the laboratory analysis or the cost of having the analysis re-supplied.*

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Nutrient Advantage Advice® Nutrient Report

GHD PTY LTD

201 Charlotte Street

BRISBANE
QLD 4000

Report Print Date: 31/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:
Purchase Order No: 4121894

Grower Name : GHD PTY LTD
Sample No: 030001866
Paddock Name: 02-12-2011
Sample Name: SITE 17
Sample Depth (cm): 45 **To** 65

Nearest Town: BRISBANE
Test Code: ADMINSOIL
Sample Type: Soil
Sampling Date:

Analyte / Assay	Units	Value
pH (1:5 Water)		9.30
pH (1:5 CaCl2)		8.50
Nitrate Nitrogen (NO3)	mg/kg	1.3
Available Potassium	mg/kg	71
Chloride	mg/kg	450.0
Electrical Conductivity	dS/m	0.50
Cation Exchange Capacity	meq/100g	17.30
Calcium (Amm-acet.)	%	32.000
Calcium (Amm-acet.)	meq/100g	5.500
Magnesium (Amm-acet.)	%	39.000
Magnesium (Amm-acet.)	meq/100g	6.800
Sodium (Amm-acet.)	%	28.000
Sodium (Amm-acet.)	meq/100g	4.800
Potassium (Amm-acet.)	%	1.000
Potassium (Amm-acet.)	meq/100g	0.180
Calcium/Magnesium Ratio		0.8
Potassium to Magnesium Ratio		0.0
% Clay	%	29
% Sand (Fine)	%	62
% Sand (Coarse)	%	5
% Silt	%	5
Sansilclay Texture		Sandy Clay Loam

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Nutrient Advantage®

Nutrient Advantage Advice® Nutrient Report

Grower Name :	GHD PTY LTD	**Nearest Town:**	BRISBANE
Sample No:	030001866	**Test Code:**	ADMINSOIL
Paddock Name:	02-12-2011	**Sample Type:**	Soil
Sample Name:	SITE 17	**Sampling Date:**	
Sample Depth (cm):	45 **To** 65		

The results reported pertain only to the sample submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
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Nutrient Advantage Advice® Summary Report

GHD PTY LTD
210 CHARLOTTE ST

BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030001747**	**030001748**	**030001749**	**030001750**	**030001751**	**030001752**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011
Sample Name	SITE 3	SITE 3	SITE 3	SITE 4	SITE 4	SITE 5
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 10	10 - 20	25 - 35	0 - 10	10 - 25	0 - 25
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		7.30	8.20	8.70	7.20	7.50	7.60
pH (1:5 CaCl2)		6.50	7.60	7.90	6.80	6.60	6.90
Organic Carbon (OC)	%	1.10	0.53		1.60		1.10
Nitrate Nitrogen (NO3)	mg/kg			<1.0		<1.0	
Total Nitrogen	%	0.09	0.06		0.21		0.13
Phosphorus (Colwell)	mg/kg	26	9		71		21
Phosphorus (BSES)	mg/kg	100	230		130		29
Available Potassium	mg/kg			49		220	
Potassium (Nitric K)	meq/100g	5.00	1.40		13.00		5.30
Sulphate Sulphur (MCP)	mg/kg	2.6	1.6		7.5		5.6
Zinc (DTPA)	mg/kg	0.13	0.32		0.77		0.34
Copper (DTPA)	mg/kg	0.92	0.27		1.10		1.80
Iron (DTPA)	mg/kg	12.0	3.9		33.0		30.0
Manganese (DTPA)	mg/kg	18.00	1.80		35.00		11.00
Boron (Hot CaCl2)	mg/kg	0.50	0.31		0.76		1.10
Chloride	mg/kg			<10.0		<10.0	
Electrical Conductivity	dS/m	0.06	0.15	0.12	0.19	0.06	0.10
Cation Exchange Capacity	meq/100g			43.80		30.10	
Calcium (Amm-acet.)	%			96.000		90.000	
Calcium (Amm-acet.)	meq/100g			42.000		27.000	
Magnesium (Amm-acet.)	%			3.400		8.300	

Analyses conducted by **Nutrient Advantage Laboratory Services**

8 South Road, Werribee VIC 3030

NATA Accreditation No: 11958

Tel: 1800 803 453

Certificate of Analysis is available upon request.

Email: lab.feedback@incitecpivot.com.au

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Sample No	**030001747**	**030001748**	**030001749**	**030001750**	**030001751**	**030001752**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011
Sample Name	SITE 3	SITE 3	SITE 3	SITE 4	SITE 4	SITE 5
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 10	10 - 20	25 - 35	0 - 10	10 - 25	0 - 25
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g			1.500		2.500	
Sodium (Amm-acet.)	%			0.300		0.260	
Sodium (Amm-acet.)	meq/100g			0.130		0.078	
Potassium (Amm-acet.)	%			0.300		1.900	
Potassium (Amm-acet.)	meq/100g			0.130		0.570	
Calcium/Magnesium Ratio				28.0		11.0	
Potassium to Magnesium Ratio				0.1		0.2	
Silicon (BSES)	mg/kg	1200	690		1000		1400
% Clay	%			25		39	
% Sand (Fine)	%			37		34	
% Sand (Coarse)	%			11		11	
% Silt	%			26		16	
Sansilclay Texture				Sandy Clay Loam		Clay Loam	
Organic Matter	%	1.9	0.9		2.8		1.9

The results reported pertain only to the samples submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
Analyses performed on plant material dried at 70 degrees Celsius and ground to <2mm
Water analyses performed on an 'as received' basis
Analytical results reported by the laboratory as 'less than' the level of reporting, will be deemed by Nutrient Advantage Advice as being equivalent to the level of reporting for both calculation and interpretive purposes

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Nutrient Advantage Advice® Summary Report

GHD PTY LTD
210 CHARLOTTE ST

BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030001753**	**030001754**	**030001755**	**030001756**	**030001757**	**030001758**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011
Sample Name	SITE 5	SITE 5	SITE 5	SITE 6	SITE 6	SITE 6
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	35 - 55	55 - 65	65 - 95	0 - 10	25 - 35	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.70	8.70	8.70	7.60	8.40	8.60
pH (1:5 CaCl2)		7.90	7.90	7.90	7.00	7.70	7.90
Organic Carbon (OC)	%				2.80		
Nitrate Nitrogen (NO3)	mg/kg	<1.0	<1.0	<1.0		<1.0	2.9
Total Nitrogen	%				0.29		
Phosphorus (Colwell)	mg/kg				21		
Phosphorus (BSES)	mg/kg				120		
Available Potassium	mg/kg	220	230	220		310	260
Potassium (Nitric K)	meq/100g				7.30		
Sulphate Sulphur (MCP)	mg/kg				8.3		
Zinc (DTPA)	mg/kg				0.90		
Copper (DTPA)	mg/kg				1.60		
Iron (DTPA)	mg/kg				23.0		
Manganese (DTPA)	mg/kg				14.00		
Boron (Hot CaCl2)	mg/kg				1.30		
Chloride	mg/kg	<10.0	<10.0	<10.0		<10.0	24.0
Electrical Conductivity	dS/m	0.18	0.21	0.22	0.19	0.19	0.24
Cation Exchange Capacity	meq/100g	48.40	47.00	43.40		69.50	61.70
Calcium (Amm-acet.)	%	81.000	79.000	76.000		86.000	81.000
Calcium (Amm-acet.)	meq/100g	39.000	37.000	33.000		60.000	50.000
Magnesium (Amm-acet.)	%	16.000	17.000	18.000		12.000	16.000

Analyses conducted by **Nutrient Advantage Laboratory Services**
8 South Road, Werribee VIC 3030
NATA Accreditation No: 11958
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Sample No	**030001753**	**030001754**	**030001755**	**030001756**	**030001757**	**030001758**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011
Sample Name	SITE 5	SITE 5	SITE 5	SITE 6	SITE 6	SITE 6
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	35 - 55	55 - 65	65 - 95	0 - 10	25 - 35	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	7.600	7.800	7.900		8.200	9.900
Sodium (Amm-acet.)	%	2.500	3.400	4.400		0.750	1.800
Sodium (Amm-acet.)	meq/100g	1.200	1.600	1.900		0.520	1.100
Potassium (Amm-acet.)	%	1.200	1.300	1.300		1.200	1.100
Potassium (Amm-acet.)	meq/100g	0.570	0.590	0.560		0.800	0.660
Calcium/Magnesium Ratio		5.1	4.7	4.2		7.3	5.1
Potassium to Magnesium Ratio		0.1	0.1	0.1		0.1	0.1
Silicon (BSES)	mg/kg				1600		
% Clay	%	54	54	49		60	59
% Sand (Fine)	%	25	28	28		27	26
% Sand (Coarse)	%	6	4	5		3	4
% Silt	%	15	14	18		10	11
Sansilclay Texture		Clay	Clay	Clay		Clay	Clay
Organic Matter	%				4.8		

The results reported pertain only to the samples submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
Analyses performed on plant material dried at 70 degrees Celsius and ground to <2mm
Water analyses performed on an 'as received' basis
Analytical results reported by the laboratory as 'less than' the level of reporting, will be deemed by Nutrient Advantage Advice as being equivalent to the level of reporting for both calculation and interpretive purposes

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GHD PTY LTD
210 CHARLOTTE ST

BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030001759**	**030001760**	**030001761**	**030001762**	**030001763**	**030001764**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011
Sample Name	SITE 6	SITE 7	SITE 7	SITE 7	SITE 8	SITE 8
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 85	0 - 10	10 - 25	35 - 55	10 - 25	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.70	7.80	8.40	9.00	7.80	8.10
pH (1:5 CaCl2)		8.00	7.10	7.40	8.20	7.10	7.00
Organic Carbon (OC)	%		1.40			1.10	
Nitrate Nitrogen (NO3)	mg/kg	<1.0		<1.0	<1.0		3.3
Total Nitrogen	%		0.13			0.11	
Phosphorus (Colwell)	mg/kg		6			18	
Phosphorus (BSES)	mg/kg		19			35	
Available Potassium	mg/kg	220		220	190		150
Potassium (Nitric K)	meq/100g		5.20			2.90	
Sulphate Sulphur (MCP)	mg/kg		3.6			7.0	
Zinc (DTPA)	mg/kg		0.82			1.90	
Copper (DTPA)	mg/kg		1.80			1.30	
Iron (DTPA)	mg/kg		25.0			43.0	
Manganese (DTPA)	mg/kg		12.00			12.00	
Boron (Hot CaCl2)	mg/kg		0.68			0.65	
Chloride	mg/kg	<10.0		<10.0	22.0		62.0
Electrical Conductivity	dS/m	0.24	0.13	0.13	0.25	0.10	0.14
Cation Exchange Capacity	meq/100g	57.90		33.90	41.30		25.40
Calcium (Amm-acet.)	%	78.000		59.000	61.000		67.000
Calcium (Amm-acet.)	meq/100g	45.000		20.000	25.000		17.000
Magnesium (Amm-acet.)	%	19.000		35.000	31.000		25.000

Analyses conducted by **Nutrient Advantage Laboratory Services**
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Sample No	**030001759**	**030001760**	**030001761**	**030001762**	**030001763**	**030001764**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011	30-11-2011
Sample Name	SITE 6	SITE 7	SITE 7	SITE 7	SITE 8	SITE 8
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 85	0 - 10	10 - 25	35 - 55	10 - 25	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	11.000		12.000	13.000		6.300
Sodium (Amm-acet.)	%	2.200		3.800	6.800		6.700
Sodium (Amm-acet.)	meq/100g	1.300		1.300	2.800		1.700
Potassium (Amm-acet.)	%	0.980		1.700	1.200		1.500
Potassium (Amm-acet.)	meq/100g	0.570		0.570	0.480		0.380
Calcium/Magnesium Ratio		4.1		1.7	1.9		2.7
Potassium to Magnesium Ratio		0.1		0.0	0.0		0.1
Silicon (BSES)	mg/kg		1400			650	
% Clay	%	60		49	48		44
% Sand (Fine)	%	24		31	29		35
% Sand (Coarse)	%	4		6	9		1
% Silt	%	13		15	14		20
Sansilclay Texture		Clay		Clay	Clay		Clay
Organic Matter	%		2.4			1.9	

The results reported pertain only to the samples submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
Analyses performed on plant material dried at 70 degrees Celsius and ground to <2mm
Water analyses performed on an ‘as received’ basis
Analytical results reported by the laboratory as ‘less than’ the level of reporting, will be deemed by Nutrient Advantage Advice as being equivalent to the level of reporting for both calculation and interpretive purposes

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GHD PTY LTD
210 CHARLOTTE ST

BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030001765**	**030001766**	**030001767**	**030001768**	**030001769**	**030001770**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	30-11-2011	30-11-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 8	SITE 8	SITE 9	SITE 9	SITE 9	SITE 10
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 85	85 - 130	0 - 25	25 - 35	35 - 55	0 - 22
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.20	8.00	6.40	7.70	8.60	6.60
pH (1:5 CaCl2)		7.70	7.60	5.10	6.30	7.60	5.70
Organic Carbon (OC)	%			0.43			0.96
Nitrate Nitrogen (NO3)	mg/kg	<1.0	1.8		<1.0	<1.0	
Total Nitrogen	%			<0.04			0.07
Phosphorus (Colwell)	mg/kg			6			<5
Phosphorus (BSES)	mg/kg			10			9
Available Potassium	mg/kg	130	130		80	65	
Potassium (Nitric K)	meq/100g			1.50			2.00
Sulphate Sulphur (MCP)	mg/kg			2.6			4.7
Zinc (DTPA)	mg/kg			2.90			0.27
Copper (DTPA)	mg/kg			0.29			0.41
Iron (DTPA)	mg/kg			44.0			39.0
Manganese (DTPA)	mg/kg			14.00			15.00
Boron (Hot CaCl2)	mg/kg			0.23			0.40
Chloride	mg/kg	390.0	380.0		39.0	53.0	
Electrical Conductivity	dS/m	0.84	1.15	0.03	0.09	0.21	0.05
Cation Exchange Capacity	meq/100g	30.20	25.70		13.10	12.70	
Calcium (Amm-acet.)	%	56.000	58.000		34.000	39.000	
Calcium (Amm-acet.)	meq/100g	17.000	15.000		4.500	4.900	
Magnesium (Amm-acet.)	%	27.000	25.000		49.000	45.000	

Analyses conducted by **Nutrient Advantage Laboratory Services**
8 South Road, Werribee VIC 3030
NATA Accreditation No: 11958
Tel: 1800 803 453
Certificate of Analysis is available upon request.
Email: lab.feedback@incitecpivot.com.au

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Nutrient Advantage Advice® Summary Report

Sample No	**030001765**	**030001766**	**030001767**	**030001768**	**030001769**	**030001770**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	30-11-2011	30-11-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 8	SITE 8	SITE 9	SITE 9	SITE 9	SITE 10
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 85	85 - 130	0 - 25	25 - 35	35 - 55	0 - 22
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	8.100	6.300		6.400	5.700	
Sodium (Amm-acet.)	%	16.000	16.000		15.000	15.000	
Sodium (Amm-acet.)	meq/100g	4.800	4.100		2.000	1.900	
Potassium (Amm-acet.)	%	1.100	1.300		1.500	1.300	
Potassium (Amm-acet.)	meq/100g	0.320	0.330		0.200	0.170	
Calcium/Magnesium Ratio		2.1	2.4		0.7	0.9	
Potassium to Magnesium Ratio		0.0	0.1		0.0	0.0	
Silicon (BSES)	mg/kg			86			200
% Clay	%	49	39		39	31	
% Sand (Fine)	%	34	56		48	51	
% Sand (Coarse)	%	1	4		11	13	
% Silt	%	16	1		3	5	
Sansilclay Texture		Clay	Sandy Clay		Sandy Clay	Sandy Clay Loam	
Organic Matter	%			0.7			1.7

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Analyses performed on plant material dried at 70 degrees Celsius and ground to <2mm
Water analyses performed on an 'as received' basis
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Nutrient Advantage Advice® Summary Report

GHD PTY LTD
210 CHARLOTTE ST

BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030001777**	**030001778**	**030001779**	**030001780**	**030001781**	**030001782**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 12	SITE 12	SITE 13	SITE 13	SITE 13	SITE 14
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	25 - 35	55 - 65	0 - 13	25 - 35	55 - 65	0 - 12
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.00	8.60	6.60	5.70	5.70	5.60
pH (1:5 CaCl2)		6.80	7.50	5.70	4.80	5.00	4.70
Aluminium Saturation	%				1.7	2.5	
Organic Carbon (OC)	%			0.29			1.30
Nitrate Nitrogen (NO3)	mg/kg	<1.0	<1.0		<1.0	1.0	
Total Nitrogen	%			<0.04			0.10
Phosphorus (Colwell)	mg/kg			<5			15
Phosphorus (BSES)	mg/kg			9			14
Available Potassium	mg/kg	90	58		41	21	
Potassium (Nitric K)	meq/100g			1.70			1.90
Sulphate Sulphur (MCP)	mg/kg			2.2			11.0
Zinc (DTPA)	mg/kg			0.24			1.30
Copper (DTPA)	mg/kg			0.21			0.32
Iron (DTPA)	mg/kg			13.0			210.0
Manganese (DTPA)	mg/kg			4.70			12.00
Boron (Hot CaCl2)	mg/kg			0.14			0.25
Chloride	mg/kg	27.0	210.0		490.0	640.0	
Electrical Conductivity	dS/m	0.10	0.23	0.03	0.30	0.47	0.15
Cation Exchange Capacity	meq/100g	14.80	12.20				
Cation Exchange Capacity	meq/100g				5.91	4.00	
Aluminium (KCl)	mg/kg				<9.00	<9.00	

Analyses conducted by **Nutrient Advantage Laboratory Services**
8 South Road, Werribee VIC 3030
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Sample No	030001777	030001778	030001779	030001780	030001781	030001782
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 12	SITE 12	SITE 13	SITE 13	SITE 13	SITE 14
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	25 - 35	55 - 65	0 - 13	25 - 35	55 - 65	0 - 12
Sampling Date						

Analyte / Assay	Unit	Value					
Aluminium (KCl)	meq/100g				0.10	0.10	
Calcium (Amm-acet.)	%	41.000	23.000				
Calcium (Amm-acet.)	meq/100g	6.000	2.800		2.200	0.650	
Calcium (Amm-acet.)	%				37.000	16.000	
Magnesium (Amm-acet.)	%	49.000	52.000				
Magnesium (Amm-acet.)	meq/100g	7.200	6.300		2.000	1.100	
Magnesium (Amm-acet.)	%				34.000	28.000	
Sodium (Amm-acet.)	%	9.500	25.000				
Sodium (Amm-acet.)	meq/100g	1.400	3.000		1.500	2.100	
Sodium % of Cations (ESP)	%				25.000	53.000	
Potassium (Amm-acet.)	%	1.600	1.200				
Potassium (Amm-acet.)	meq/100g	0.230	0.150		0.110	0.053	
Potassium (Amm-acet.)	%				1.900	1.300	
Calcium/Magnesium Ratio		0.8	0.4		1.1	0.6	
Potassium to Magnesium Ratio		0.0	0.0		0.1	0.0	
Silicon (BSES)	mg/kg			96			140
% Clay	%	40	21		10	6	
% Sand (Fine)	%	47	64		62	69	
% Sand (Coarse)	%	2	5		15	23	
% Silt	%	11	10		14	3	
Sansilclay Texture		Sandy Clay	Sandy Clay Loam		Sandy Loam	Sand	
Organic Matter	%			0.5			2.2

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BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030001771**	**030001772**	**030001773**	**030001774**	**030001775**	**030001776**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 10	SITE 10	SITE 11	SITE 11	SITE 11	SITE 12
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	35 - 55	65 - 85	0 - 20	55 - 65	65 - 85	0 - 13
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.00	9.20	5.90	9.00	9.50	7.00
pH (1:5 CaCl2)		7.30	8.30	4.50	8.00	8.70	6.30
Organic Carbon (OC)	%			0.46			1.40
Nitrate Nitrogen (NO3)	mg/kg	1.2	1.3		<1.0	1.0	
Total Nitrogen	%			<0.04			0.14
Phosphorus (Colwell)	mg/kg			6			5
Phosphorus (BSES)	mg/kg			7			13
Available Potassium	mg/kg	79	65		72	60	
Potassium (Nitric K)	meq/100g			1.80			2.60
Sulphate Sulphur (MCP)	mg/kg			3.4			3.5
Zinc (DTPA)	mg/kg			1.30			1.40
Copper (DTPA)	mg/kg			0.17			0.33
Iron (DTPA)	mg/kg			62.0			46.0
Manganese (DTPA)	mg/kg			6.40			16.00
Boron (Hot CaCl2)	mg/kg			0.20			0.62
Chloride	mg/kg	1000.0	370.0		180.0	330.0	
Electrical Conductivity	dS/m	0.85	0.59	0.03	0.24	0.37	0.08
Cation Exchange Capacity	meq/100g	19.20	14.60		13.10	13.80	
Calcium (Amm-acet.)	%	24.000	29.000		37.000	43.000	
Calcium (Amm-acet.)	meq/100g	4.700	4.300		4.900	6.000	
Magnesium (Amm-acet.)	%	36.000	30.000		43.000	36.000	

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Sample No	**030001771**	**030001772**	**030001773**	**030001774**	**030001775**	**030001776**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 10	SITE 10	SITE 11	SITE 11	SITE 11	SITE 12
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	35 - 55	65 - 85	0 - 20	55 - 65	65 - 85	0 - 13
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	6.900	4.400		5.600	5.000	
Sodium (Amm-acet.)	%	39.000	39.000		18.000	20.000	
Sodium (Amm-acet.)	meq/100g	7.400	5.700		2.400	2.700	
Potassium (Amm-acet.)	%	1.000	1.200		1.400	1.100	
Potassium (Amm-acet.)	meq/100g	0.200	0.170		0.180	0.150	
Calcium/Magnesium Ratio		0.7	1.0		0.9	1.2	
Potassium to Magnesium Ratio		0.0	0.0		0.0	0.0	
Silicon (BSES)	mg/kg			67			250
% Clay	%	49	26		34	24	
% Sand (Fine)	%	37	58		52	56	
% Sand (Coarse)	%	5	7		4	7	
% Silt	%	9	9		10	14	
Sansilclay Texture		Clay	Sandy Clay Loam		Sandy Clay Loam	Sandy Clay Loam	
Organic Matter	%			0.8			2.4

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Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030001783**	**030001784**	**030001785**	**030001786**	**030001787**	**030001788**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 14	SITE 14	SITE 15	SITE 15	SITE 21	SITE 21
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	25 - 35	55 - 90	0 - 15	35 - 55	25 - 35	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		7.10	8.40	7.80	9.10	7.70	8.70
pH (1:5 CaCl2)		6.30	7.60	7.00	8.20	6.70	7.90
Organic Carbon (OC)	%			1.20			
Nitrate Nitrogen (NO3)	mg/kg	<1.0	1.1		<1.0	<1.0	<1.0
Total Nitrogen	%			0.09			
Phosphorus (Colwell)	mg/kg			11			
Phosphorus (BSES)	mg/kg			13			
Available Potassium	mg/kg	95	77		130	210	150
Potassium (Nitric K)	meq/100g			4.40			
Sulphate Sulphur (MCP)	mg/kg			5.7			
Zinc (DTPA)	mg/kg			0.44			
Copper (DTPA)	mg/kg			1.10			
Iron (DTPA)	mg/kg			26.0			
Manganese (DTPA)	mg/kg			9.60			
Boron (Hot CaCl2)	mg/kg			0.81			
Chloride	mg/kg	700.0	710.0		230.0	<10.0	<10.0
Electrical Conductivity	dS/m	0.66	0.85	0.15	0.47	0.05	0.15
Cation Exchange Capacity	meq/100g	16.30	15.50		38.40	33.80	44.50
Calcium (Amm-acet.)	%	25.000	18.000		60.000	83.000	88.000
Calcium (Amm-acet.)	meq/100g	4.000	2.800		23.000	28.000	39.000
Magnesium (Amm-acet.)	%	37.000	33.000		26.000	14.000	10.000

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Sample No	**030001783**	**030001784**	**030001785**	**030001786**	**030001787**	**030001788**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 14	SITE 14	SITE 15	SITE 15	SITE 21	SITE 21
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	25 - 35	55 - 90	0 - 15	35 - 55	25 - 35	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	6.000	5.100		9.900	4.900	4.500
Sodium (Amm-acet.)	%	37.000	48.000		14.000	1.000	1.400
Sodium (Amm-acet.)	meq/100g	6.100	7.400		5.200	0.340	0.610
Potassium (Amm-acet.)	%	1.500	1.300		0.890	1.600	0.830
Potassium (Amm-acet.)	meq/100g	0.240	0.200		0.340	0.530	0.370
Calcium/Magnesium Ratio		0.7	0.6		2.3	5.7	8.7
Potassium to Magnesium Ratio		0.0	0.0		0.0	0.1	0.1
Silicon (BSES)	mg/kg			1500			
% Clay	%	45	40		49	46	41
% Sand (Fine)	%	41	47		32	33	45
% Sand (Coarse)	%	6	6		10	8	11
% Silt	%	8	8		9	13	3
Sansilclay Texture		Sandy Clay	Sandy Clay		Clay	Clay	Sandy Clay
Organic Matter	%			2.1			

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BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
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Sample No	**030001789**	**030001790**	**030001791**	**030001792**	**030001793**	**030001794**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 21	SITE 22	SITE 22	SITE 22	SITE 23	SITE 23
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 15	0 - 15	35 - 55	65 - 100	0 - 10	25 - 35
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		7.50	7.80	8.90	8.80	7.40	8.50
pH (1:5 CaCl2)		6.80	7.20	8.00	8.20	6.70	7.80
Organic Carbon (OC)	%	1.80	2.30			1.60	
Nitrate Nitrogen (NO3)	mg/kg			<1.0	<1.0		<1.0
Total Nitrogen	%	0.16	0.22			0.13	
Phosphorus (Colwell)	mg/kg	<5	27			8	
Phosphorus (BSES)	mg/kg	45	130			13	
Available Potassium	mg/kg			190	200		170
Potassium (Nitric K)	meq/100g	4.80	4.50			3.50	
Sulphate Sulphur (MCP)	mg/kg	4.5	11.0			5.4	
Zinc (DTPA)	mg/kg	0.46	0.69			0.55	
Copper (DTPA)	mg/kg	0.99	1.70			0.87	
Iron (DTPA)	mg/kg	23.0	23.0			22.0	
Manganese (DTPA)	mg/kg	18.00	8.30			17.00	
Boron (Hot CaCl2)	mg/kg	0.58	1.10			0.73	
Chloride	mg/kg			<10.0	820.0		<10.0
Electrical Conductivity	dS/m	0.10	0.20	0.19	0.80	0.08	0.15
Cation Exchange Capacity	meq/100g			69.30	69.50		37.20
Calcium (Amm-acet.)	%			79.000	68.000		83.000
Calcium (Amm-acet.)	meq/100g			55.000	47.000		31.000
Magnesium (Amm-acet.)	%			17.000	22.000		14.000

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Sample No Test Code	**030001789** ADMINSOIL	**030001790** ADMINSOIL	**030001791** ADMINSOIL	**030001792** ADMINSOIL	**030001793** ADMINSOIL	**030001794** ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 21	SITE 22	SITE 22	SITE 22	SITE 23	SITE 23
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 15	0 - 15	35 - 55	65 - 100	0 - 10	25 - 35
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g			12.000	15.000		5.300
Sodium (Amm-acet.)	%			2.600	10.000		1.400
Sodium (Amm-acet.)	meq/100g			1.800	7.000		0.520
Potassium (Amm-acet.)	%			0.690	0.720		1.100
Potassium (Amm-acet.)	meq/100g			0.480	0.500		0.420
Calcium/Magnesium Ratio				4.6	3.1		5.8
Potassium to Magnesium Ratio				0.0	0.0		0.1
Silicon (BSES)	mg/kg	900	1500			760	
% Clay	%			64	65		49
% Sand (Fine)	%			28	22		33
% Sand (Coarse)	%			1	1		11
% Silt	%			8	11		8
Sansilclay Texture				Clay	Clay		Clay
Organic Matter	%	3.1	4.0			2.8	

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Nutrient Advantage Advice® Summary Report

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BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030001795**	**030001796**	**030001797**	**030001798**	**030001799**	**030001800**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 23	SITE 24	SITE 24	SITE 24	SITE 25	SITE 25
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	55 - 65	0 - 10	25 - 35	55 - 65	0 - 15	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.80	8.40	8.90	9.20	6.50	8.00
pH (1:5 CaCl2)		8.00	7.80	8.00	8.20	5.50	6.70
Organic Carbon (OC)	%		1.60			0.92	
Nitrate Nitrogen (NO3)	mg/kg	<1.0		<1.0	<1.0		<1.0
Total Nitrogen	%		0.15			0.06	
Phosphorus (Colwell)	mg/kg		42			40	
Phosphorus (BSES)	mg/kg		150			67	
Available Potassium	mg/kg	150		150	120		150
Potassium (Nitric K)	meq/100g		2.70			5.30	
Sulphate Sulphur (MCP)	mg/kg		5.0			2.1	
Zinc (DTPA)	mg/kg		0.41			0.88	
Copper (DTPA)	mg/kg		1.10			0.61	
Iron (DTPA)	mg/kg		14.2			93.0	
Manganese (DTPA)	mg/kg		5.50			34.00	
Boron (Hot CaCl2)	mg/kg		0.97			0.29	
Chloride	mg/kg	11.0		<10.0	20.0		<10.0
Electrical Conductivity	dS/m	0.16	0.17	0.19	0.26	0.04	0.04
Cation Exchange Capacity	meq/100g	41.30		68.30	67.70		12.80
Calcium (Amm-acet.)	%	82.000		81.000	74.000		55.000
Calcium (Amm-acet.)	meq/100g	34.000		55.000	50.000		7.000
Magnesium (Amm-acet.)	%	15.000		16.000	19.000		38.000

Analyses conducted by **Nutrient Advantage Laboratory Services**
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Sample No	**030001795**	**030001796**	**030001797**	**030001798**	**030001799**	**030001800**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 23	SITE 24	SITE 24	SITE 24	SITE 25	SITE 25
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	55 - 65	0 - 10	25 - 35	55 - 65	0 - 15	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	6.000		11.000	13.000		4.900
Sodium (Amm-acet.)	%	2.200		2.800	6.500		3.800
Sodium (Amm-acet.)	meq/100g	0.910		1.900	4.400		0.480
Potassium (Amm-acet.)	%	0.900		0.590	0.470		3.100
Potassium (Amm-acet.)	meq/100g	0.370		0.400	0.320		0.400
Calcium/Magnesium Ratio		5.7		5.0	3.8		1.4
Potassium to Magnesium Ratio		0.1		0.0	0.0		0.1
Silicon (BSES)	mg/kg		1300			270	
% Clay	%	48		58	56		31
% Sand (Fine)	%	31		28	27		38
% Sand (Coarse)	%	13		4	5		21
% Silt	%	9		10	13		10
Sansilclay Texture		Clay		Clay	Clay		Sandy Clay Loam
Organic Matter	%		2.8			1.6	

The results reported pertain only to the samples submitted.
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Sample No Test Code	**030001801** ADMINSOIL	**030001802** ADMINSOIL	**030001803** ADMINSOIL	**030001804** ADMINSOIL	**030001805** ADMINSOIL	**030001806** ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 25	SITE 25	SITE 26	SITE 26	SITE 26	SITE 27
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 80	80 - 120	0 - 10	35 - 55	65 - 130	0 - 12
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.80	9.00	8.30	8.80	9.10	7.10
pH (1:5 CaCl2)		7.60	7.90	7.70	8.10	8.30	6.50
Organic Carbon (OC)	%			1.40			1.60
Nitrate Nitrogen (NO3)	mg/kg	<1.0	<1.0		2.1	<1.0	
Total Nitrogen	%			0.13			0.13
Phosphorus (Colwell)	mg/kg			52			44
Phosphorus (BSES)	mg/kg			240			59
Available Potassium	mg/kg	150	120		240	180	
Potassium (Nitric K)	meq/100g			6.50			15.00
Sulphate Sulphur (MCP)	mg/kg			7.7			3.9
Zinc (DTPA)	mg/kg			0.57			0.71
Copper (DTPA)	mg/kg			1.20			1.10
Iron (DTPA)	mg/kg			11.0			36.0
Manganese (DTPA)	mg/kg			4.50			40.00
Boron (Hot CaCl2)	mg/kg			1.10			0.45
Chloride	mg/kg	<10.0	14.0		<10.0	54.0	
Electrical Conductivity	dS/m	0.07	0.08	0.22	0.33	0.48	0.10
Cation Exchange Capacity	meq/100g	13.20	11.90		54.40	52.20	
Calcium (Amm-acet.)	%	53.000	55.000		72.000	65.000	
Calcium (Amm-acet.)	meq/100g	7.000	6.500		39.000	34.000	
Magnesium (Amm-acet.)	%	39.000	37.000		22.000	23.000	

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Sample No	**030001801**	**030001802**	**030001803**	**030001804**	**030001805**	**030001806**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 25	SITE 25	SITE 26	SITE 26	SITE 26	SITE 27
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 80	80 - 120	0 - 10	35 - 55	65 - 130	0 - 12
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	5.100	4.400		12.000	12.000	
Sodium (Amm-acet.)	%	5.300	5.500		5.100	11.000	
Sodium (Amm-acet.)	meq/100g	0.700	0.650		2.800	5.700	
Potassium (Amm-acet.)	%	2.900	2.600		1.100	0.900	
Potassium (Amm-acet.)	meq/100g	0.380	0.310		0.610	0.470	
Calcium/Magnesium Ratio		1.4	1.5		3.3	2.8	
Potassium to Magnesium Ratio		0.1	0.1		0.1	0.0	
Silicon (BSES)	mg/kg			1400			930
% Clay	%	29	21		58	58	
% Sand (Fine)	%	42	52		25	25	
% Sand (Coarse)	%	21	18		1	1	
% Silt	%	9	9		16	16	
Sansilclay Texture		Sandy Clay Loam	Sandy Clay Loam		Clay	Clay	
Organic Matter	%			2.4			2.8

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Sample No Test Code	**030001807** ADMINSOIL	**030001808** ADMINSOIL	**030001809** ADMINSOIL	**030001810** ADMINSOIL	**030001811** ADMINSOIL	**030001812** ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 27	SITE 27	SITE 28	SITE 28	SITE 28	SITE 29
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	25 - 35	55 - 65	0 - 15	25 - 35	55 - 65	25 - 35
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		7.30	7.60	6.80	7.10	7.60	8.40
pH (1:5 CaCl2)		6.30	6.40	6.00	6.00	6.30	7.80
Organic Carbon (OC)	%			1.40			
Nitrate Nitrogen (NO3)	mg/kg	<1.0	<1.0		<1.0	<1.0	<1.0
Total Nitrogen	%			0.12			
Phosphorus (Colwell)	mg/kg			21			
Phosphorus (BSES)	mg/kg			35			
Available Potassium	mg/kg	190	130		170	88	320
Potassium (Nitric K)	meq/100g			13.00			
Sulphate Sulphur (MCP)	mg/kg			2.7			
Zinc (DTPA)	mg/kg			0.66			
Copper (DTPA)	mg/kg			0.86			
Iron (DTPA)	mg/kg			30.0			
Manganese (DTPA)	mg/kg			60.00			
Boron (Hot CaCl2)	mg/kg			0.48			
Chloride	mg/kg	<10.0	<10.0		<10.0	<10.0	<10.0
Electrical Conductivity	dS/m	0.05	0.04	0.05	0.03	0.03	0.15
Cation Exchange Capacity	meq/100g	31.60	34.80		32.80	39.20	50.40
Calcium (Amm-acet.)	%	66.000	72.000		76.000	82.000	91.000
Calcium (Amm-acet.)	meq/100g	21.000	25.000		25.000	32.000	46.000
Magnesium (Amm-acet.)	%	31.000	26.000		22.000	17.000	6.900

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Sample No	**030001807**	**030001808**	**030001809**	**030001810**	**030001811**	**030001812**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 27	SITE 27	SITE 28	SITE 28	SITE 28	SITE 29
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	25 - 35	55 - 65	0 - 15	25 - 35	55 - 65	25 - 35
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	9.900	9.100		7.300	6.700	3.500
Sodium (Amm-acet.)	%	0.700	1.100		0.290	0.590	0.190
Sodium (Amm-acet.)	meq/100g	0.220	0.370		0.096	0.230	0.096
Potassium (Amm-acet.)	%	1.500	0.920		1.300	0.560	1.600
Potassium (Amm-acet.)	meq/100g	0.480	0.320		0.440	0.220	0.820
Calcium/Magnesium Ratio		2.1	2.7		3.4	4.8	13.0
Potassium to Magnesium Ratio		0.0	0.0		0.1	0.0	0.2
Silicon (BSES)	mg/kg			890			
% Clay	%	46	26		34	18	50
% Sand (Fine)	%	31	44		38	35	26
% Sand (Coarse)	%	7	15		11	35	5
% Silt	%	16	15		18	13	19
Sansilclay Texture		Clay	Sandy Clay Loam		Sandy Clay Loam	Sandy Loam	Clay
Organic Matter	%			2.4			

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Sample No	**030001813**	**030001814**	**030001815**	**030001816**	**030001817**	**030001818**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 29	SITE 30	SITE 30	SITE 31	SITE 31	SITE 31
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	55 - 65	35 - 55	65 - 140	0 - 10	25 - 35	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.90	9.00	8.80	8.10	8.40	8.70
pH (1:5 CaCl2)		8.00	8.00	8.30	7.50	7.70	7.90
Organic Carbon (OC)	%				2.20		
Nitrate Nitrogen (NO3)	mg/kg	<1.0	<1.0	<1.0		<1.0	<1.0
Total Nitrogen	%				0.20		
Phosphorus (Colwell)	mg/kg				36		
Phosphorus (BSES)	mg/kg				350		
Available Potassium	mg/kg	150	190	180		220	59
Potassium (Nitric K)	meq/100g				10.00		
Sulphate Sulphur (MCP)	mg/kg				4.6		
Zinc (DTPA)	mg/kg				0.89		
Copper (DTPA)	mg/kg				0.76		
Iron (DTPA)	mg/kg				21.0		
Manganese (DTPA)	mg/kg				12.00		
Boron (Hot CaCl2)	mg/kg				0.72		
Chloride	mg/kg	<10.0	41.0	1300.0		<10.0	<10.0
Electrical Conductivity	dS/m	0.12	0.23	1.07	0.15	0.14	0.11
Cation Exchange Capacity	meq/100g	42.30	46.40	50.20		45.60	46.10
Calcium (Amm-acet.)	%	90.000	78.000	60.000		94.000	95.000
Calcium (Amm-acet.)	meq/100g	38.000	36.000	30.000		43.000	44.000
Magnesium (Amm-acet.)	%	8.700	16.000	22.000		4.400	4.100

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Sample No	**030001813**	**030001814**	**030001815**	**030001816**	**030001817**	**030001818**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 29	SITE 30	SITE 30	SITE 31	SITE 31	SITE 31
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	55 - 65	35 - 55	65 - 140	0 - 10	25 - 35	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	3.700	7.200	11.000		2.000	1.900
Sodium (Amm-acet.)	%	0.470	5.800	17.000		0.110	0.190
Sodium (Amm-acet.)	meq/100g	0.200	2.700	8.700		0.052	0.087
Potassium (Amm-acet.)	%	0.870	1.000	0.900		1.200	0.330
Potassium (Amm-acet.)	meq/100g	0.370	0.480	0.450		0.560	0.150
Calcium/Magnesium Ratio		10.0	5.0	2.7		22.0	23.0
Potassium to Magnesium Ratio		0.1	0.1	0.0		0.3	0.1
Silicon (BSES)	mg/kg				1200		
% Clay	%	44	45	46		45	21
% Sand (Fine)	%	31	30	31		30	44
% Sand (Coarse)	%	6	13	9		12	19
% Silt	%	20	13	14		13	16
Sansilclay Texture		Clay	Clay	Clay		Clay	Sandy Clay Loam
Organic Matter	%				3.8		

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Sample No	**030001825**	**030001826**	**030001827**	**030001828**	**030001829**	**030001830**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	11/01/2012	11/01/2012	09/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 34	SITE 35	SITE 35	SITE 35	SITE 35	SITE 36
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 120	0 - 10	25 - 35	55 - 65	65 - 90	0 - 25
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.90	6.10	6.60	6.80	6.80	6.80
pH (1:5 CaCl2)		8.20	5.10	5.50	5.90	5.90	5.80
Organic Carbon (OC)	%		0.83				0.50
Nitrate Nitrogen (NO3)	mg/kg	<1.0		<1.0	<1.0	<1.0	
Total Nitrogen	%		0.05				<0.04
Phosphorus (Colwell)	mg/kg		12				9
Phosphorus (BSES)	mg/kg		20				25
Available Potassium	mg/kg	120		91	78	72	
Potassium (Nitric K)	meq/100g		2.20				1.80
Sulphate Sulphur (MCP)	mg/kg		3.8				<1.0
Zinc (DTPA)	mg/kg		0.47				0.17
Copper (DTPA)	mg/kg		0.46				0.15
Iron (DTPA)	mg/kg		26.0				10.0
Manganese (DTPA)	mg/kg		61.00				17.00
Boron (Hot CaCl2)	mg/kg		0.33				0.09
Chloride	mg/kg	560.0		<10.0	<10.0	<10.0	
Electrical Conductivity	dS/m	0.78	0.04	0.02	0.02	0.02	0.02
Cation Exchange Capacity	meq/100g	51.60		6.17	10.60	12.00	
Calcium (Amm-acet.)	%	54.000		71.000	71.000	71.000	
Calcium (Amm-acet.)	meq/100g	28.000		4.400	7.500	8.500	
Magnesium (Amm-acet.)	%	29.000		24.000	26.000	27.000	

Analyses conducted by **Nutrient Advantage Laboratory Services**
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Sample No	**030001825**	**030001826**	**030001827**	**030001828**	**030001829**	**030001830**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	11/01/2012	11/01/2012	09/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 34	SITE 35	SITE 35	SITE 35	SITE 35	SITE 36
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 120	0 - 10	25 - 35	55 - 65	65 - 90	0 - 25
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	15.000		1.500	2.800	3.200	
Sodium (Amm-acet.)	%	16.000		0.580	0.820	1.300	
Sodium (Amm-acet.)	meq/100g	8.300		0.036	0.087	0.150	
Potassium (Amm-acet.)	%	0.600		3.700	1.900	1.600	
Potassium (Amm-acet.)	meq/100g	0.310		0.230	0.200	0.190	
Calcium/Magnesium Ratio		1.9		2.9	2.7	2.7	
Potassium to Magnesium Ratio		0.0		0.2	0.1	0.1	
Silicon (BSES)	mg/kg		150				110
% Clay	%	56		26	53	55	
% Sand (Fine)	%	25		30	19	20	
% Sand (Coarse)	%	10		39	22	20	
% Silt	%	9		5	6	5	
Sansilclay Texture		Clay		Sandy Clay Loam	Clay	Clay	
Organic Matter	%		1.4				0.9

The results reported pertain only to the samples submitted.
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Analyses performed on plant material dried at 70 degrees Celsius and ground to <2mm
Water analyses performed on an 'as received' basis
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Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No Test Code	**030001831** ADMINSOIL	**030001832** ADMINSOIL	**030001833** ADMINSOIL	**030001834** ADMINSOIL	**030001835** ADMINSOIL	**030001836** ADMINSOIL
Lab Results Received Date	11/01/2012	11/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 36	SITE 36	SITE 37	SITE 37	SITE 37	SITE 37
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	35 - 55	65 - 100	0 - 10	25 - 35	55 - 65	65 - 100
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		7.30	7.50	6.60	6.90	7.20	7.60
pH (1:5 CaCl2)		6.30	6.40	5.60	5.80	6.00	6.30
Organic Carbon (OC)	%			0.48			
Nitrate Nitrogen (NO3)	mg/kg	1.3	<1.0		<1.0	<1.0	<1.0
Total Nitrogen	%			<0.04			
Phosphorus (Colwell)	mg/kg			13			
Phosphorus (BSES)	mg/kg			65			
Available Potassium	mg/kg	43	58		91	200	210
Potassium (Nitric K)	meq/100g			3.80			
Sulphate Sulphur (MCP)	mg/kg			1.1			
Zinc (DTPA)	mg/kg			0.32			
Copper (DTPA)	mg/kg			0.14			
Iron (DTPA)	mg/kg			23.0			
Manganese (DTPA)	mg/kg			15.00			
Boron (Hot CaCl2)	mg/kg			0.16			
Chloride	mg/kg	<10.0	<10.0		<10.0	<10.0	<10.0
Electrical Conductivity	dS/m	0.01	0.01	0.03	0.01	0.02	0.02
Cation Exchange Capacity	meq/100g	1.68	2.20		2.97	11.40	12.60
Calcium (Amm-acet.)	%	71.000	68.000		61.000	57.000	60.000
Calcium (Amm-acet.)	meq/100g	1.200	1.500		1.800	6.500	7.500
Magnesium (Amm-acet.)	%	21.000	24.000		31.000	37.000	35.000

Analyses conducted by **Nutrient Advantage Laboratory Services**
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Sample No	**030001831**	**030001832**	**030001833**	**030001834**	**030001835**	**030001836**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	11/01/2012	11/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 36	SITE 36	SITE 37	SITE 37	SITE 37	SITE 37
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	35 - 55	65 - 100	0 - 10	25 - 35	55 - 65	65 - 100
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	0.350	0.530		0.910	4.200	4.400
Sodium (Amm-acet.)	%	<1.310	<1.000		1.000	1.300	1.500
Sodium (Amm-acet.)	meq/100g	<0.022	<0.022		0.031	0.150	0.190
Potassium (Amm-acet.)	%	6.500	6.800		7.700	4.500	4.200
Potassium (Amm-acet.)	meq/100g	0.110	0.150		0.230	0.510	0.530
Calcium/Magnesium Ratio		3.4	2.8		2.0	1.5	1.7
Potassium to Magnesium Ratio		0.3	0.3		0.3	0.1	0.1
Silicon (BSES)	mg/kg			170			
% Clay	%	3	6		4	26	29
% Sand (Fine)	%	13	20		43	35	39
% Sand (Coarse)	%	82	68		43	30	24
% Silt	%	3	5		10	9	9
Sansilclay Texture		Sand	Sand		Loamy Sand	Sandy Clay Loam	Sandy Clay Loam
Organic Matter	%			0.8			

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Sample No	**030001837**	**030001838**	**030001839**	**030001840**	**030001841**	**030001842**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	11/01/2012	11/01/2012	09/01/2012	11/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 38	SITE 38	SITE 38	SITE 39	SITE 39	SITE 39
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 7	7 - 25	65 - 110	0 - 25	35 - 55	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		6.10	6.60	7.90	5.80	7.10	7.10
pH (1:5 CaCl2)		5.10	5.50	6.70	4.70	5.70	5.70
Organic Carbon (OC)	%	0.97			0.63		
Nitrate Nitrogen (NO3)	mg/kg		<1.0	<1.0		<1.0	<1.0
Total Nitrogen	%	0.07			0.05		
Phosphorus (Colwell)	mg/kg	33			14		
Phosphorus (BSES)	mg/kg	64			26		
Available Potassium	mg/kg		110	230		110	110
Potassium (Nitric K)	meq/100g	3.30			4.80		
Sulphate Sulphur (MCP)	mg/kg	1.6			2.0		
Zinc (DTPA)	mg/kg	0.87			0.43		
Copper (DTPA)	mg/kg	0.73			0.28		
Iron (DTPA)	mg/kg	77.0			55.0		
Manganese (DTPA)	mg/kg	21.00			21.00		
Boron (Hot CaCl2)	mg/kg	0.15			0.12		
Chloride	mg/kg		<10.0	<10.0		<10.0	<10.0
Electrical Conductivity	dS/m	0.03	0.02	0.02	0.03	0.02	0.02
Cation Exchange Capacity	meq/100g		4.42	11.30		11.80	12.80
Calcium (Amm-acet.)	%		72.000	71.000		51.000	51.000
Calcium (Amm-acet.)	meq/100g		3.200	8.000		6.000	6.500
Magnesium (Amm-acet.)	%		21.000	23.000		44.000	45.000

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Sample No	**030001837**	**030001838**	**030001839**	**030001840**	**030001841**	**030001842**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	11/01/2012	11/01/2012	09/01/2012	11/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 38	SITE 38	SITE 38	SITE 39	SITE 39	SITE 39
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 7	7 - 25	65 - 110	0 - 25	35 - 55	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g		0.910	2.600		5.200	5.700
Sodium (Amm-acet.)	%		0.900	1.400		2.500	2.400
Sodium (Amm-acet.)	meq/100g		0.040	0.160		0.300	0.310
Potassium (Amm-acet.)	%		6.100	5.100		2.300	2.200
Potassium (Amm-acet.)	meq/100g		0.270	0.580		0.270	0.280
Calcium/Magnesium Ratio			3.5	3.1		1.2	1.1
Potassium to Magnesium Ratio			0.3	0.2		0.1	0.0
Silicon (BSES)	mg/kg	240			170		
% Clay	%		6	16		28	33
% Sand (Fine)	%		17	18		53	48
% Sand (Coarse)	%		64	60		9	9
% Silt	%		13	6		11	11
Sansilclay Texture			Loamy Sand	Sandy Loam		Sandy Clay Loam	Sandy Clay Loam
Organic Matter	%	1.7			1.1		

The results reported pertain only to the samples submitted.
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Phone:

Sample No	**030001843**	**030001844**	**030001845**	**030001846**	**030001847**	**030001848**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	11/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012	09/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 39	SITE 40	SITE 40	SITE 40	SITE 40	SITE 41
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	90 - 150	0 - 15	35 - 55	65 - 80	80 - 140	0 - 10
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.40	6.10	8.00	8.80	8.80	6.80
pH (1:5 CaCl2)		7.00	5.10	6.80	8.10	7.80	5.90
Organic Carbon (OC)	%		1.20				1.20
Nitrate Nitrogen (NO3)	mg/kg	<1.0		<1.0	<1.0	<1.0	
Total Nitrogen	%		0.09				0.10
Phosphorus (Colwell)	mg/kg		24				75
Phosphorus (BSES)	mg/kg		44				380
Available Potassium	mg/kg	120		110	110	100	
Potassium (Nitric K)	meq/100g		6.00				6.60
Sulphate Sulphur (MCP)	mg/kg		3.6				2.8
Zinc (DTPA)	mg/kg		0.95				0.97
Copper (DTPA)	mg/kg		1.30				0.53
Iron (DTPA)	mg/kg		100.0				57.0
Manganese (DTPA)	mg/kg		46.00				13.00
Boron (Hot CaCl2)	mg/kg		0.40				0.35
Chloride	mg/kg	<10.0		78.0	240.0	140.0	
Electrical Conductivity	dS/m	0.04	0.05	0.11	0.31	0.16	0.05
Cation Exchange Capacity	meq/100g	12.40		22.80	23.20	14.50	
Calcium (Amm-acet.)	%	48.000		48.000	56.000	48.000	
Calcium (Amm-acet.)	meq/100g	6.000		11.000	13.000	7.000	
Magnesium (Amm-acet.)	%	44.000		43.000	35.000	40.000	

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Sample No	**030001843**	**030001844**	**030001845**	**030001846**	**030001847**	**030001848**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	11/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012	09/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 39	SITE 40	SITE 40	SITE 40	SITE 40	SITE 41
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	90 - 150	0 - 15	35 - 55	65 - 80	80 - 140	0 - 10
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	5.500		9.900	8.200	5.800	
Sodium (Amm-acet.)	%	4.600		7.000	7.300	9.700	
Sodium (Amm-acet.)	meq/100g	0.570		1.600	1.700	1.400	
Potassium (Amm-acet.)	%	2.300		1.300	1.300	1.800	
Potassium (Amm-acet.)	meq/100g	0.290		0.290	0.290	0.260	
Calcium/Magnesium Ratio		1.1		1.1	1.6	1.2	
Potassium to Magnesium Ratio		0.1		0.0	0.0	0.0	
Silicon (BSES)	mg/kg		410				460
% Clay	%	20		45	34	23	
% Sand (Fine)	%	53		38	41	56	
% Sand (Coarse)	%	11		3	6	8	
% Silt	%	16		14	19	14	
Sansilclay Texture		Sandy Clay Loam		Clay	Sandy Clay Loam	Sandy Clay Loam	
Organic Matter	%		2.1				2.1

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Sample No	**030001849**	**030001850**	**030001851**	**030001852**	**030001853**	**030001854**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	11/01/2012	11/01/2012	11/01/2012	09/01/2012	11/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 41	SITE 41	SITE 41	SITE 42	SITE 42	SITE 42
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	25 - 35	65 - 100	100 - 150	0 - 17	25 - 35	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		7.20	7.70	8.00	6.20	6.90	7.30
pH (1:5 CaCl2)		6.20	6.70	7.00	5.30	5.80	5.90
Organic Carbon (OC)	%				0.45		
Nitrate Nitrogen (NO3)	mg/kg	<1.0	<1.0	<1.0		1.7	<1.0
Total Nitrogen	%				<0.04		
Phosphorus (Colwell)	mg/kg				16		
Phosphorus (BSES)	mg/kg				41		
Available Potassium	mg/kg	100	74	76		97	88
Potassium (Nitric K)	meq/100g				2.20		
Sulphate Sulphur (MCP)	mg/kg				1.8		
Zinc (DTPA)	mg/kg				0.47		
Copper (DTPA)	mg/kg				0.13		
Iron (DTPA)	mg/kg				36.0		
Manganese (DTPA)	mg/kg				16.00		
Boron (Hot CaCl2)	mg/kg				0.06		
Chloride	mg/kg	<10.0	<10.0	<10.0		<10.0	<10.0
Electrical Conductivity	dS/m	0.03	0.02	0.03	0.03	0.02	0.02
Cation Exchange Capacity	meq/100g	9.90	8.62	10.30		2.40	8.44
Calcium (Amm-acet.)	%	76.000	75.000	73.000		63.000	55.000
Calcium (Amm-acet.)	meq/100g	7.500	6.500	7.500		1.500	4.600
Magnesium (Amm-acet.)	%	21.000	22.000	25.000		26.000	40.000

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Sample No	**030001849**	**030001850**	**030001851**	**030001852**	**030001853**	**030001854**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	11/01/2012	11/01/2012	11/01/2012	09/01/2012	11/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 41	SITE 41	SITE 41	SITE 42	SITE 42	SITE 42
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	25 - 35	65 - 100	100 - 150	0 - 17	25 - 35	55 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	2.100	1.900	2.600		0.620	3.400
Sodium (Amm-acet.)	%	0.270	0.340	0.470		1.100	2.500
Sodium (Amm-acet.)	meq/100g	0.027	0.029	0.048		0.027	0.210
Potassium (Amm-acet.)	%	2.700	2.200	1.800		10.000	2.700
Potassium (Amm-acet.)	meq/100g	0.270	0.190	0.190		0.250	0.230
Calcium/Magnesium Ratio		3.6	3.4	2.9		2.4	1.4
Potassium to Magnesium Ratio		0.1	0.1	0.1		0.4	0.1
Silicon (BSES)	mg/kg				110		
% Clay	%	9	11	14		3	23
% Sand (Fine)	%	66	72	64		44	30
% Sand (Coarse)	%	15	11	12		45	40
% Silt	%	10	6	10		9	8
Sansilclay Texture		Loamy Sand	Loamy Sand	Sandy Loam		Sand	Sandy Clay Loam
Organic Matter	%				0.8		

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Analyses performed on plant material dried at 70 degrees Celsius and ground to <2mm
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BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030001855**	**030001856**	**030001857**	**030001858**	**030001859**	**030001860**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	11/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012	09/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 42	SITE 43	SITE 43	SITE 43	SITE 43	SITE 44
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 130	0 - 10	25 - 35	55 - 65	100 - 140	0 - 13
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		7.70	7.10	8.70	9.00	9.60	8.20
pH (1:5 CaCl2)		6.00	6.10	8.10	8.40	8.60	7.60
Organic Carbon (OC)	%		0.78				1.70
Nitrate Nitrogen (NO3)	mg/kg	<1.0		<1.0	<1.0	<1.0	
Total Nitrogen	%		0.07				0.17
Phosphorus (Colwell)	mg/kg		25				25
Phosphorus (BSES)	mg/kg		61				72
Available Potassium	mg/kg	82		86	88	130	
Potassium (Nitric K)	meq/100g		5.70				4.00
Sulphate Sulphur (MCP)	mg/kg		2.6				4.7
Zinc (DTPA)	mg/kg		0.44				0.63
Copper (DTPA)	mg/kg		0.88				1.60
Iron (DTPA)	mg/kg		45.0				24.0
Manganese (DTPA)	mg/kg		32.00				6.60
Boron (Hot CaCl2)	mg/kg		0.60				0.80
Chloride	mg/kg	<10.0		610.0	330.0	12.0	
Electrical Conductivity	dS/m	0.02	0.15	0.67	0.82	0.28	0.19
Cation Exchange Capacity	meq/100g	7.83		25.70	36.40	28.00	
Calcium (Amm-acet.)	%	54.000		54.000	60.000	61.000	
Calcium (Amm-acet.)	meq/100g	4.200		14.000	22.000	17.000	
Magnesium (Amm-acet.)	%	40.000		26.000	21.000	23.000	

Analyses conducted by **Nutrient Advantage Laboratory Services**
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Sample No	**030001855**	**030001856**	**030001857**	**030001858**	**030001859**	**030001860**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	11/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012	09/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 42	SITE 43	SITE 43	SITE 43	SITE 43	SITE 44
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 130	0 - 10	25 - 35	55 - 65	100 - 140	0 - 13
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	3.100		6.700	7.700	6.300	
Sodium (Amm-acet.)	%	4.100		19.000	18.000	16.000	
Sodium (Amm-acet.)	meq/100g	0.320		4.800	6.500	4.400	
Potassium (Amm-acet.)	%	2.700		0.860	0.630	1.200	
Potassium (Amm-acet.)	meq/100g	0.210		0.220	0.230	0.330	
Calcium/Magnesium Ratio		1.4		2.1	2.9	2.7	
Potassium to Magnesium Ratio		0.1		0.0	0.0	0.1	
Silicon (BSES)	mg/kg		710				1200
% Clay	%	20		28	23	11	
% Sand (Fine)	%	33		47	47	52	
% Sand (Coarse)	%	38		2	6	7	
% Silt	%	9		24	24	30	
Sansilclay Texture		Sandy Clay Loam		Sandy Clay Loam	Sandy Clay Loam	Sandy Loam	
Organic Matter	%		1.3				2.9

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Report Print Date: 13/01/2012
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Advisor/Contact: David Doolan
Phone:

Sample No	**030001861**	**030001862**	**030001863**	**030001864**	**030001865**	**030001866**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 16	SITE 16	SITE 16	SITE 17	SITE 17	SITE 17
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 10	35 - 55	65 - 100	0 - 10	30 - 45	45 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		5.50	6.50	9.60	6.10	8.00	9.30
pH (1:5 CaCl2)		4.50	5.20	8.80	5.10	6.90	8.50
Aluminium Saturation	%		1.0				
Organic Carbon (OC)	%	1.20			0.64		
Nitrate Nitrogen (NO3)	mg/kg		<1.0	<1.0		<1.0	1.3
Total Nitrogen	%	0.10			0.06		
Phosphorus (Colwell)	mg/kg	8			8		
Phosphorus (BSES)	mg/kg	14			12		
Available Potassium	mg/kg		50	64		110	71
Potassium (Nitric K)	meq/100g	2.00			1.50		
Sulphate Sulphur (MCP)	mg/kg	5.6			3.2		
Zinc (DTPA)	mg/kg	1.40			0.36		
Copper (DTPA)	mg/kg	0.82			0.10		
Iron (DTPA)	mg/kg	150.0			100.0		
Manganese (DTPA)	mg/kg	35.00			6.20		
Boron (Hot CaCl2)	mg/kg	0.28			0.36		
Chloride	mg/kg		240.0	470.0		350.0	450.0
Electrical Conductivity	dS/m	0.07	0.20	0.78	0.05	0.29	0.50
Cation Exchange Capacity	meq/100g			17.20		14.20	17.30
Cation Exchange Capacity	meq/100g		10.20				
Aluminium (KCl)	mg/kg		<9.00				

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Sample No	**030001861**	**030001862**	**030001863**	**030001864**	**030001865**	**030001866**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 16	SITE 16	SITE 16	SITE 17	SITE 17	SITE 17
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 10	35 - 55	65 - 100	0 - 10	30 - 45	45 - 65
Sampling Date						

Analyte / Assay	Unit	Value					
Aluminium (KCl)	meq/100g		0.10				
Calcium (Amm-acet.)	%			38.000		22.000	32.000
Calcium (Amm-acet.)	meq/100g		3.000	6.500		3.100	5.500
Calcium (Amm-acet.)	%		29.000				
Magnesium (Amm-acet.)	%			23.000		50.000	39.000
Magnesium (Amm-acet.)	meq/100g		4.200	4.000		7.100	6.800
Magnesium (Amm-acet.)	%		41.000				
Sodium (Amm-acet.)	%			38.000		26.000	28.000
Sodium (Amm-acet.)	meq/100g		2.800	6.500		3.700	4.800
Sodium % of Cations (ESP)	%		27.000				
Potassium (Amm-acet.)	%			0.930		2.000	1.000
Potassium (Amm-acet.)	meq/100g		0.130	0.160		0.290	0.180
Potassium (Amm-acet.)	%		1.300				
Calcium/Magnesium Ratio			0.7	1.6		0.4	0.8
Potassium to Magnesium Ratio			0.0	0.0		0.0	0.0
Silicon (BSES)	mg/kg	180			83		
% Clay	%		24	20		36	29
% Sand (Fine)	%		52	66		57	62
% Sand (Coarse)	%		9	10		3	5
% Silt	%		15	4		4	5
Sansilclay Texture			Sandy Clay Loam	Sandy Clay Loam		Sandy Clay	Sandy Clay Loam
Organic Matter	%	2.1			1.1		

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Advisor/Contact: David Doolan
Phone:

Sample No	**030001867**	**030001868**	**030001869**	**030001870**	**030001871**	**030001872**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 18	SITE 18	SITE 18	SITE 19	SITE 19	SITE 19
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	35 - 55	65 - 75	0 - 25	0 - 10	25 - 35	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		9.00	9.40	5.90	6.90	7.30	8.20
pH (1:5 CaCl2)		8.20	8.60	4.60	6.00	6.20	7.60
Organic Carbon (OC)	%			0.56	2.00		
Nitrate Nitrogen (NO3)	mg/kg	<1.0	1.0			<1.0	<1.0
Total Nitrogen	%			0.05	0.17		
Phosphorus (Colwell)	mg/kg			<5	55		
Phosphorus (BSES)	mg/kg			8	140		
Available Potassium	mg/kg	75	80			170	130
Potassium (Nitric K)	meq/100g			1.20	5.80		
Sulphate Sulphur (MCP)	mg/kg			2.5	4.4		
Zinc (DTPA)	mg/kg			1.70	0.78		
Copper (DTPA)	mg/kg			0.40	0.37		
Iron (DTPA)	mg/kg			98.0	65.0		
Manganese (DTPA)	mg/kg			6.40	29.00		
Boron (Hot CaCl2)	mg/kg			0.12	0.58		
Chloride	mg/kg	470.0	810.0			<10.0	<10.0
Electrical Conductivity	dS/m	0.46	0.67	0.04	0.06	0.04	0.16
Cation Exchange Capacity	meq/100g	16.40	17.80			37.40	52.90
Calcium (Amm-acet.)	%	34.000	31.000			91.000	95.000
Calcium (Amm-acet.)	meq/100g	5.500	5.500			34.000	50.000
Magnesium (Amm-acet.)	%	41.000	36.000			7.500	4.500

Analyses conducted by **Nutrient Advantage Laboratory Services**
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Sample No	**030001867**	**030001868**	**030001869**	**030001870**	**030001871**	**030001872**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012	09/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011	02-12-2011
Sample Name	SITE 18	SITE 18	SITE 18	SITE 19	SITE 19	SITE 19
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	35 - 55	65 - 75	0 - 25	0 - 10	25 - 35	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	6.700	6.400			2.800	2.400
Sodium (Amm-acet.)	%	24.000	32.000			0.480	0.320
Sodium (Amm-acet.)	meq/100g	4.000	5.700			0.180	0.170
Potassium (Amm-acet.)	%	1.200	1.100			1.200	0.640
Potassium (Amm-acet.)	meq/100g	0.190	0.200			0.440	0.340
Calcium/Magnesium Ratio		0.8	0.9			12.0	21.0
Potassium to Magnesium Ratio		0.0	0.0			0.2	0.1
Silicon (BSES)	mg/kg			83	770		
% Clay	%	29	29			51	40
% Sand (Fine)	%	54	55			27	34
% Sand (Coarse)	%	11	6			6	8
% Silt	%	6	10			16	19
Sansilclay Texture		Sandy Clay Loam	Sandy Clay Loam			Clay	Clay
Organic Matter	%			1.0	3.4		

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Report Print Date: 13/01/2012
Agent/Dealer:
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Sample No Test Code	**030001873** ADMINSOIL	**030001874** ADMINSOIL	**030001875** ADMINSOIL	**030002123** ADMINSOIL	**030002124** ADMINSOIL	**030002125** ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 20	SITE 20	SITE 20	SITE 44	SITE 44	SITE 44
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 10	10 - 25	35 - 55	35 - 55	65 - 110	110 - 150
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.20	8.60	8.90	8.90	8.50	8.00
pH (1:5 CaCl2)		7.50	7.80	8.00	8.00	8.10	7.60
Organic Carbon (OC)	%	1.50					
Nitrate Nitrogen (NO3)	mg/kg		<1.0	<1.0	<1.0	<1.0	<1.0
Total Nitrogen	%	0.15					
Phosphorus (Colwell)	mg/kg	8					
Phosphorus (BSES)	mg/kg	260					
Available Potassium	mg/kg		120	50	170	160	80
Potassium (Nitric K)	meq/100g	5.70					
Sulphate Sulphur (MCP)	mg/kg	2.5					
Zinc (DTPA)	mg/kg	0.26					
Copper (DTPA)	mg/kg	0.17					
Iron (DTPA)	mg/kg	11.0					
Manganese (DTPA)	mg/kg	10.00					
Boron (Hot CaCl2)	mg/kg	0.60					
Chloride	mg/kg		<10.0	<10.0	88.0	1700.0	2300.0
Electrical Conductivity	dS/m	0.12	0.12	0.09	0.29	1.38	1.53
Cation Exchange Capacity	meq/100g		44.20	36.80	46.40	49.30	34.30
Calcium (Amm-acet.)	%		97.000	98.000	73.000	57.000	44.000
Calcium (Amm-acet.)	meq/100g		43.000	36.000	34.000	28.000	15.000
Magnesium (Amm-acet.)	%		1.900	1.600	17.000	20.000	27.000

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Sample No	**030001873**	**030001874**	**030001875**	**030002123**	**030002124**	**030002125**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	09/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012
Paddock Name	02-12-2011	02-12-2011	02-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 20	SITE 20	SITE 20	SITE 44	SITE 44	SITE 44
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 10	10 - 25	35 - 55	35 - 55	65 - 110	110 - 150
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g		0.820	0.580	7.900	9.900	9.100
Sodium (Amm-acet.)	%		0.170	0.350	8.800	22.000	29.000
Sodium (Amm-acet.)	meq/100g		0.074	0.130	4.100	11.000	10.000
Potassium (Amm-acet.)	%		0.700	0.350	0.950	0.830	0.580
Potassium (Amm-acet.)	meq/100g		0.310	0.130	0.440	0.410	0.200
Calcium/Magnesium Ratio			52.0	62.0	4.3	2.8	1.6
Potassium to Magnesium Ratio			0.4	0.2	0.1	0.0	0.0
Silicon (BSES)	mg/kg	770					
% Clay	%		30	13	54	58	46
% Sand (Fine)	%		41	35	28	24	26
% Sand (Coarse)	%		11	36	4	3	1
% Silt	%		18	16	14	16	28
Sansilclay Texture			Sandy Clay Loam	Sandy Loam	Clay	Clay	Clay
Organic Matter	%	2.6					

The results reported pertain only to the samples submitted.
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Report Print Date: 13/01/2012
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Phone:

Sample No Test Code	**030002126** ADMINSOIL	**030002127** ADMINSOIL	**030002128** ADMINSOIL	**030002129** ADMINSOIL	**030002130** ADMINSOIL	**030002131** ADMINSOIL
Lab Results Received Date	09/01/2012	11/01/2012	11/01/2012	11/01/2012	09/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 45	SITE 45	SITE 45	SITE 45	SITE 46	SITE 46
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 11	0 - 11	55 - 65	65 - 80	0 - 22	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		7.50	8.50	8.80	9.10	6.90	7.30
pH (1:5 CaCl2)		6.90	7.80	8.10	8.30	6.20	6.20
Organic Carbon (OC)	%	1.20				0.54	
Nitrate Nitrogen (NO3)	mg/kg		<1.0	<1.0	1.0		<1.0
Total Nitrogen	%	0.11				0.04	
Phosphorus (Colwell)	mg/kg	110				6	
Phosphorus (BSES)	mg/kg	470				22	
Available Potassium	mg/kg		110	69	52		120
Potassium (Nitric K)	meq/100g	5.70				2.70	
Sulphate Sulphur (MCP)	mg/kg	7.1				1.6	
Zinc (DTPA)	mg/kg	0.52				0.47	
Copper (DTPA)	mg/kg	0.46				0.48	
Iron (DTPA)	mg/kg	25.0				22.0	
Manganese (DTPA)	mg/kg	14.00				31.00	
Boron (Hot CaCl2)	mg/kg	0.46				0.12	
Chloride	mg/kg		<10.0	<10.0	<10.0		<10.0
Electrical Conductivity	dS/m	0.13	0.10	0.10	0.09	0.04	0.03
Cation Exchange Capacity	meq/100g		16.50	26.50	25.20		17.40
Calcium (Amm-acet.)	%		85.000	91.000	87.000		86.000
Calcium (Amm-acet.)	meq/100g		14.000	24.000	22.000		15.000
Magnesium (Amm-acet.)	%		13.000	7.900	11.000		11.000

Analyses conducted by **Nutrient Advantage Laboratory Services**
8 South Road, Werribee VIC 3030
NATA Accreditation No: 11958
Tel: 1800 803 453
Certificate of Analysis is available upon request.
Email: lab.feedback@incitecpivot.com.au

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Sample No	**030002126**	**030002127**	**030002128**	**030002129**	**030002130**	**030002131**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	11/01/2012	11/01/2012	11/01/2012	09/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 45	SITE 45	SITE 45	SITE 45	SITE 46	SITE 46
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 11	0 - 11	55 - 65	65 - 80	0 - 22	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g		2.100	2.100	2.800		1.900
Sodium (Amm-acet.)	%		0.850	0.790	1.100		1.100
Sodium (Amm-acet.)	meq/100g		0.140	0.210	0.270		0.190
Potassium (Amm-acet.)	%		1.600	0.680	0.520		1.700
Potassium (Amm-acet.)	meq/100g		0.270	0.180	0.130		0.300
Calcium/Magnesium Ratio			6.7	11.0	7.9		7.9
Potassium to Magnesium Ratio			0.1	0.1	0.0		0.2
Silicon (BSES)	mg/kg	580				180	
% Clay	%		14	11	6		30
% Sand (Fine)	%		46	28	38		32
% Sand (Coarse)	%		40	51	48		30
% Silt	%		0	10	8		9
Sansilclay Texture			Loamy Sand	Sandy Loam	Loamy Sand		Sandy Clay Loam
Organic Matter	%	2.1				0.9	

The results reported pertain only to the samples submitted.
Analyses performed on soil dried at 40 degrees Celsius and ground to <2mm (excluding moisture assay)
Analyses performed on plant material dried at 70 degrees Celsius and ground to <2mm
Water analyses performed on an 'as received' basis
Analytical results reported by the laboratory as 'less than' the level of reporting, will be deemed by Nutrient Advantage Advice as being equivalent to the level of reporting for both calculation and interpretive purposes

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Nutrient Advantage Advice® Summary Report

GHD PTY LTD
210 CHARLOTTE ST

BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No Test Code	**030002132** ADMINSOIL	**030002133** ADMINSOIL	**030002134** ADMINSOIL	**030002135** ADMINSOIL	**030002136** ADMINSOIL	**030002137** ADMINSOIL
Lab Results Received Date	11/01/2012	11/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 46	SITE 46	SITE 47	SITE 47	SITE 47	SITE 47
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 95	95 - 120	0 - 12	25 - 35	55 - 65	65 - 90
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.70	9.00	7.80	8.70	8.90	8.90
pH (1:5 CaCl2)		8.00	8.10	7.20	7.80	8.00	8.00
Organic Carbon (OC)	%			2.00			
Nitrate Nitrogen (NO3)	mg/kg	<1.0	<1.0		<1.0	<1.0	<1.0
Total Nitrogen	%			0.21			
Phosphorus (Colwell)	mg/kg			39			
Phosphorus (BSES)	mg/kg			41			
Available Potassium	mg/kg	91	68		210	200	200
Potassium (Nitric K)	meq/100g			4.80			
Sulphate Sulphur (MCP)	mg/kg			7.4			
Zinc (DTPA)	mg/kg			0.57			
Copper (DTPA)	mg/kg			1.70			
Iron (DTPA)	mg/kg			24.0			
Manganese (DTPA)	mg/kg			11.00			
Boron (Hot CaCl2)	mg/kg			0.96			
Chloride	mg/kg	<10.0	<10.0		<10.0	67.0	130.0
Electrical Conductivity	dS/m	0.10	0.08	0.16	0.16	0.26	0.33
Cation Exchange Capacity	meq/100g	28.60	26.20		49.90	50.10	48.90
Calcium (Amm-acet.)	%	94.000	95.000		78.000	68.000	65.000
Calcium (Amm-acet.)	meq/100g	27.000	25.000		39.000	34.000	32.000
Magnesium (Amm-acet.)	%	4.200	3.500		18.000	24.000	25.000

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Sample No Test Code	030002132 ADMINSOIL	030002133 ADMINSOIL	030002134 ADMINSOIL	030002135 ADMINSOIL	030002136 ADMINSOIL	030002137 ADMINSOIL
Lab Results Received Date	11/01/2012	11/01/2012	09/01/2012	11/01/2012	11/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 46	SITE 46	SITE 47	SITE 47	SITE 47	SITE 47
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	65 - 95	95 - 120	0 - 12	25 - 35	55 - 65	65 - 90
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	1.200	0.910		9.100	12.000	12.000
Sodium (Amm-acet.)	%	0.490	0.460		2.600	7.200	9.000
Sodium (Amm-acet.)	meq/100g	0.140	0.120		1.300	3.600	4.400
Potassium (Amm-acet.)	%	0.800	0.650		1.100	1.000	1.000
Potassium (Amm-acet.)	meq/100g	0.230	0.170		0.530	0.510	0.510
Calcium/Magnesium Ratio		23.0	27.0		4.3	2.8	2.7
Potassium to Magnesium Ratio		0.2	0.2		0.1	0.0	0.0
Silicon (BSES)	mg/kg			1400			
% Clay	%	13	6		53	55	58
% Sand (Fine)	%	29	26		28	23	21
% Sand (Coarse)	%	49	62		6	8	7
% Silt	%	9	6		14	15	15
Sansilclay Texture		Sandy Loam	Loamy Sand		Clay	Clay	Clay
Organic Matter	%			3.4			

The results reported pertain only to the samples submitted.
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Nutrient Advantage Advice® Summary Report

GHD PTY LTD
210 CHARLOTTE ST

BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030002138**	**030002139**	**030002140**	**030002141**	**030002142**	**030002143**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	11/01/2012	11/01/2012	11/01/2012	09/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 48	SITE 48	SITE 48	SITE 48	SITE 49	SITE 49
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 13	35 - 55	65 - 90	90 - 120	0 - 22	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.30	9.10	9.10	9.10	8.30	8.80
pH (1:5 CaCl2)		7.70	8.20	8.30	8.30	7.60	7.90
Organic Carbon (OC)	%	1.60				1.60	
Nitrate Nitrogen (NO3)	mg/kg		<1.0	<1.0	<1.0		<1.0
Total Nitrogen	%	0.14				0.15	
Phosphorus (Colwell)	mg/kg	8				6	
Phosphorus (BSES)	mg/kg	18				200	
Available Potassium	mg/kg		130	120	110		47
Potassium (Nitric K)	meq/100g	4.00				3.40	
Sulphate Sulphur (MCP)	mg/kg	4.5				3.0	
Zinc (DTPA)	mg/kg	0.28				0.33	
Copper (DTPA)	mg/kg	0.96				0.33	
Iron (DTPA)	mg/kg	17.0				8.1	
Manganese (DTPA)	mg/kg	4.90				6.10	
Boron (Hot CaCl2)	mg/kg	1.00				0.65	
Chloride	mg/kg		16.0	260.0	550.0		<10.0
Electrical Conductivity	dS/m	0.17	0.23	0.45	0.66	0.14	0.10
Cation Exchange Capacity	meq/100g		44.90	41.00	36.50		34.20
Calcium (Amm-acet.)	%		71.000	63.000	58.000		96.000
Calcium (Amm-acet.)	meq/100g		32.000	26.000	21.000		33.000
Magnesium (Amm-acet.)	%		22.000	24.000	25.000		2.700

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Sample No	**030002138**	**030002139**	**030002140**	**030002141**	**030002142**	**030002143**
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL
Lab Results Received Date	09/01/2012	11/01/2012	11/01/2012	11/01/2012	09/01/2012	11/01/2012
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011	03-12-2011
Sample Name	SITE 48	SITE 48	SITE 48	SITE 48	SITE 49	SITE 49
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil
Sample Depth (cm)	0 - 13	35 - 55	65 - 90	90 - 120	0 - 22	35 - 55
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g		9.900	9.900	9.100		0.910
Sodium (Amm-acet.)	%		6.000	12.000	17.000		0.560
Sodium (Amm-acet.)	meq/100g		2.700	4.800	6.100		0.190
Potassium (Amm-acet.)	%		0.730	0.760	0.770		0.350
Potassium (Amm-acet.)	meq/100g		0.330	0.310	0.280		0.120
Calcium/Magnesium Ratio			3.2	2.6	2.3		36.0
Potassium to Magnesium Ratio			0.0	0.0	0.0		0.1
Silicon (BSES)	mg/kg	1100				830	
% Clay	%		46	45	40		19
% Sand (Fine)	%		27	26	29		46
% Sand (Coarse)	%		12	10	10		10
% Silt	%		15	19	21		25
Sansilclay Texture			Clay	Clay	Clay		Sandy Loam
Organic Matter	%	2.8				2.8	

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210 CHARLOTTE ST

BRISBANE
QLD 4000

Report Print Date: 13/01/2012
Agent/Dealer:
Advisor/Contact: David Doolan
Phone:

Sample No	**030002144**	**030002145**	**030002146**	**030002147**		
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL		
Lab Results Received Date	11/01/2012	09/01/2012	11/01/2012	11/01/2012		
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011		
Sample Name	SITE 49	SITE 50	SITE 50	SITE 50		
Sample Type	Soil	Soil	Soil	Soil		
Sample Depth (cm)	55 - 65	0 - 22	35 - 55	65 - 90		
Sampling Date						

Analyte / Assay	Unit	Value					
pH (1:5 Water)		8.90	8.80	8.80	8.70		
pH (1:5 CaCl2)		8.00	8.00	8.20	8.20		
Organic Carbon (OC)	%		1.20				
Nitrate Nitrogen (NO3)	mg/kg	<1.0		5.4	140.0		
Total Nitrogen	%		0.13				
Phosphorus (Colwell)	mg/kg		7				
Phosphorus (BSES)	mg/kg		160				
Available Potassium	mg/kg	47		140	130		
Potassium (Nitric K)	meq/100g		4.80				
Sulphate Sulphur (MCP)	mg/kg		11.0				
Zinc (DTPA)	mg/kg		0.18				
Copper (DTPA)	mg/kg		1.10				
Iron (DTPA)	mg/kg		12.0				
Manganese (DTPA)	mg/kg		4.50				
Boron (Hot CaCl2)	mg/kg		1.50				
Chloride	mg/kg	<10.0		730.0	1700.0		
Electrical Conductivity	dS/m	0.09	0.21	0.86	1.54		
Cation Exchange Capacity	meq/100g	34.30		49.80	54.30		
Calcium (Amm-acet.)	%	96.000		66.000	59.000		
Calcium (Amm-acet.)	meq/100g	33.000		33.000	32.000		
Magnesium (Amm-acet.)	%	2.900		20.000	22.000		

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Sample No	**030002144**	**030002145**	**030002146**	**030002147**		
Test Code	ADMINSOIL	ADMINSOIL	ADMINSOIL	ADMINSOIL		
Lab Results Received Date	11/01/2012	09/01/2012	11/01/2012	11/01/2012		
Paddock Name	03-12-2011	03-12-2011	03-12-2011	03-12-2011		
Sample Name	SITE 49	SITE 50	SITE 50	SITE 50		
Sample Type	Soil	Soil	Soil	Soil		
Sample Depth (cm)	55 - 65	0 - 22	35 - 55	65 - 90		
Sampling Date						

Analyte / Assay	Unit	Value					
Magnesium (Amm-acet.)	meq/100g	0.990		9.900	12.000		
Sodium (Amm-acet.)	%	0.610		13.000	18.000		
Sodium (Amm-acet.)	meq/100g	0.210		6.500	10.000		
Potassium (Amm-acet.)	%	0.350		0.720	0.590		
Potassium (Amm-acet.)	meq/100g	0.120		0.360	0.320		
Calcium/Magnesium Ratio		33.0		3.3	2.7		
Potassium to Magnesium Ratio		0.1		0.0	0.0		
Silicon (BSES)	mg/kg		880				
% Clay	%	14		51	50		
% Sand (Fine)	%	33		23	21		
% Sand (Coarse)	%	37		5	5		
% Silt	%	16		21	25		
Sansilclay Texture		Sandy Loam		Clay	Clay		
Organic Matter	%		2.1				

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Analyses performed on plant material dried at 70 degrees Celsius and ground to <2mm
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Analysis Results (SOIL)

Customer GHD
COLLINSVILLE

Distributor ENVIRONMENTAL SOIL SOLUTIONS
5 DUNPHY ST
SUNNYBANK HILLS
QLD

Sample Ref TP1 (0-0.08m)

Date Received 04/12/2009

Sample No B046487-01 / SAC3713

Crop DATA ONLY

Analysis	Result
pH [H2O]	6.4
pH [CaCl2]	5.9
Organic Matter (%)	2.6
CEC (meq/100g)	14.78
EC (dS/m)	0.05
NO3-N (ppm)	1.7
Phosphorus [Olsen] (ppm)	6
Potassium (meq/100g)	0.98
Calcium (meq/100g)	9.51
Magnesium (meq/100g)	3.90
Sulphur (ppm)	6
Boron (ppm)	1.1
Copper (ppm)	1.0
Iron (ppm)	35
Manganese (ppm)	50.5
Zinc (ppm)	1.0
Aluminium (meq/100g)	0.28
Sodium (meq/100g)	0.1
Chloride (ppm)	17
Ca base saturation (%)	64.3
K base saturation (%)	6.6
Mg base saturation (%)	26.4
Na base saturation (%)	0.7
Ca:Mg Ratio	2.4
Aluminium Base Sat. (%)	1.90
Potassium (ppm)	383.0
Magnesium (ppm)	472.0
Calcium (ppm)	1902.0
Sodium (ppm)	25.0
Aluminium (ppm)	25.0

Phosyn Analytical, 1/60 Junction Road,
Andrews, Queensland 4220, Australia
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Fax: +61 7 5522 0720
Email: phosynanalytical@phosyn.com

Date Printed : 09/12/2009

Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP1 (0.08-0.16m)	**Date Received**	04/12/2009
Sample No	B046487-02 / SAC3714		
Crop	DATA ONLY		

Analysis	Result
pH [H2O]	6.2
CEC (meq/100g)	17.01
EC (dS/m)	0.04
Potassium (meq/100g)	0.76
Calcium (meq/100g)	11.41
Magnesium (meq/100g)	4.43
Aluminium (meq/100g)	0.28
Sodium (meq/100g)	0.1
Ca base saturation (%)	67.1
K base saturation (%)	4.5
Mg base saturation (%)	26.0
Na base saturation (%)	0.8
Ca:Mg Ratio	2.6
Aluminium Base Sat. (%)	1.60
Potassium (ppm)	297.0
Magnesium (ppm)	536.0
Calcium (ppm)	2282.0
Sodium (ppm)	30.0
Aluminium (ppm)	25.0

Additional Comments

You should consult your local agronomist and/or Yara representative before deciding upon any course of action based on this report.

Please Note

Whilst every care is taken to ensure that the Results from Analysis are as accurate as possible, it is important to note that the analysis relates to the sample received by the laboratory, and is representative only of that sample. No warranty is given by the laboratory that the Results from Analysis relates to any part of a field or growing area not covered by the sample received. It is important to ensure that any soil, leaf, silage or fruitlet sample sent for analysis is representative of the area requiring analysis and that samples are obtained in accordance with established sampling techniques. A leaflet containing instructions on how to take soil, leaf, herbage, silage and fruit samples for analysis is available from the laboratory on request.

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Date Printed : 09/12/2009

Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP1 (0.16-0.31m)	**Date Received**	04/12/2009
Sample No	B046487-03 / SAC3715		
Crop	DATA ONLY		

Analysis	Result
pH [H2O]	6.2
CEC (meq/100g)	22.51
EC (dS/m)	0.03
Potassium (meq/100g)	0.66
Calcium (meq/100g)	14.51
Magnesium (meq/100g)	6.76
Aluminium (meq/100g)	0.31
Sodium (meq/100g)	0.3
Ca base saturation (%)	64.5
K base saturation (%)	2.9
Mg base saturation (%)	30.0
Na base saturation (%)	1.2
Ca:Mg Ratio	2.2
Aluminium Base Sat. (%)	1.40
Potassium (ppm)	258.0
Magnesium (ppm)	818.0
Calcium (ppm)	2902.0
Sodium (ppm)	62.0
Aluminium (ppm)	28.0

Additional Comments

You should consult your local agronomist and/or Yara representative before deciding upon any course of action based on this report.

Please Note

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Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP1 (0.4-0.5m)	**Date Received**	04/12/2009
Sample No	B046487-04 / SAC3716		
Crop	DATA ONLY		

Analysis	Result
pH [H2O]	6.4
CEC (meq/100g)	31.58
EC (dS/m)	0.04
Potassium (meq/100g)	0.64
Calcium (meq/100g)	21.60
Magnesium (meq/100g)	8.52
Aluminium (meq/100g)	0.29
Sodium (meq/100g)	0.5
Ca base saturation (%)	68.4
K base saturation (%)	2.0
Mg base saturation (%)	27.0
Na base saturation (%)	1.7
Ca:Mg Ratio	2.5
Aluminium Base Sat. (%)	0.90
Potassium (ppm)	250.0
Magnesium (ppm)	1031.0
Calcium (ppm)	4320.0
Sodium (ppm)	122.0
Aluminium (ppm)	26.0

Additional Comments

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Date Printed : 09/12/2009

Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP1 (0-0.08m)	**Date Received**	04/12/2009
Sample No	B046487-01 / SAC3713		
Crop	DATA ONLY		

Additional Comments

You should consult your local agronomist and/or Yara representative before deciding upon any course of action based on this report.

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Date Printed : 09/12/2009

Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP1 (0.7-0.8m)	**Date Received**	04/12/2009
Sample No	B046487-05 / SAC3717		
Crop	DATA ONLY		

Analysis	Result
pH [H2O]	6.8
CEC (meq/100g)	34.75
EC (dS/m)	0.04
Potassium (meq/100g)	0.56
Calcium (meq/100g)	25.15
Magnesium (meq/100g)	8.10
Aluminium (meq/100g)	0.28
Sodium (meq/100g)	0.7
Ca base saturation (%)	72.4
K base saturation (%)	1.6
Mg base saturation (%)	23.3
Na base saturation (%)	1.9
Ca:Mg Ratio	3.1
Aluminium Base Sat. (%)	0.80
Potassium (ppm)	219.0
Magnesium (ppm)	980.0
Calcium (ppm)	5030.0
Sodium (ppm)	152.0
Aluminium (ppm)	25.0

Additional Comments

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Analysis Results (SOIL)

Customer GHD
COLLINSVILLE

Distributor ENVIRONMENTAL SOIL SOLUTIONS
5 DUNPHY ST
SUNNYBANK HILLS
QLD

Sample Ref TP2 (0-0.1m)

Date Received 04/12/2009

Sample No B046487-06 / SAC3718

Crop DATA ONLY

Analysis	Result
pH [H2O]	7.3
pH [CaCl2]	6.9
Organic Matter (%)	3.0
CEC (meq/100g)	37.57
EC (dS/m)	0.18
NO3-N (ppm)	8.5
Phosphorus [Olsen] (ppm)	6
Potassium (meq/100g)	1.08
Calcium (meq/100g)	27.66
Magnesium (meq/100g)	7.88
Sulphur (ppm)	8
Boron (ppm)	2.0
Copper (ppm)	2.2
Iron (ppm)	52
Manganese (ppm)	23.6
Zinc (ppm)	0.8
Aluminium (meq/100g)	0.28
Sodium (meq/100g)	0.7
Chloride (ppm)	22
Ca base saturation (%)	73.6
K base saturation (%)	2.9
Mg base saturation (%)	21.0
Na base saturation (%)	1.8
Ca:Mg Ratio	3.5
Aluminium Base Sat. (%)	0.70
Potassium (ppm)	422.0
Magnesium (ppm)	953.0
Calcium (ppm)	5532.0
Sodium (ppm)	154.0
Aluminium (ppm)	25.0

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Date Printed : 09/12/2009

Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP2 (0.2-0.3m)	**Date Received**	04/12/2009
Sample No	B046487-07 / SAC3719		
Crop	DATA ONLY		

Analysis	Result
pH [H2O]	8.4
CEC (meq/100g)	45.18
EC (dS/m)	0.15
Potassium (meq/100g)	0.97
Calcium (meq/100g)	30.94
Magnesium (meq/100g)	11.01
Aluminium (meq/100g)	0.28
Sodium (meq/100g)	2.0
Ca base saturation (%)	68.5
K base saturation (%)	2.1
Mg base saturation (%)	24.4
Na base saturation (%)	4.4
Ca:Mg Ratio	2.8
Aluminium Base Sat. (%)	0.60
Potassium (ppm)	379.0
Magnesium (ppm)	1332.0
Calcium (ppm)	6188.0
Sodium (ppm)	455.0
Aluminium (ppm)	25.0

Additional Comments

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Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP2 (0.5-0.6m)	**Date Received**	04/12/2009
Sample No	B046487-08 / SAC3720		
Crop	DATA ONLY		

Analysis	Result
pH [H2O]	8.7
CEC (meq/100g)	40.40
EC (dS/m)	0.26
Potassium (meq/100g)	0.89
Calcium (meq/100g)	21.85
Magnesium (meq/100g)	12.86
Aluminium (meq/100g)	0.27
Sodium (meq/100g)	4.5
Ca base saturation (%)	54.1
K base saturation (%)	2.2
Mg base saturation (%)	31.8
Na base saturation (%)	11.2
Ca:Mg Ratio	1.7
Aluminium Base Sat. (%)	0.70
Potassium (ppm)	348.0
Magnesium (ppm)	1556.0
Calcium (ppm)	4370.0
Sodium (ppm)	1042.0
Aluminium (ppm)	24.0

Additional Comments

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Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP2 (0.8-0.9m)	**Date Received**	04/12/2009
Sample No	B046487-09 / SAC3721		
Crop	DATA ONLY		

Analysis	Result
pH [H2O]	8.1
CEC (meq/100g)	35.97
EC (dS/m)	1.04
Potassium (meq/100g)	0.77
Calcium (meq/100g)	16.49
Magnesium (meq/100g)	13.33
Aluminium (meq/100g)	0.30
Sodium (meq/100g)	5.1
Ca base saturation (%)	45.8
K base saturation (%)	2.1
Mg base saturation (%)	37.1
Na base saturation (%)	14.1
Ca:Mg Ratio	1.2
Aluminium Base Sat. (%)	0.80
Potassium (ppm)	301.0
Magnesium (ppm)	1613.0
Calcium (ppm)	3298.0
Sodium (ppm)	1168.0
Aluminium (ppm)	27.0

Additional Comments

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Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP2 (1.1-1.2m)	**Date Received**	04/12/2009
Sample No	B046487-10 / SAC3722		
Crop	DATA ONLY		

Analysis	Result
pH [H2O]	8.0
CEC (meq/100g)	31.61
EC (dS/m)	0.97
Potassium (meq/100g)	0.70
Calcium (meq/100g)	13.25
Magnesium (meq/100g)	12.41
Aluminium (meq/100g)	0.28
Sodium (meq/100g)	5.0
Ca base saturation (%)	41.9
K base saturation (%)	2.2
Mg base saturation (%)	39.3
Na base saturation (%)	15.7
Ca:Mg Ratio	1.1
Aluminium Base Sat. (%)	0.90
Potassium (ppm)	274.0
Magnesium (ppm)	1502.0
Calcium (ppm)	2650.0
Sodium (ppm)	1143.0
Aluminium (ppm)	25.0

Additional Comments

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Analysis Results (SOIL)

Customer GHD
COLLINSVILLE

Distributor ENVIRONMENTAL SOIL SOLUTIONS
5 DUNPHY ST
SUNNYBANK HILLS
QLD

Sample Ref TP3 (0-0.1m)

Date Received 04/12/2009

Sample No B046487-11 / SAC3723

Crop DATA ONLY

Analysis	Result
pH [H2O]	5.5
pH [CaCl2]	5.0
Organic Matter (%)	0.6
CEC (meq/100g)	2.51
EC (dS/m)	0.02
NO3-N (ppm)	< 1.0
Phosphorus [Olsen] (ppm)	5
Potassium (meq/100g)	0.38
Calcium (meq/100g)	0.86
Magnesium (meq/100g)	0.87
Sulphur (ppm)	5
Boron (ppm)	1.2
Copper (ppm)	0.3
Iron (ppm)	67
Manganese (ppm)	5.0
Zinc (ppm)	0.3
Aluminium (meq/100g)	0.31
Sodium (meq/100g)	0.1
Chloride (ppm)	13
Ca base saturation (%)	34.3
K base saturation (%)	15.1
Mg base saturation (%)	34.7
Na base saturation (%)	3.6
Ca:Mg Ratio	1.0
Aluminium Base Sat. (%)	12.40
Potassium (ppm)	149.0
Magnesium (ppm)	105.0
Calcium (ppm)	172.0
Sodium (ppm)	21.0
Aluminium (ppm)	28.0

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Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP2 (0-0.1m)	**Date Received**	04/12/2009
Sample No	B046487-06 / SAC3718		
Crop	DATA ONLY		

Additional Comments

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Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP3 (0-0.1m)	**Date Received**	04/12/2009
Sample No	B046487-11 / SAC3723		
Crop	DATA ONLY		

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Analysis Results (SOIL)

Customer GHD
COLLINSVILLE

Distributor ENVIRONMENTAL SOIL SOLUTIONS
5 DUNPHY ST
SUNNYBANK HILLS
QLD

Sample Ref TP3 (0.1-0.3m)

Date Received 04/12/2009

Sample No B046487-12 / SAC3724

Crop DATA ONLY

Analysis	Result
pH [H2O]	5.0
CEC (meq/100g)	2.46
EC (dS/m)	0.03
Potassium (meq/100g)	0.21
Calcium (meq/100g)	0.70
Magnesium (meq/100g)	0.92
Aluminium (meq/100g)	0.41
Sodium (meq/100g)	0.2
Ca base saturation (%)	28.5
K base saturation (%)	8.5
Mg base saturation (%)	37.4
Na base saturation (%)	8.9
Ca:Mg Ratio	0.8
Aluminium Base Sat. (%)	16.70
Potassium (ppm)	82.0
Magnesium (ppm)	111.0
Calcium (ppm)	140.0
Sodium (ppm)	51.0
Aluminium (ppm)	37.0

Additional Comments

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Date Printed : 09/12/2009

Analysis Results (SOIL)

Customer	GHD COLLINSVILLE	**Distributor**	ENVIRONMENTAL SOIL SOLUTIONS 5 DUNPHY ST SUNNYBANK HILLS QLD
Sample Ref	TP3 (0.5-0.6m)	**Date Received**	04/12/2009
Sample No	B046487-13 / SAC3725		
Crop	DATA ONLY		

Analysis	Result
pH [H2O]	5.2
CEC (meq/100g)	11.81
EC (dS/m)	0.35
Potassium (meq/100g)	0.35
Calcium (meq/100g)	1.59
Magnesium (meq/100g)	6.89
Aluminium (meq/100g)	0.50
Sodium (meq/100g)	2.5
Ca base saturation (%)	13.5
K base saturation (%)	3.0
Mg base saturation (%)	58.3
Na base saturation (%)	21.0
Ca:Mg Ratio	0.2
Aluminium Base Sat. (%)	4.20
Potassium (ppm)	137.0
Magnesium (ppm)	834.0
Calcium (ppm)	318.0
Sodium (ppm)	570.0
Aluminium (ppm)	45.0

Additional Comments

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Date Printed : 09/12/2009

Appendix D

Soil Criteria

Generalised Interpretation of Soil $pH_{w1:5}$ in Water

pH	Rating	pH	Rating
> 9.0	Very strongly alkaline	6.5 – 6.1	Slightly acid
9.0 – 8.5	Strongly alkaline	6.0 - 5.6	Moderately acidic
8.4 - 7.9	Moderately alkaline	5.5 – 5.1	Strongly acidic
7.8 – 7.4	Mildly alkaline	5.0 – 4.5	Very strongly acidic
7.3 – 6.6	Neutral	< 4.4	Extremely acidic

Sourced: Hazelton and Murphy, 2007.

Soil Salinity Ratings with $EC_{1:5}$ for Different Soil Textures

Crop Tolerance	EC for a range of clay contents (dS/m)				Soil Salinity Rating
	10 – 20%	20 – 40%	40 – 60%	60 – 80%	
Sensitive	< 0.07	< 0.09	< 0.12	< 0.15	Very low
Moderately sensitive	0.07 – 0.15	0.09 – 0.19	0.12 – 0.24	0.15 – 0.30	Low
Moderately tolerant	0.15 – 0.34	0.19 – 0.45	0.24 – 0.56	0.30 – 0.70	Medium
Tolerant	0.34 – 0.63	0.45 – 0.76	0.56 – 0.96	0.70 – 1.18	High
Very tolerant	0.63 – 0.93	0.76 – 1.21	0.96 – 1.53	1.18 – 1.87	Very high
Generally too saline for crops	> 0.93	> 1.21	> 1.53	> 1.87	Extreme

Sourced: Shaw, 1999.

Sodicity Rating Based on ESP

Sodicity Rating	Exchangeable Sodium Percentage (ESP)
Non-sodic	0 – 6%
Marginally sodic to sodic	6 – 14%
Strongly sodic	>14%

Sourced: Hazelton and Murphy, 2007.

Guidelines for Some Element Soil Concentrations Necessary for Satisfactory Vegetative Growth

Element	Extract Method	Range below which deficiencies identified	Range above which toxicities identified	Remarks	References
Nitrate	KCl	20 – 60 mg kg^{-1}		Leaf analysis is thought to be a better guide than soil concentrations to deficiencies	(Dickson *et al.* 1993; Menzel *et al.* 1992; Strong 1990; Taylor *et al.* 1988)
Phosphorus	0.5 M $NaHCO_3$	10 – 30 mg kg^{-1}		For soil P results to be useful, they must be correlated to crop yield or growth responses to increasing soil P availability. Phosphorus buffering capacity is known to strongly influence availability of P	(Bruce and Bruce 1972; Charman 2000b; Moody and Bolland 1999; Rayment *et al.* 1977)
Potassium	1 M NH_4Cl	0.3 – 0.5 meq $100g^{-1}$		Potassium buffering capacity is known to strongly influence the availability of K	(Charman 2000b; Doll and Lucas 1973; Gourley 1999; Standley 1981)
Calcium	1 M NH_4Cl	0.5-1.4 meq $100g^{-1}$		Ratios of Ca:Mg in exchangeable form of 5:1 to 1:1 are desirable for good plant production	(Armour *et al.* 1985; Charman 2000b; Kingston and Aitken 1996)
Magnesium	1 M NH_4Cl	0.1 - 0.3 meq $100g^{-1}$		Texture influences the deficiency range, with Mg^{2+} deficiencies at >0.2 $cmol_{(+)}$ kg^{-1} in sandy soils or >0.5 $cmol_{(+)}$ kg^{-1} in clay soils. A K:Mg ratio of <0.4 is desirable for adequate magnesium nutrition	(Aitken and Scott 1999; Charman 2000b)
Aluminium	0.01 M $CaCl_2$		>3 mg kg^{-1}	Soluble aluminium concentration increases with decreasing pH, decreasing organic matter levels and increasing soluble salt levels	(Charman 2000b; Dolling *et al.* 1991; Geeves *et al.* 1992; Helyar and Conyers 1994; Horsnell 1995)
Chloride			200 – 600 mg kg^{-1}*		(Bruce and Rayment 1982)

Notes: * indicates plant growth can be retarded where concentrations exceed this range.

Appendix E

Land Suitability Classification Criteria

Suitability for Rainfed Broadacre Cropping

Limitation	Land suitability class				
	1	2	3	4	5
Water availability (See Table 1.3)	PAWC >150 mm	PAWC 125-150 mm	PAWC 100-125 mm	PAWC 75-100 mm	PAWC <75 mm
Nutrient deficiency	Bicarbonate P >10 ppm	Bicarbonate P 5-10 ppm and Exchangeable K >0.3 meq. %	Bicarbonate P 5-10 ppm and Exchangeable K ≤0.3 meq. % or pH <5 60-90 cm below surface or pH >9 60-90 cm below surface	Bicarbonate P <10 ppm and Exchangeable K ≤0.3 meq. %, and Exchangeable Ca <3 meq.%, or pH <5 30-60 cm below surface, or pH >9 30-60 cm below surface	pH <5 within 30 cm of surface or pH >9 within 30 cm of surface
Soil physical factors	Cracking clays with very fine self-mulch (peds <2 mm), or Rigid soils with a loose, soft or firm surface when dry	Cracking clays with fine self-mulch (peds 2-10 mm)	Cracking clays with coarse self-mulch (peds 10-20 mm) or Rigid soils with a hard setting surface when dry	Cracking clays with coarse peds at the surface (≥20 mm)	
Soil workability	Friable cracking clays (indicated by very fine self-mulch), or Rigid soils with a loose, soft or firm surface when dry	Firm cracking clays (indicated by fine self-mulch) or Rigid soils with a hard setting surface when dry	Stiff cracking clays (indicated by coarse self-mulch with peds>10 mm, crusting or hard setting surface)		
Salinity	Rootzone EC <0.15mS/cm or Rootzone Cl <300 ppm	Rootzone EC 0.15 -0.3 mS/cm or Rootzone Cl 300-600 ppm	Rootzone EC 0.3-0.9 mS/cm or Rootzone Cl 600-900 ppm	Rootzone EC 0.9-1.2 mS/cm, or Rootzone Cl 900-1500 ppm	Rootzone EC >1.2 mS/cm or Rootzone Cl ≥1500 ppm
Rockiness	<10% coarse surface gravel (>6 cm diam.) and rock outcrop	10-20% coarse surface gravel and rock outcrop	20-50% surface cobble (6-20 cm diam.)and rock outcrop	50-90% surface cobble and rock outcrop, or 20-50% stone and boulders (>20 cm diam.)	>90% surface cobble and rock outcrop, or >50% stone and boulders and rock outcrop
Microrelief	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	Melonholes 30-60 cm deep cover <20% surface area or Melonholes >60 cm deep cover <10% surface area	Melonholes 30-60 cm deep cover 20-50% of surface area or Melonholes >60 cm deep cover 10-20% surface area	Melonholes 60-100 cm deep cover 50 % surface area	Melonholes at least 100 cm deep cover 50% surface area
Wetness	Undulating terrain or elevated plains	Low-lying level plains with melonholes covering <25% surface area, or Rigid soils with sodic subsoil (ESP 6-14) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 75 cm of the surface	Low-lying level plains with melonholes covering 25-50% surface area, or Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	Seasonal swamps and low-lying run-on areas	Permanent swamps and lakes
Topography	No gully dissection	Occasional deep gullies impede cultivation slightly	Many deep gullies reduce arable area by < 33% or require major changes to cultivation practices	Many deep gullies make the arable areas too small to cultivate	Abundant deep gullies prevent any practical cultivation
Water erosion	Slopes <0.5% on cracking clays without melonholes, or Slopes <1% on melonhole clays, or Slopes <1% on non-sodic rigid soils, or Slopes <0.5% on sodic rigid soils	Slopes 0.5-1% on cracking clays without melonholes or Slopes 1-3% on melonhole clays, or Slopes 1-2% on non-sodic rigid soils, or Slopes 0.5-1% on sodic rigid soils	Slopes 1-3% on cracking clays without melonholes or Slopes 2-4% on non-sodic rigid soils or Slopes 1-2% on sodic rigid soils	Slopes 3-5% on all cracking clays or Slopes 4-6% on non-sodic rigid soils or Slopes 2-3% on sodic rigid soils	Slopes >5% on all cracking clays or Slopes >6% on non-sodic rigid soils or Slopes >3% on sodic rigid soils
Flooding	No flooding	Rare flooding (only during abnormal 1 in 50 to 100 year events)	Infrequent flooding (inundation occurs <half the times that stream flow increases)	Occasional flooding (inundation occurs ≥half the times that stream flow increases)	Regular flooding (inundation occurs whenever stream flow increases)

Suitability For Beef cattle Grazing

Limitation	Land suitability class (see Table 2.4)				
	1	2	3	4	5
Water availability (See Table 1.3)	PAWC >125 mm	PAWC 100-125 mm	PAWC 75-100mm	PAWC 50-75 mm	PAWC ≤50 mm
Nutrient deficiency	Brigalow, gidgee, blackwood or softwood scrub soils and former scrub soils with Bicarbonate P >10 ppm	Eucalypt vegetation and downs with Bicarbonate P >10 ppm	Other soils with Bicarbonate P 5-10 ppm except Sands and loams at least 75 cm deep or overlying rock at shallow depth	Sands and loams at least 75 cm deep or overlying rock at shallow depth, with Bicarbonate P 5-10 ppm, or Bicarbonate P ≤4 ppm	
Soil physical factors	Cracking clays with very fine self-mulch (peds <2 mm), or Rigid soils with a loose, soft or firm surface when dry	Cracking clays with fine self-mulch (peds 2-10 mm), or Rigid soils with a hard setting surface when dry	Cracking clays with coarse peds (peds ≥10 mm) or crust on the surface		
Salinity	Rootzone EC < 0.15 mS/cm or Rootzone Cl <300 ppm	Rootzone EC 0.15-0.3 mS/cm or Rootzone Cl 300-600 ppm	Rootzone EC 0.3-0.9 mS/cm or Rootzone Cl 600-900 ppm	Rootzone EC 0.9-1.2 mS/cm or Rootzone Cl 900-1500 ppm	Rootzone EC >1.2 mS/cm or Rootzone Cl ≥1500 ppm
Rockiness	<20% coarse surface gravel (>6 cm diam.) and rock outcrop	20-50% coarse surface gravel and rock outcrop	50-90% surface cobble and rock outcrop	>90% surface cobble and rock outcrop	Rock outcrop and surface coarse fragments cover total area
Microrelief	Melonholes cover <20% surface area (semi-circular depressions at least 30 cm deep and usually surrounded by mounds)	Shallow melonholes (30-60 cm deep) cover 20-50% surface area	Deep melonholes (>60 cm deep) cover 20-50% of surface area		
pH (1:5)	5.6-6.6	6.6-8.0 5.0-5.6	8.0-9.0 4.5-5.0	9.0-10.0 4.0-4.5	>10.0 < 4.0
ESP (10cm)% Exchangable Sodium Percentage	<5.0	5-10	10-15	15-30	>30
Wetness	Undulating terrain or elevated plains	Low-lying level plains , or Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	Shallow seasonal and permanent swamps		Permanent lakes and deep swamps
Topography				Many deep gullies make cultivation for sowing pastures impractical, or Slopes >15% make cultivation along contours impractical	Strongly dissected terrain over ≥75% of the area preventing adequate herd management
Water erosion	Slopes <1% on sodic rigid soils or Slopes <3% on all other soils	Slopes 1-3% on sodic rigid soils or Slopes 3-6% on cracking clays, or Slopes 3-12% on non-sodic rigid soils	Slopes 3-6% on sodic rigid soils or Slopes 6-9% on cracking clays, or Slopes 12-20% on non-sodic rigid soils	Slopes 6-12% on sodic rigid soils or Slopes 9-15% on cracking clays or Slopes 20-45% on non-sodic rigid soils	Slopes >45%
Flooding	No flooding	Periodic flooding (from once in 50 years to whenever stream flow increases)			
Vegetation regrowth (management limitation)	Softwood, brigalow, gidgee or blackwood scrub without melonholes , or Queensland bluegrass grasslands, or Mountain coolabah, bloodwood and ironbark open woodlands	Brigalow, gidgee or blackwood scrub with melonholes, or Box and ironbark woodlands without wattle understorey, or Coolabah woodlands on flooded country		Eucalypt woodlands with wattle understorey or Broad-leaved teatree woodlands	

Appendix F

Land Suitability Assessment Tables

Land Unit 1: Vertosols on Low Lying Areas

Limitation	Land Quality	Land Suitability Class	
		Broadacre Cropping	Grazing
Water availability	120-150 mm	2	1
Nutrient deficiency	P: >10 ppm, Brigalow vegetation community	1	1
Soil physical factors	Cracking clays with coarse self mulching peds >20 mm	4	3
Soil workability	Cracking clays with coarse self mulch > 10 mm	3	NA
Salinity	EC of root zone 0.085 – 0.8 dS/m; Cl: 11-820 ppm	3	3
Rockiness	Coarse surface gravel (> 6 cm diameter) and rock outcrop <10%	1	1
Micro relief	Melon holes < 0.3-0.6m deep across <10% or the surface.	2	1
pH	7.4-9.2	NA	3
ESP upper 0.1m	<5.0	NA	1
Wetness	Low-lying level plains with melon holes covering <25% of the surface	2	2
Topography	Occasional deep gullies impede cultivation slightly	2	1
Water erosion	Slopes 1-3% on melon holes clays	2	1
Flooding	Rare flooding	2	2

Land Unit 2: Vertosols on Undulating Terrain

Limitation	Land Quality	Land Suitability Class	
		Broadacre Cropping	Grazing
Water availability	90-125 mm	3	2
Nutrient deficiency	P >10 ppm, Brigalow vegetation community	1	1
Soil physical factors	Cracking clays with self mulching peds 10-20 mm	3	2
Soil workability	Friable cracking clay soils	1	NA
Salinity	EC of root zone < 0.1 to 0.45 dS/m	2	2
Rockiness	Coarse surface gravel (> 6 cm diameter) and rock outcrop <10%	1	1
Micro relief	Minor melon holes	2	1
Soil pH	7.6-9.1	NA	3
ESP upper 0.1m	<5.0	NA	1
Wetness	Undulating terrain or elevated plains	1	1
Topography	Occasional deep gullies impede cultivation slightly	2	1
Water erosion	Slopes <3% on cracking clay soils	2	1
Flooding	No flooding	1	1

Land Unit 3: Sodosols on Undulating Low Hills

Limitation	Land Quality	Land Suitability Class	
		Broadacre Cropping	Grazing
Water availability	50-75 mm	5	4
Nutrient deficiency	P: <5-10 ppm, K: <0.3 meq/100g	3	3
Soil physical factors	Rigid soils with a loose, soft or firm surface when dry.	1	1
Soil workability	Rigid soils with a loose, soft or firm surface when dry.	1	NA
Salinity	EC of root zone 0.3 - 0.9 dS/m	3	3
Rockiness	Coarse surface gravel (> 6 cm diameter) and rock outcrop <10%	1	1
Micro relief	No melon holes	1	1
pH	5.5-9.0	NA	2
ESP upper 0.1m	5.0 – 10	NA	2
Wetness	Undulating terrain or elevated plains	1	1
Topography	Many deep gullies reduce arable land area < 33%	3	1
Water erosion	Slopes >3% on sodic rigid soils	5	3
Flooding	No flooding	1	1

Land Unit 4: Sodosols on a Flood Plain with Secondary Rudosols

Limitation	Land Quality	Land Suitability Class	
		Broadacre Cropping	Grazing
Water availability	75-125 mm	3	3
Nutrient deficiency	P: >10 ppm, K: >0.3 meq/100g	1	2
Soil physical factors	Rigid soils with a hard setting surface when dry	3	2
Soil workability	Rigid soils with a hardsetting surface when dry	2	NA
Salinity	EC of root zone 0.01 - 0.82 dS/m; Cl <10-300ppm	2	2
Rockiness	Coarse surface gravel (> 6 cm diameter) and rock outcrop <10%	1	1
Micro relief	No melon holes	1	1
pH	5.8-9.0	NA	3
ESP upper 0.1m	<5.0	NA	1
Wetness	Low lying plains	2	2
Topography	Gully dissection reduces arable area	4	1
Water erosion	Slopes 0.5-1% on sodic rigid soils	2	2
Flooding	Infrequent flooding	3	2

Land Unit 5: Dermosols and Vertosols on Undulating Terrain

Limitation	Land Quality	Land Suitability Class	
		Broadacre Cropping	Grazing
Water availability	75-100 mm	4	3
Nutrient deficiency	P >10 ppm, K >0.3 meq/100g	1	2
Soil physical factors	Rigid soils with a loose, soft or firm surface when dry	1	1
Soil workability	Rigid soils with a loose, soft or firm surface when dry	1	NA
Salinity	EC of root zone 0.15 - 0.3 dS/m	2	2
Rockiness	Coarse surface gravel (> 6 cm diameter) and rock outcrop <10%	1	1
Micro relief	No melon holes	1	1
pH	6.5-8.6	NA	3
ESP upper 0.1m	<5.0	NA	1
Wetness	Undulating terrain or elevated plains	1	1
Topography	Occasional deep gullies impede cultivation slightly	2	1
Water erosion	Slopes 4-6% on non sodic rigid soils	4	2
Flooding	No flooding	1	1

Land Unit 6: Tenosols and Rudosols Adjacent to Intermittent or Permanent Watercourses

Limitation	Land Quality	Land Suitability Class	
		Broadacre Cropping	Grazing
Water availability	>150 mm	1	1
Nutrient deficiency	P: >10 ppm; Eucalypt woodlands	1	2
Soil physical factors	Rigid soils with a loose or firm surface when dry	1	1
Soil workability	Rigid soils with a loose or firm surface when dry	1	NA
Salinity	EC of root zone 0.01 - 0.3 dS/m;	1	1
Rockiness	<10% surface gravel (> 6 cm diameter) and rock outcrop <10%	1	1
Micro relief	No melon holes	1	1
pH	6.8-7.7	NA	2
ESP upper 0.1m	<5.0[1]	NA	1
Wetness	Low lying plains	2	2
Topography	Terrace slopes reduce arable area for sowing pastures	4	3
Water erosion	Slopes <3% on non rigid soils	3	1
Flooding	Infrequent flooding	4	2

[1] The ESP of the A1 horizon was not assessed for this small land unit. ESP results for the 2 horizon were included as they are considered representative

Appendix G

Land Quality Definitions

Land Qualities used in the assessment are based on the *Land Suitability Assessment Techniques* (EPA, 1995); *Guidelines for Agricultural Land Evaluation in Queensland*, (DPI, 1990), and *Land evaluation standards for land resource mapping* (DoA, 2005).

Water availability

Soils with very low water storage are likely to limit crop yields in most seasons, whilst those with low water storage are likely to limit yields in low rainfall seasons or where distribution of the rainfall is irregular. Poor ground cover associated with low yields increases the risk of wind and water erosion as well as contributing to recharge leading to the development of salinity. Deep-rooted crops such as lupins are an option on deep sands with low soil water storage.

On soils with very low water storage, pastures are less productive and dry off rapidly. Poor ground cover increases the risk of wind and water erosion as well as contributing to recharge leading to the development of salinity.

Nutrient deficiency

Plants and animals require adequate, but not excessive levels of nutrients to maintain growth. Periods of inadequate supply may cause reductions in plant yield, particularly during critical periods such as flowering or fruiting. Livestock production may be limited by either reduction in pasture growth or nutritive value caused by low soil nutrients.

The addition of fertilisers is an accepted practice for many landuses where inherent fertility between soil types are not considered important enough to downgrade suitability. However nutrient deficiency may be used to downgrade suitability where returns may be too low or unreliable to justify the application of fertilisers in more extensive land uses such as grazing or broad acre rainfed cropping in marginal areas.

Soil physical factors

Surface soil structure decline, subsurface acidification, subsurface compaction and water repellence all affect pasture production but are rarely prohibitive. Management practices to control and alleviate these problems have been developed. However wide scale adoption has yet to be achieved and land is still deteriorating in many areas. Adoption is more economic in higher rainfall areas where there is greater production per hectare.

Soil workability

Rock outcrops and large stones on or near the surface make cultivation difficult and can damage machinery. Heavy soils can also be hard to work, especially if they are sodic.

Salinity

Whilst crop tolerance to salinity varies it is the combination of salinity and waterlogging that has the greatest impact on crops. Management of affected areas can include increasing plant water use in recharge areas, improving site drainage and establishment of salt tolerant pastures.

On grazing land salinity can be a serious limitation to production while the establishment of low water use annual pastures contributes to development of salinity. Land with high to extreme surface salinity is generally unsuited to conventional grazing though some productivity from saltland pastures may be possible. Management of affected areas can include increasing plant water use in recharge areas, improving site drainage and establishment of salt tolerant pastures.

Rockiness

Stony or rocky soils influence soil properties such as infiltration, erosivity, susceptibility to compaction, and soil water storage, as well as causing an impedance to cultivation and damage to machinery. Surface scree or outcrops of large stones limit production by reducing the surface area available for plant growth and may lead to difficulties in mustering livestock and fencing.

Microrelief

The presence of gilgai, small gullies, or small differences in topography will increase the amount of levelling and earthworks required for that for cultivation alone. Melonholes greater than 60 cm deep over 50% of the area can result in the land being unsuitable to cultivation.

pH

Extremes of pH affect the availability of nutrients resulting in deficiencies and/or toxicities that adversely affect production. Management options are limited to growing tolerant crops or the use of lime to increase the pH of acidic soils.

In pasture highly acidic soils reduce production of most legume species. Management options include growing tolerant species and using acid-tolerant Rhizobia and/or applications of lime. Medics can be selected for highly alkaline soils.

Exchangeable Sodium Percentage of the Upper 0.1m

A soil is considered sodic when sodium reaches a concentration where it starts to affect soil structure, which in Australian soils is commonly at exchangeable sodium percentage (ESP) is > 6% (Isbell, *et al* 1983).

Wetness

Waterlogging reduces crop yields especially if it occurs early in crop development or when the temperatures are higher in spring. Management options include cropping on raised beds, improved site drainage and/or growing tolerant crops such as oats or faba beans.

Waterlogging can limit pasture production with varying degrees of severity. The effects of waterlogging are often far from obvious. Mildly waterlogged pastures can look healthy but have significant yield reductions. Management options include the uses of waterlogging tolerant pasture species and the construction of surface drains.

Topography

The cost of earthworks to level land sufficiently to enable cultivation or furrow irrigation may make the landuse uneconomic. Slopes greater than 20% are regarded as unsafe for machinery use and therefore regarded as unsuitable. The presence of many gullies may result in discontinuities make cultivation and sowing of pastures impracticable, whilst greatly dissected terrain (i.e. >75% of the area) may prevent adequate herd management.

Water erosion

Water erosion can reduce crop yields; result in the loss of nutrients and reduce productive potential. As a general rule, the risk of water erosion is likely to become limiting on slopes with gradients in excess of 10 per cent. Management options include the adoption of no-till systems, sowing on the contour and installing banks to control the length of slope and/or reduce waterlogging.

Water erosion and *Wind erosion* generally lead to a slow decline in productivity, though extreme events can have a more immediate impact. Management can include excluding stock from highly susceptible areas, maintaining ground cover through control of stocking rates, the construction of earthworks to control runoff and the establishment of windbreaks.

Flooding

Floods can damage crops greatly reducing the yield. Areas prone to flooding also have a higher risk of water erosion. For grazing land uses flood hazard is only severe if flooding would affect pasture production or endanger stock.

Vegetation regrowth

After clearing, some native species will rapidly re-establish to a density greater than before. Where cultivation and cropping is practiced this regrowth is controlled; however in some extensive grazing land uses the cost of timber clearing and regrowth is considered significant to determining suitability.

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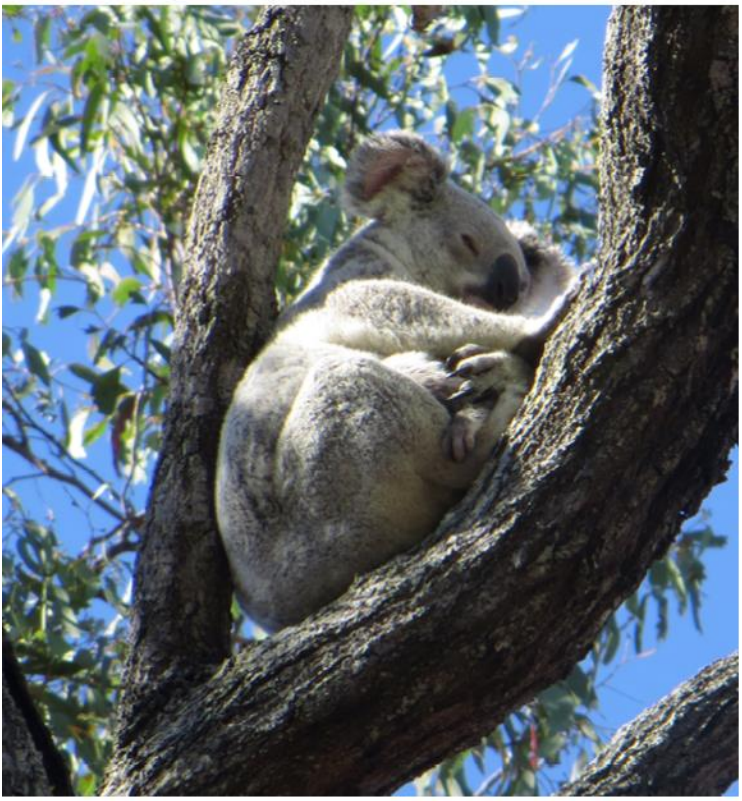
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Rehabilitation Monitoring 2021

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EXECUTIVE SUMMARY

Kleinfelder Australia Pty Ltd were engaged by QCoal Pty Ltd to undertake the 2021 annual rehabilitation monitoring for the QCoal Northern Hub (QNH). The QNH is a collective of four mines:

- Cows Coal Mine (CCM).
- Drake Coal Mine (DCM).
- Jax Coal Mine (JCM).
- Sonoma Coal Mine (SCM).

Monitoring was undertaken at thirty-eight rehabilitation sites across ten Management Units and four reference sites as per the information and methods in the QNH Rehabilitation Management Plan (2020). Soil sampling and analysis was also undertaken.

In summary, four of the Management Units (Sonoma Pit 2010, Sonoma Cows B Pit, Jax Dump and Drake 5) were assessed as compliant for 11 out of the 12 criteria, with the remainder of the MUs (Sonoma Pit 2011 and 2011 No Topsoil, Sonoma Pit 2012, Sonoma Pit 2013, Sonoma Pit 2014, and Q Pit) assessed as compliant for ten of the 12 criteria.

While the vegetation overall appears to be suitable for grazing, the majority of the individual Management Units were rated as non-compliant in two key vegetation acceptance criteria. The first was the "Proportion of non-preferred species not increasing" where the majority of the Sonoma Pit Management Units and Sonoma Cows B Pit were non-compliant. The second was the "Proportion of declared plant pest species not increasing", where all MUs across the QNH were rated as non-compliant. *Parthenium hysterophorus* (Parthenium) has been found to be a key factor influencing this result.

Rehabilitation on Sonoma Mine is older than the revegetation at other locations, and the overall impression gained from the monitoring work is that the rehabilitation on the B Pit, Drake 5, Jax and Q Pit is in better condition. The quality of the revegetation on B Pit and Drake 5 support this observation.

No slope failure or slumping was observed on any of the rehabilitated areas. No recent erosion was evident from the previous 12 months and since the 2020 monitoring event. The main form of historic erosion was localised rilling. This appears to be mostly stable, vegetation has covered/stabilised most exposed soils aside from steep bank faces. In several areas gully erosion is present, remediation of gully bank faces is recommended to prevent further erosion occurring. Contouring of the banks to a more suitable slope would allow seeding, or re-spreading of topsoil with a viable seed bank to be undertaken.

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1 INTRODUCTION

1.1 BACKGROUND AND SCOPE

The QCoal Group (QCoal) operates several coal mine assets in the northern region of Central Queensland. The QCoal Northern Hub (QNH) collectively represents four mine sites located to the south of Collinsville. Each mine is regulated under their respective Environmental Authority (EA) and each EA stipulates the requirement for rehabilitation of areas that have been disturbed by mining activities upon completion of the activity. Rehabilitation is to be conducted in accordance with an approved Rehabilitation Management Plan (RMP) which works towards achieving a grazing pasture post-mining land use (PMLU). The success of rehabilitation is demonstrated by meeting the completion criteria set out in the RMP. Monitoring of rehabilitated areas is to be conducted annually to assess progress towards the achievement of the completion criteria and provide proactive recommendations for rehabilitation improvement.

Kleinfelder Australia Pty Ltd were engaged by QCoal to undertake the 2021 annual rehabilitation monitoring for the QNH, as per the information and methods within the QNH RMP (2020), and to provide a report detailing the progress of rehabilitated areas. The report is to include pragmatic recommendations to support the progress of rehabilitation efforts towards achieving the completion criteria and eventual surrender of the site.

Specifically, the requirements for the 2021 annual monitoring program included survey and assessment of:

- Four reference sites.
- Thirty-eight rehabilitation sites across ten Management Units.
- Soil sampling and analysis within each Management Unit.
- Provision of a draft annual rehabilitation monitoring report detailing:
  - Fieldwork results
  - Trend and statistical analysis
  - Progress against completion criteria, and
  - The development of pragmatic recommendations for future monitoring events and rehabilitation requirements.
- Provision of final document addressing any amendments/comments.

This report details the results of the 2021 rehabilitation monitoring. Rehabilitation has been compared to the 2020 monitoring results where feasible.

1.2 STUDY AREA

The QNH mines run in series between the Bowen River and Collinsville, adjacent to the Bowen Developmental Road in Central Queensland (**Figure 1**). The four mines of the QNH (and their associated EAs) are:

- Cows Coal Mine (CCM) - (EPML00334613).
- Drake Coal Mine (DCM) - (EPML00393013).
- Jax Coal Mine (JCM) - (EPML00337613).
- Sonoma Coal Mine (SCM) - (EPML00707713).

Rehabilitation areas at each mine collectively form the study area. All rehabilitation areas fall within the Overburden Dump domain. Each area of rehabilitation (categorised by mine site and year of completion) is classified as a Management Unit (MU). More information on the MUs and their associated transects is provided in **Section 2.2**

The locality is characterised by disjointed vegetation communities, that are generally modified by grazing, which is the predominant land use of the region. The grassy woodland communities are generally dominated by ironbark species (*Eucalyptus crebra* and *E. melanophloia*) with an understorey prominent in varying pasture species, with *Cenchrus ciliaris* (Buffel Grass) being the dominant species of the region.

The agricultural land classification for the topsoils of the study area indicates good soils for pasture development. The study area is predominantly categorised as C1 (pastureland - land suitable for grazing sown pastures requiring ground disturbance for establishment, or native pastures on higher fertility soils) and B (land suitable for a narrow range of crops, and suitable for sown pastures) (QldGlobe 2021; Guidelines for Agricultural Land Evaluation in Queensland 2015).

Restricted Invasive Plants (listed weed species) have also been recorded onsite including species that have the ability to negatively impact rehabilitated areas.

The region is known for its high-quality metalliferous coal. Situated in the northern extent of the Bowen Basin, the surface rock geology is characterised by labile and lithic sandstone, siltstone, mudstone, coal, carbonaceous shale, coal, tuff, tuffaceous (cherty) mudstone of the late Permian era (GeoResGlobe 2021).

1.3 COMPLETION CRITERIA AND POST-MINING LAND USE

The QNH completion criteria align to the Rehabilitation Goals outlined in the RMP. The goals are to produce rehabilitation that is:

- Safe to humans and wildlife.
- Stable.
- Non-polluting.
- Self-sustaining for the post-mining land use of grazing pasture (except for residual voids).

These goals, or objectives, apply to all Domains of Disturbance (as per Table 9 of the RMP), and there are completion criteria specific to each Domain. To date the only Domain to be rehabilitated at the QNH is Domain 2 – Overburden Dumps. Whilst all objectives are assessed for performance during the monitoring, the focus of the assessment relates to the Post-Mining Land Use (PMLU). The accepted PMLU for all rehabilitated areas is grazing pasture[1]. Grazing pasture must meet the acceptance criteria which is based on the Class 4 land suitability criteria for beef cattle grazing in Table 2.2 of the Land Suitability Techniques guideline contained within the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland* (DME, 1995). The adopted acceptance criteria for Class 4 land suitability are detailed in **Table 1**. These parameters form the focus of the field survey methodology. The completion criteria for all domains can be found in **Table 12** of the QNH RMP.

Table 1: Class 4 land acceptance criteria

Parameter	Acceptance criteria
Plant Available Water Capacity (PAWC)	>50 mm
Salinity	EC1:5 <1.2 mS/cm or Cl1:5 <1,500 ppm in the root zone (60 cm depth)
Rockiness	<100% (% coarse fragments at soil surface)
Soil pH	<10 and >4 as measured at any part of the root zone.
Exchangeable Sodium Percentage (ESP %)	<30% (0-10 cm depth)
Water erosion (a function of slope % and ESP %)	Mean Slope <15% on cracking clay soils Mean Slope <12% on sodic soils (ESP >15% within 500 mm of surface) rigid soils Mean Slope <45% on non-sodic (ESP <15% within 500 mm of surface) rigid soils
Grazing Criteria	≥70% of the productivity (or carrying capacity) of non-mined land in the lease area or, Carrying capacity within the range of values reported for the region, taken as 15 ha/head

[1] Haul roads and access tracks may be retained by the landholder though written agreement; voids are to be filled or are permitted to remain as per the specific EA.

Parameter	Acceptance criteria
Groundcover	Mean groundcover ≥50% or > than the reference site mean, minus one standard deviation.
Grazing Trials	Undertaken following groundcover establishment to confirm carrying capacity.
Species Mix and Composition	Proportion of non-preferred species not increasing* Proportion class will not be more than one class** greater than the grazed reference sites. Proportion of declared plant*** pest species not increasing, and proportion class** will not be more than one class greater than the grazed reference sites.

* Refer to Section 2.3.1

Proportion Classes based on State Rural Leasehold Land Strategy: Guidelines for determining land condition prepared by DNRM (2013). Further information is available in **Section 2.4.

***It is noted that 'declared plant' is a term that is no longer in use due to elements of the *Land Protection (Pest and Stock Route Management Act 2002* being superseded by the *Biodiversity Act 2014*. Restricted invasive plants are used in this report as a surrogate for declared weeds.

1.4 CLIMATE

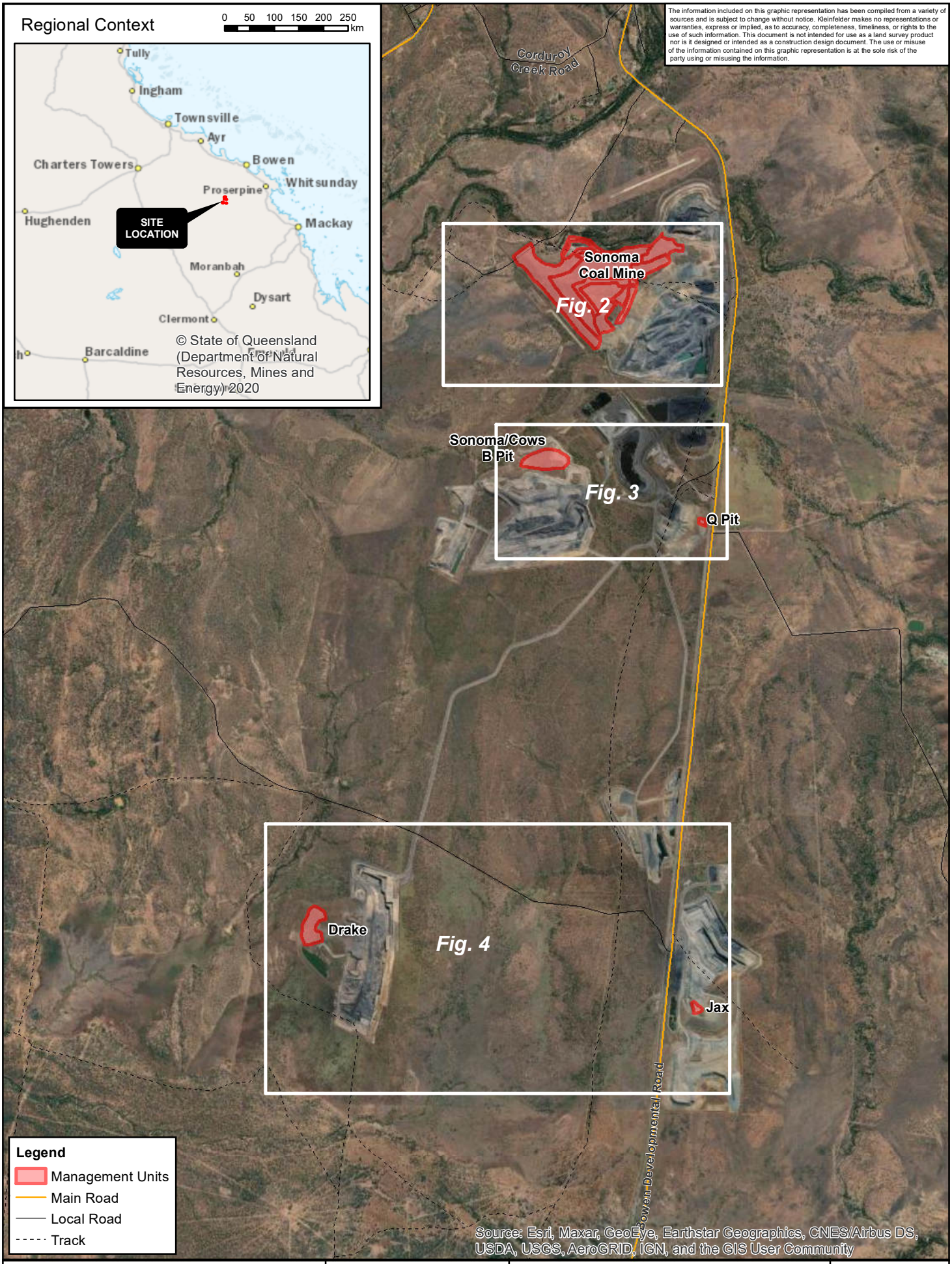
Climate variability can impact the success of the rehabilitation over the long term. Understanding seasonal variations and past conditions can support the planning and implementation of rehabilitation works. Without due consideration, this variation can contribute to poor success rates of young rehabilitation or temporary declines in measurable attributes.

For rehabilitation monitoring, annual monitoring results can be impacted by seasonal weather preceding the monitoring event; rainfall is particularly important. Year to date (01 January – 30 June 2021), and preceding the survey, Collinsville[2] received below average rainfall (-28%), however, the previous twelve months (2020) were consistent with the long-term average (702mm). Monthly rainfall totals since the initial rehabilitation works have been detailed in **Table 2**.

Table 2: Monthly rainfall (mm) for Collinsville for all years of rehabilitation

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	*134.5*	*154.9*	*96.6*	*42.7*	*33*	*27*	*19.3*	*16.8*	*11.2*	*21.8*	*48.7*	*93.5*	*701.7*
2010	89.8	194.2	143.2	18.6	13.6	20.2	3.4	87.0	56.2	45.6	183.2	-	-
2011	154.4	96.4	240.6	67.4	21.6	27.0	0.8	13.8	0.0	4.2	9.8	221.6	857.6
2012	174.8	58.2	282.8	67.2	63.0	25.6	66.4	1.8	11.0	1.2	12.4	18.4	782.8
2013	270.6	95.4	61.6	57.2	34.6	2.6	4.9	0.0	11.6	6.8	76.4	25.4	647.1
2014	64.4	104.2	30.2	63.9	1.4	11.0	0.0	5.4	23.8	0.0	2.8	141.2	448.3
2015	221.2	39.0	14.2	58.4	2.8	8.4	0.8	-	-	-	-	15.5	221.2
2016	60.8	55.1	86.6	3.8	15.9	129.1	53.1	10.4	21.8	16.8	13.6	28.4	495.4
2017	101.8	38.4	337	1	186.4	0.8	0	7.9	0	92.8	27.9	105.2	899.2
2018	52.8	182.4	32.6	33.6	2.4	0	0.5	0	0	50.2	25	68.9	448.4
2019	201.3	126.6	89.2	69.7	26.5	7.7	15.6	1	0	6.2	1.8	8.8	554.4
2020	134.5	141.3	65.2	44.2	64.5	23.2	19.9	5.8	2.8	13.6	0	192.8	707.8
2021	83.4	67.1	67.6	86.2	3.2	45.5							

[2] Collinsville Post Office, Bureau of Meteorology Station 33013.



km
0 0.5 1 1.5 2 2.5

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DATA SOURCE:
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QCoal - 2021

Locality

QCoal
QNH Rehabilitation Monitoring
July 2021

FIGURE:

1

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2 METHODOLOGY

2.1 DESKTOP ANALYSIS AND LITERATURE

Desktop analysis was undertaken prior to the field survey as a matter of due diligence, and to collate up to date information that may support findings or recommendations of the monitoring event. This analysis included any relevant matters of significance and a review of spatial mapping datasets associated to Queensland Regional Ecosystems, soils, and agricultural land classifications. Database Reports used were:

- Maps of Environmentally Sensitive Areas – Mining Activities (DES 2021a).
- Environmental Reports – Matters of State Environmental Significance (DES 2021b).
- Vegetation Management Report (Regulated Vegetation Management Map, Vegetation Management Supporting Map, Essential Habitat Mapping, Vegetation Management Wetlands, Agricultural Land Classification) (Department of Resources 2021).
- Environmental Protection Regulation Wetland Map (DES 2021c).
- EPBC Act Protected Matters Report (DAWE 2021a).
- Wildlife Online (Queensland Government 2021a).

The following literature was also reviewed prior to field works:

- QCoal Northern Hub Rehabilitation Management Plan (QCoal Group 2020).
- Guidelines for Agricultural Land Evaluation in Queensland (DSITI & DNRM 2015).
- State Rural Leasehold Land Strategy - Guidelines for determining land condition (DNRM 2013).
- QCoal Northern Hub Rehabilitation Monitoring 2020 (AusEcology 2020).
- Sonoma Coal Mine 2017 Rehabilitation Monitoring of the Overburden Dumps (NRA 2017).

2.2 MONITORING SITES

Rehabilitation works (completed) at each QNH mine have been split into Management Units (MUs) based on the year of completion (ten MUs total). The number of monitoring sites within each MU varies depending on the extent (in ha) of the rehabilitation. Four new reference sites were required to be selected during the 2021 monitoring event as the area containing the previous reference locations had been cultivated by the landholder. These new sites collectively form the Reference Site MU. At each new reference site, two star pickets were installed to mark the start and end point of each transect and the location was recorded by GPS. The ongoing suitability of these new reference sites will be assessed prior to the 2022 rehabilitation monitoring program. The QNH RMP provides guidance on the selection of reference sites.

Details on the QNH MUs have been provided in **Table 3**. These MUs form the basis of reporting and data interpretation. The locations of the monitoring sites along with the MU extents, have been illustrated in **Figure 2** to **Figure 4**. The coordinates of all sites have been provided in **Appendix A**.

Table 3: Rehabilitation management units

Management Unit	Year of completion	Area (ha)	Number of sites	Site labels
Sonoma Coal Mine				
Sonoma pit overburden dump	2010	48.8	6	V01, V02, V03, V09, V10, V11
Sonoma pit overburden dump	2011	66.2	8	V04, V08, V12, V13, V18, V31, V32
Sonoma pit overburden dump NT (no topsoil)	2011	12.6	3	V05, V06, V07

Management Unit	Year of completion	Area (ha)	Number of sites	Site labels
Sonoma pit overburden dump	2012	11.5	3	V15, V16, V17
Sonoma pit overburden dump	2013	25.7	6	V22, V23, V24, V25, V26, V27
Sonoma pit overburden dump	2014	18	3	V28, V29, V30
Q Pit	2017	0.9	2	Q01, Q01
Sonoma / Cows Coal Mine				
B Pit 2017	2017	17.6	3	B01, B02, B03
Jax Coal Mine				
Jax dump	2018	1.7	1	J01
Drake Coal Mine				
Drake 5 pit	2019	13.8	3	D01, D02, D03
Reference sites				
Reference site 1 – 4	2021	Na	4	REF01, REF02, REF03, REF04

2.3 FIELD SURVEY

Field surveys were conducted between Wednesday 14th and Sunday 18th of July 2021.

2.3.1 Vegetation dynamics

The methodology for the 2021 annual rehabilitation monitoring at QNH was consistent with information provided in the RMP for vegetation dynamics, and considered a 50m transect with smaller nested quadrats, based on specific data collection requirements.

2.3.1.1 Ground cover

Ground cover percentage was assessed at ten 1x1m quadrats, placed every five metres along the transect, starting at five metres. Quadrats were placed on alternating sides along the transect. The results were then averaged to identify a percentage score for each site. The following parameters were recorded:

- Percentage cover of lower stratum vegetation for all species combined.
- Percentage cover of litter.
- Percentage cover of bare ground.
- Percentage cover of rock and logs >5mm.
- Three dominant species present.

2.3.1.2 Vegetation composition

Preferred, Intermediate and Non-Preferred vegetation species for rehabilitation at the QNH are determined in reference to the following documents:

- Grazing Land Management (GLM) land type descriptions for the Burdekin region:
    - Box Country (BD05)
    - Brigalow/Gidgee Scrubs (BD06)
- Where a species is present within the rehabilitation that is not classed as preferred, intermediate or non-preferred within the above land type descriptions, the 'Intermediate Species' definition in the *State Rural Leasehold Land Strategy Guidelines for Determining Land Condition* is utilised:

Intermediate species—all perennial grass species that are not weed species and are any of the following:

a) not recognised as preferred or non-preferred species.

- Native trees and shrubs are considered to be preferred/intermediate species for rehabilitation at the QNH.

The adoption of the Preferred and Intermediate Species listed in the BD05 and BD06 GLM land types of the Burdekin Region is consistent with the previous year's approach, The Guideline definition has also been added to ensure any desirable pasture species which is not captured in the land type descriptions is not automatically classed as non-preferred (this approach has been used in previous years). All flora species and abundance within the 50x10m plot were recorded. Abundances were recorded in the 50x10m plot to give an estimation of vegetation cover to account for biases in cover that may be encountered with smaller unit areas of measurement. The larger area was felt to represent the MU where the transect was situated more accurately, including areas of bare soil or higher vegetation cover.

Abundance was assessed utilising the ACFOR scale as described below:

- Abundant >75%.
- Common ≥50 – 75%.
- Frequent ≥25 – 49.9%.
- Occasional ≥5 -14.9%.
- Rare <5%.

Any prohibited or restricted invasive plants listed under the *Biosecurity Act 2014* (Qld), or under the Weeds of National Significance (WoNS) strategy (Federal), were also recorded in the 50x10m plot using the same abundance scale and percentage cover.

2.3.1.3 Vegetation structure (stem density)

Tree counts to calculate stem density were conducted in a 50x20m plot separating data into trees greater than 4m and less than 4m. Tree species were defined as native species that commonly have a single woody stem and generally exceed 4m in height when mature. Additionally, any evidence of fruiting and/or flowering, recruitment, threatened or rare flora, or feral animal presence was recorded.

The presence of native trees within the rehabilitation areas at the QNH is considered to be incidental to (and not essential to) the achievement of the grazing pasture PMLU. As such, the presence, density and species of trees and shrubs within the rehabilitation area is not part of the QNH completion criteria, and this information is collected for internal reference only (no results or discussion have been included in this report).

2.3.2 Stock carrying capacity

A Stock Carrying Capacity assessment was completed for all sites. The following methodology was used:

- Pasture biomass was assessed using the Future Beef photo standards.
- A stake with clear 10cm increments was placed in a suitable reference point within the site and images captured.
- The photo standards used were either Buffel Grass, Buffel Regrowth, or Indian Couch. The dominant species recorded in the 1x1m quadrats determined which photo standard was used during analysis.
- The pasture yields were estimated (in kg/ha) using the appropriate photo standard.
- The carrying capacity was calculated as per the head/ha equation detailed **Section 8.1.4** of the RMP and considered a dry biomass per annum requirement of 14,600kg per head to retain consistency with previous years' monitoring.

2.3.3 Photo monitoring

Photo monitoring was undertaken to visually assess any temporal changes at each site.

- Photos at established sites were taken to be consistent with previous years' images.
- Photos at new sites considered five images (Transect Line, N, E, S, W) or along a defined bearing that was recorded, along with the GPS location of the start point.

2.3.4 Soil analysis

Kleinfelder recommended a modification to the soil sampling methodology of the RMP. It was suggested that soil profile (horizons) development in rehabilitated spoil dump subsoil can take 10 years (and potentially up to 20 years), and, as such, was not relevant for the 2021 event. The justification was that the focus of the RMP completion criteria primarily relates to healthy and sustainable pastures, and soil sampling to assess such development could be efficiently undertaken with hand tools to recover topsoil (up to 200mm depth) with minimal ground disturbance.

Soil analysis was undertaken at a frequency of 1 sample per 36 hectares with a minimum of two samples per domain (N=20).

- Samples at each location were collected via four subsamples collected at even spacing along the survey transect. The subsamples were combined and sent for laboratory analysis.
- Analysis included:
  - Plant available water capacity
  - Exchangeable Sodium Percentage
  - Organic Carbon
  - Salinity
  - Soil pH
  - Water erosion (slope % and ESP)
  - Major plant nutrients e.g. nitrogen, phosphorus, calcium, sulfur and magnesium
  - Minor plant nutrients e.g. manganese, copper and boron.
- Samples were collected at reference sites for suitable comparison.

Additional information that was recorded included (where relevant):

- Slope (Nikon Forestry Pro II Rangefinder).
- Surface Condition.
- Coarse Fragment content at the soil surface.
- Root depth.
- Presence of water logging features.
- Presence of free carbonates and other segregations.

2.3.5 General observations

A general observation assessment was done on a landscape scale and considered a 100m diameter area around the transect start point. General observations relating to disturbance and fauna were recorded.

Disturbance

The following disturbance factors were recorded:

- Grazing.
- Animal pads.
- Rubbish.
- Feral animals.
- Weeds (Restricted/Prohibited Invasive and Noxious).
- Fire.
- Erosion.
- Slope failure.
- Leachate.

Fauna activity

Any evidence of native fauna using the area was recorded. Both the species (or animal group) and the activity was recorded, including any notable breeding features.

2.4 DATA ANALYSIS

The results of the 2021 monitoring event have been compared to the results of previous monitoring (where practical) to identify trends and anomalies, and to identify progress towards achieving the completion criteria and objectives of the RMP. The analysis findings lead to the formation of relevant recommendations for current and future rehabilitation sites.

The results of all monitoring sites were collated and averaged to give a result per MU. To address the land acceptance criteria (**Section 1.3**) for Species Mix and Composition, classification of the following parameters was necessary:

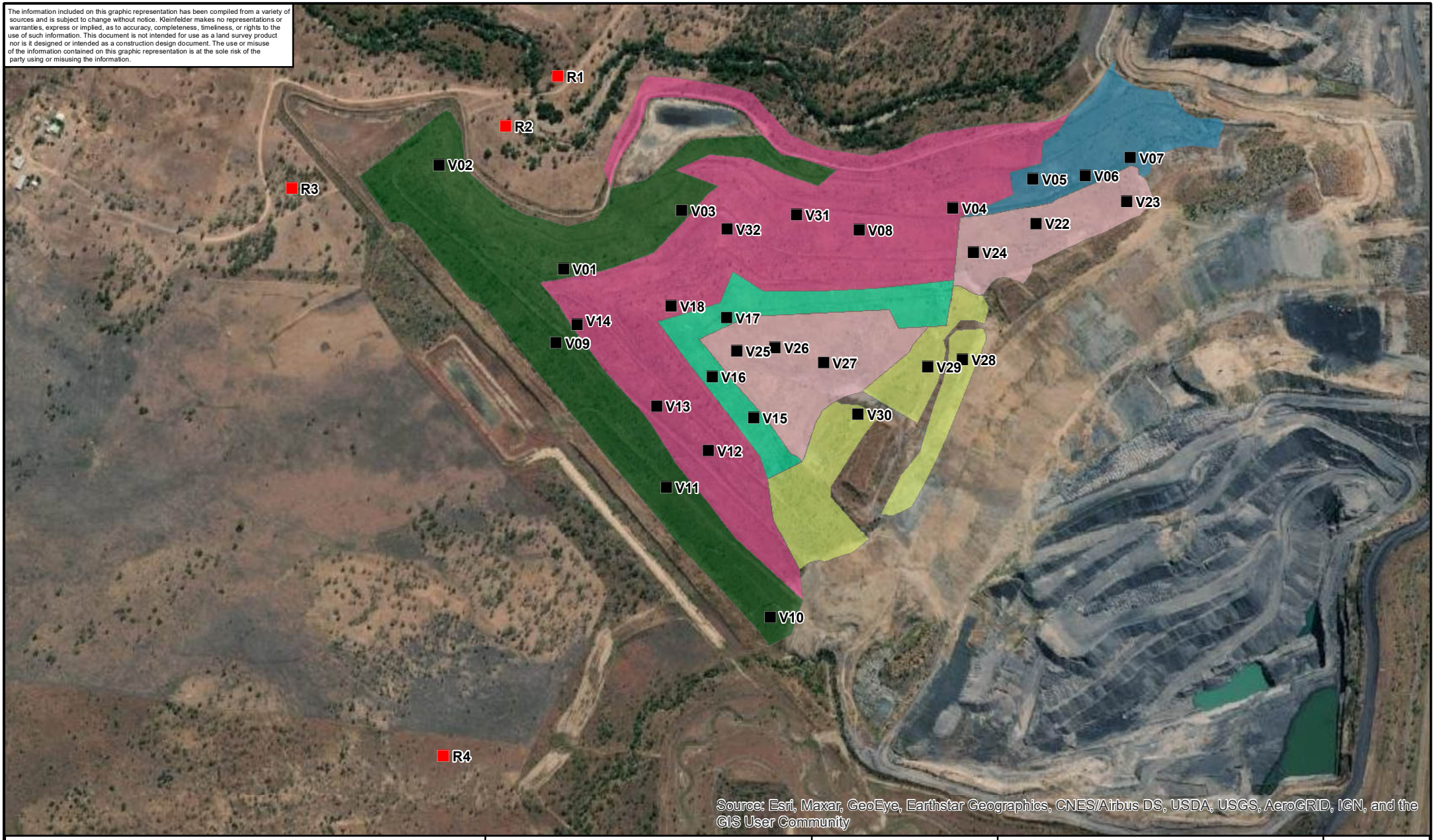
- Preferred and Intermediate pasture species composition.
- Non - preferred species composition (being all species not considered as Preferred or Intermediate) – see 2.3.1.
- Restricted Matter and WoNS.

Classification was attained by allocating the results per MU through the Rating system detailed in Part 3 of the Guidelines for determining land condition (State Rural Leasehold - Land Strategy 2013) (as per the QNH RMP). The Classification ratings are provided in **Table 4**.

Table 4: Classification ratings for each of the vegetation cover parameters

Classification	% Composition Cover
Preferred and Intermediate Species	
1	>80%
2	61 – 80%
3	10 – 60%
4	<10%
Non - Preferred Species	
1	<10%
2	10 – 60%
3	61 – 80%
4	>80%
Restricted Matter and WoNS	
1	0%
2	<10%
3	≥10% and <30%
4	≥30%

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Legend

- Monitoring Locations
- Reference Location (indicative)

Management Units

- 2010
- 2011
- 2011 - No Topsoil
- 2012
- 2013
- 2014

Metres
0 50 100 200 300 400 500

N

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Sonoma Coal Mine Management Units and Monitoring Locations

QCoal
QNH Rehabilitation Monitoring
July 2021

FIGURE:
2

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Legend

- Monitoring Locations

Management Units

- 2017

Metres
0 50 100 200 300 400 500

N

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Sonoma Cows B Pit and Q Pit Management Units and Monitoring Locations

QCoal
QNH Rehabilitation Monitoring
July 2021

FIGURE:
3

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Legend

- Monitoring Locations

Management Units

- Drake
- Jax

Metres
0 100 200 400 600 800 1,000

N

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QCoal - 2021

Drake and Jax Management Units and Monitoring Locations

QCoal
QNH Rehabilitation Monitoring
July 2021

FIGURE:
4

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3 RESULTS

3.1 VEGETATION DYNAMICS

3.1.1 Ground cover

The results of the ground cover assessment demonstrate that all MUs significantly exceed the acceptance criteria of 50% as well as the reference site ground cover, with the exception of the Jax Dump (**Chart 1**). Jax Dump and Drake 5 have shown good cover increases (7% and 16%), whilst the majority of other units remained relatively steady or have decreased slightly with Sonoma Pit 2013 showing the biggest decrease, declining by 6%.

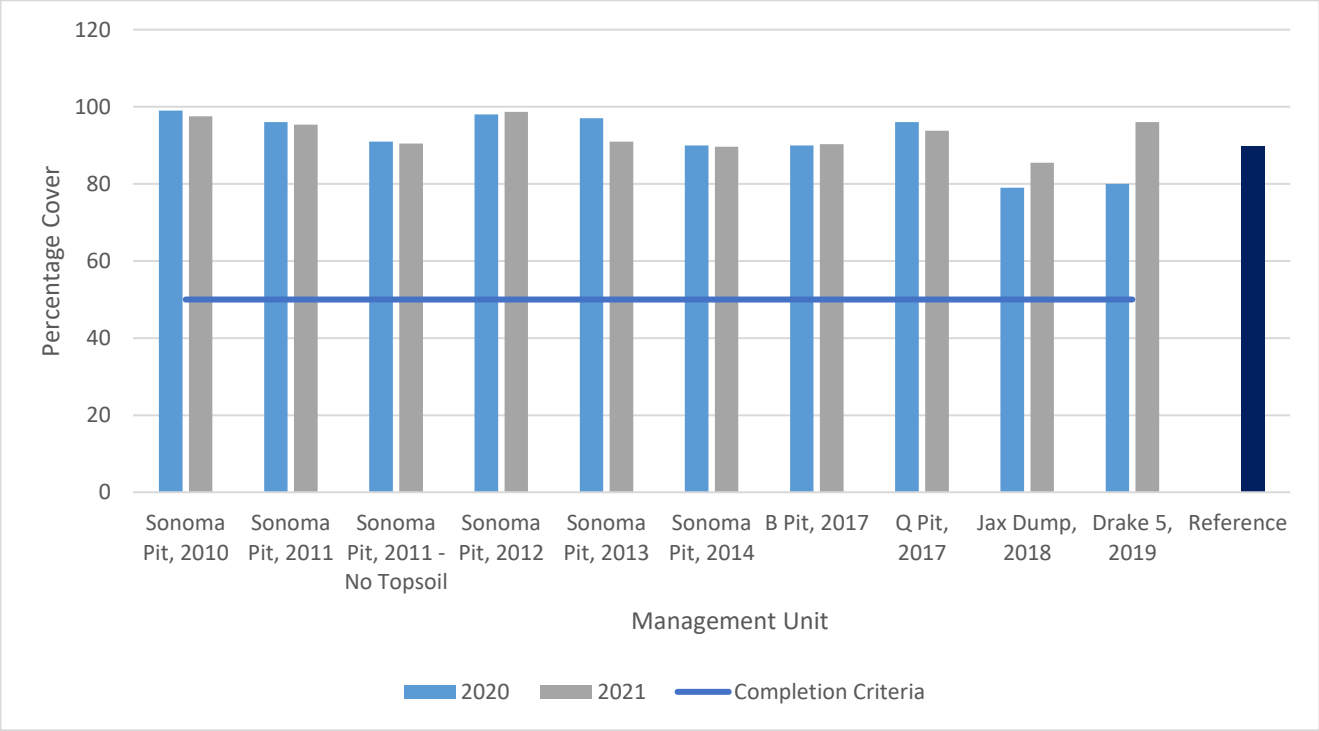


Chart 1: Ground cover comparison per Management Unit 2020 - 2021

3.1.2 Vegetation composition

3.1.2.1 Preferred species composition

The preferred species composition, calculated as a proportion of Preferred and Intermediate pasture species (**Section 2.3.1**) over total vegetation cover, is illustrated in **Chart 2**. The proportion of preferred species increased at four MUs and decreased at six. All sites, except for Sonoma Pit 2012 and Sonoma Pit 2014, demonstrated a proportion that exceeded the Reference Unit.

Annual variation, calculated as a percentage change between 2020 and 2021, was generally within 10%. The outliers to this were Sonoma Pit 2012 (-28%) and Drake 5 Pit (+160%).

Proportion class scores remained consistent for six MUs between 2020 and 2021 (**Chart 3**). Three MUs decreased by one class (Sonoma 2011 NT, Sonoma 2012, and Sonoma 2013) while one MU increased (Drake 5). Two sites were below the Reference Class score (2), however, not by more than one class.

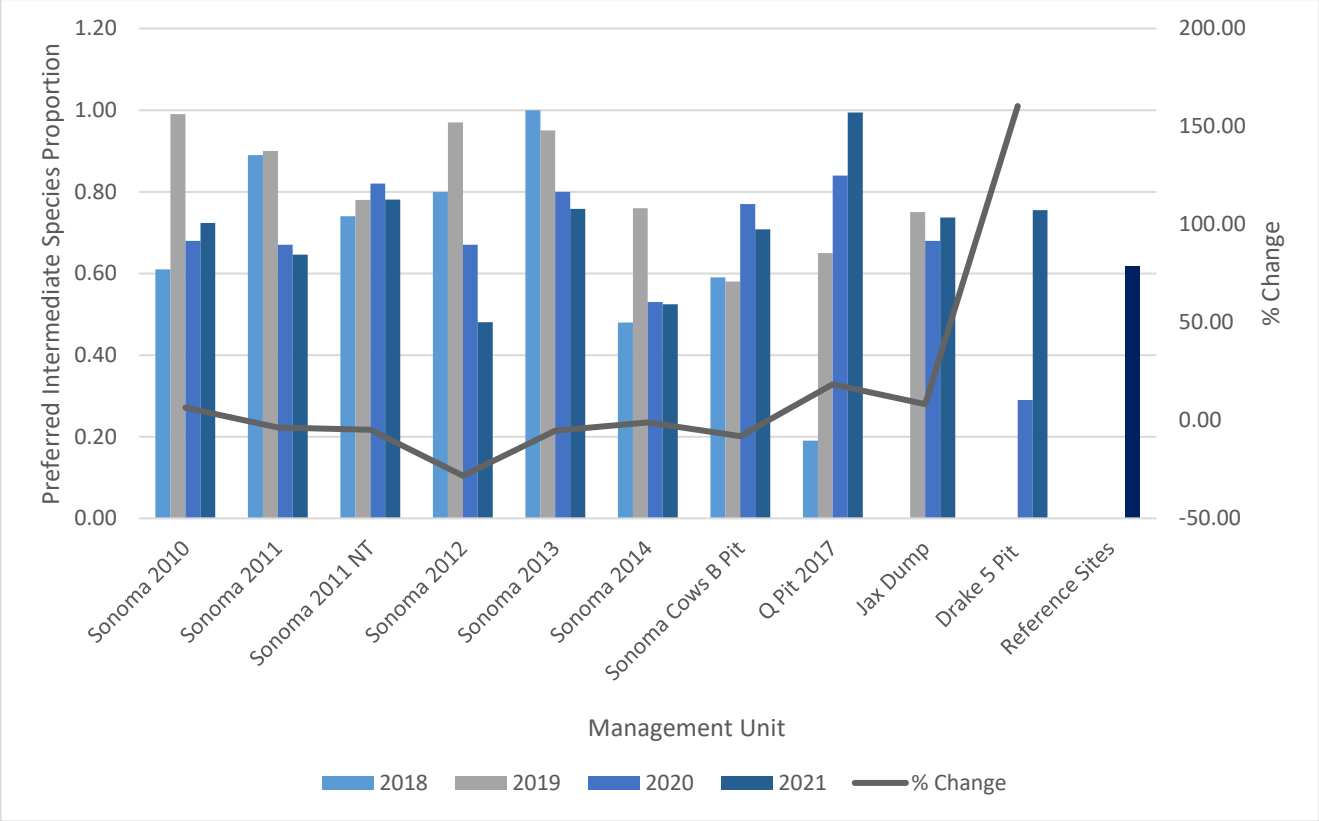


Chart 2: Preferred species composition

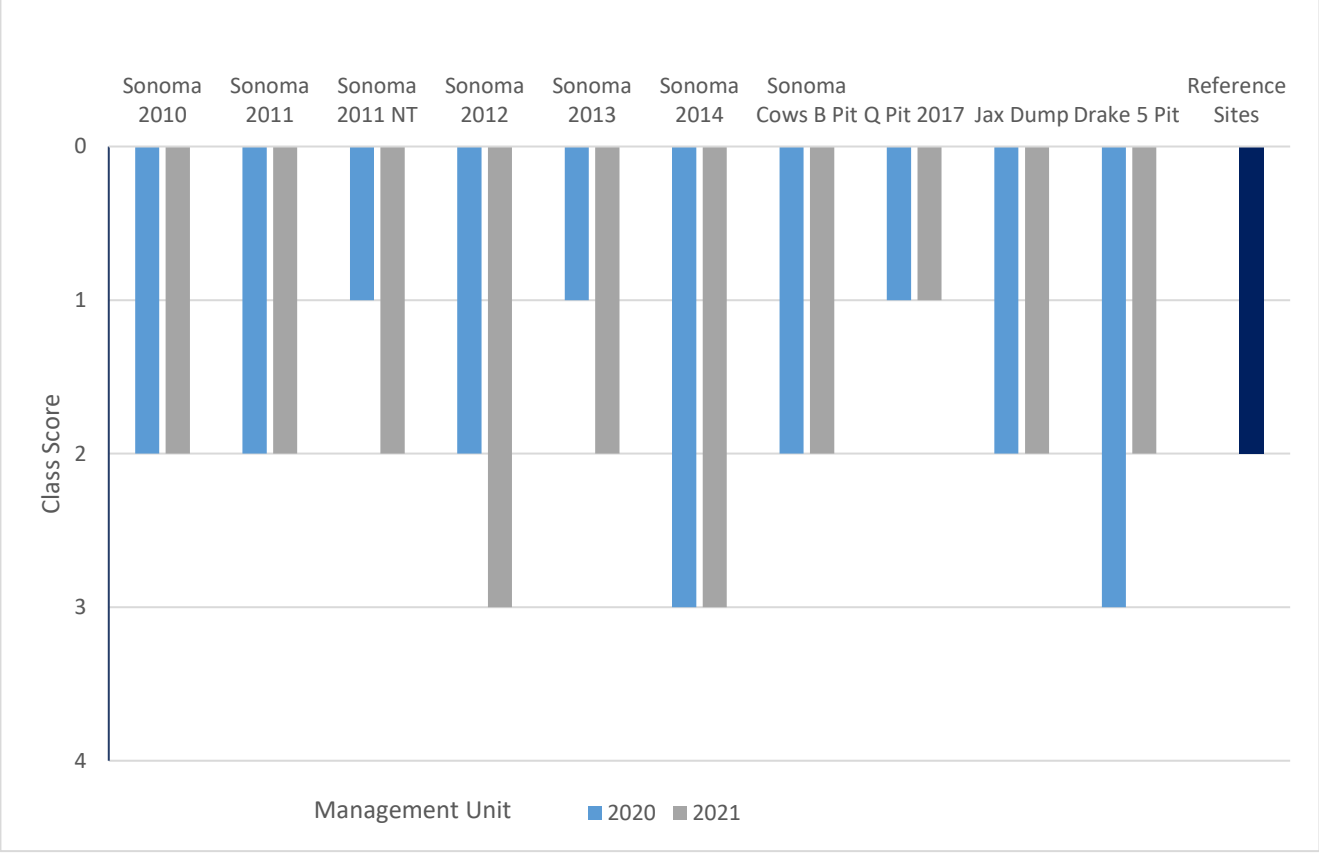


Chart 3: Proportion Class

3.1.2.2 Restricted Invasive Plants

Restricted Invasive Plant (RIP) cover has increased at all locations from the 2020 monitoring program. The highest coverages were recorded at Sonoma 2010, Sonoma 2014, and Jax Dump (**Chart 4**). Only Q Pit and Drake 5 recorded a cover percentage below the Reference site cover (11%).

Four RIP species were recorded across the study area during the monitoring event. *Parthenium hysterophorus* (Parthenium) was the prevalent invasive species and was recorded in all MUs (**Chart 5**). *Cryptostegia grandiflora* (Rubber Vine) was observed at three MUs at Sonoma Mine, due to the vicinity of the rehabilitation sites to Coral Creek and Two Mile Creek; Rubber Vine readily colonises and spreads through major and minor watercourses. *Vachellia nilotica* (Prickly Acacia) and *Ziziphus mauritiana* (Chinee Apple) were also recorded at lower levels of impact (**Plate 1**). All four species are classified as Restricted Invasive Plants under the *Biosecurity Act 2014*. Parthenium, Rubber Vine, and Prickly Acacia are classified as WoNS.

Class scores for RIP are presented in **Chart 6**. All MUs returned a score of 2 which was equal to the Reference Site MU. There were no deviations from the 2020 MU score.

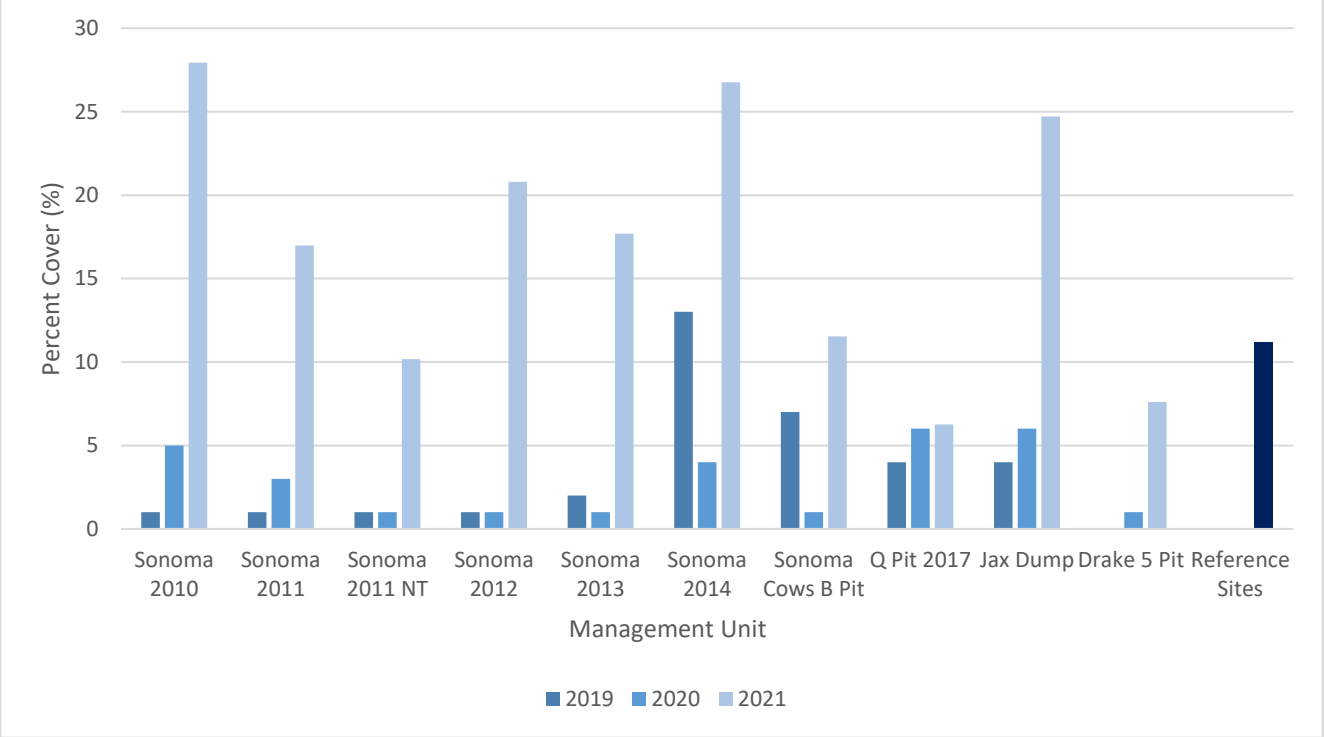


Chart 4: Restricted Invasive Plant Cover

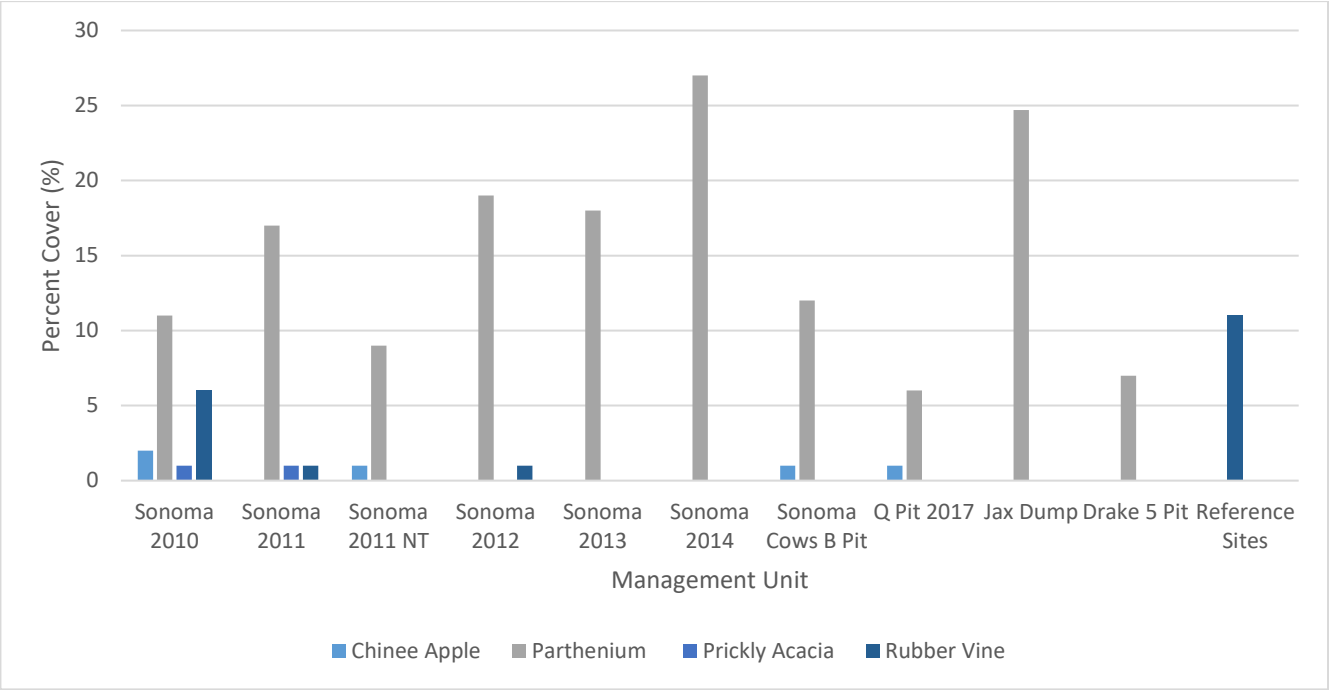


Chart 5: Species breakdown

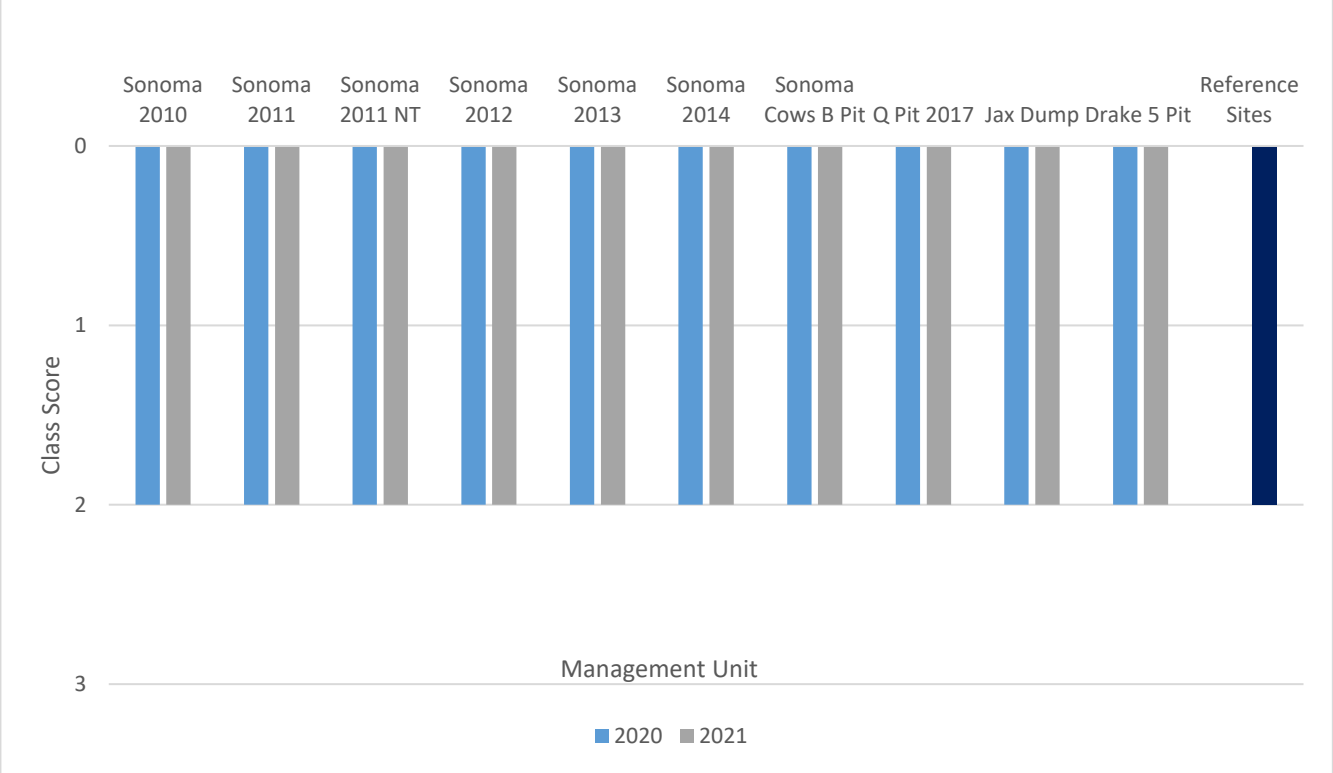


Chart 6: Restricted Invasive Plant class scores



Plate 1: Mature Chinee Apple with Parthenium dominant understorey at Sonoma 2011 (V11)

3.2 STOCK CARRYING CAPACITY

The stock carrying capacity has increased or remained even at seven of the ten MUs (**Chart 8**). Significant increases were recorded at Sonoma Cows B Pit (+65%), and Drake 5 (+91%) (**Plate 2**). The largest decrease was calculated at Sonoma 2011 NT (-31%), however this MU still significantly exceeds the carrying capacity of the Reference MU. All rehabilitation MUs had a carrying capacity in excess of the Reference Site MU (15 head/100ha) therefore the completion criteria (>70% of the reference site or 15ha/head). Pasture photos for all monitoring sites are provided in **Appendix B**.

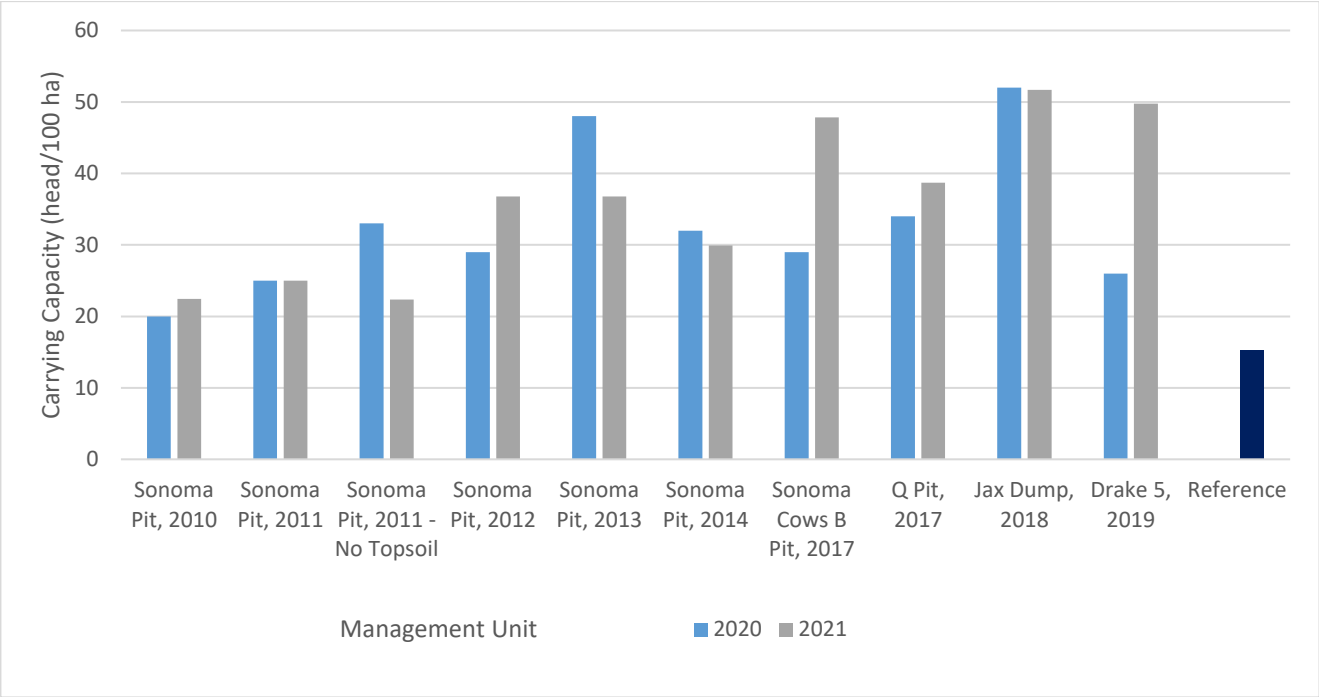


Chart 7: Stock carrying capacity



Plate 2: Healthy pastures (Buffel Grass) supporting a high stock carrying capacity at Drake 5 (D02)

3.3 PHOTO MONITORING

Photo monitoring was undertaken at all sites. The results of the photo monitoring have been incorporated into the discussion and used to support findings associated with vegetation dynamics and stock carrying capacity. The full suite of images per site has been provided in **Appendix B**.

3.4 SOIL AND LANDSCAPE

3.4.1 Soils

Soil samples were taken at 18 locations across all MUs, including two reference site samples (**Table 5**). Full results of the soil analysis are provided in **Appendix D**, and specific results are discussed below.

Table 5: Soil sample locations and designations for the QCoal Northern Hub sites

Management Unit	Monitoring site
Sonoma 2010	V02
Sonoma 2011	V08, V12
Sonoma 2011 NT	V05, V07
Sonoma 2012	V15, V17
Sonoma 2013	V22, V27
Sonoma 2014	V28, V30
B Pit	B01, B02
Q Pit	Q01, Q02
Jax Pit	JAX
Drake 5	D03
Reference	REF01, REF02

3.4.1.1 Class 4 land suitability acceptance criteria

Plant Available Water Capacity

Plant Available Water Capacity (PAWC), the maximum amount of water stored in a soil profile that can be used by plants, was positive across all MUs. Results ranged from 86mm at Sonoma 2011 NT to 154mm at Sonoma 2014. All MUs exceed the completion criteria minimum of 50mm and six MUs exceed the Reference MU result of 119mm.

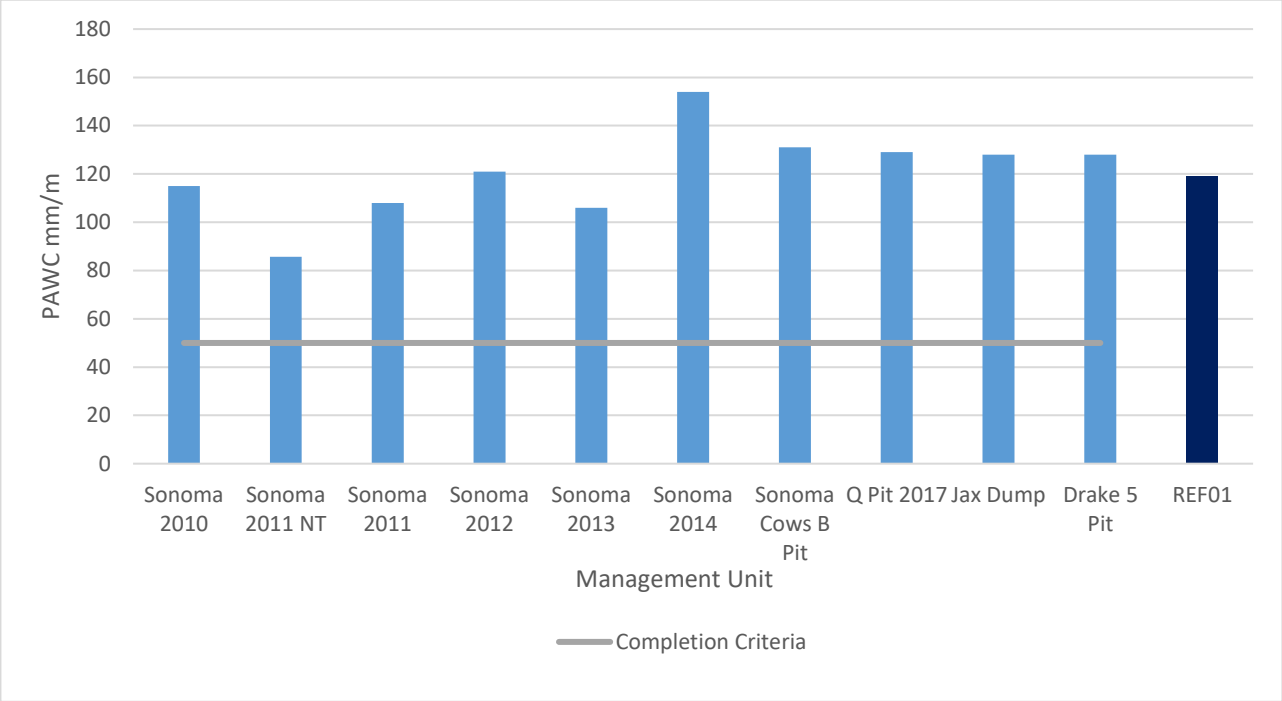


Chart 8: Plant available water capacity

Salinity

Salinity, as measured by Electrical Conductivity, generally recorded relatively high levels. Five sample locations D05 (Drake 5), J01 (Jax Pit), Q01 (Q Pit), V08 (Sonoma 2011) and V17 (Sonoma 2012) all recorded salinity levels of 0.17 - 023 milliseimens per centimetre (mS/cm) (in a loam soil). V07 (Sonoma 2011 no topsoil) had an elevated level of 0.83 mS/cm. The four remaining sites recorded values just below this level (0.15 – 0.16 mS/cm). However, all rehabilitation MUs met the acceptance criteria (<1.2mS/cm).

In contrast the reference sites recorded salinity levels of 0.049 and 0.029 mS/cm for REF01 and REF02 respectively.

Soil pH

Of the 15 samples taken from the rehabilitation MUs 14 were within the desirable range of 5.2 - 8.0, and ranged from 7.5 to 8.0, categorised as slightly alkaline. One sample, V02 (Sonoma 2010) was lower at 6.6 and therefore slightly acidic, while another sample V07 (Sonoma 2011 no topsoil) recorded a pH of 8.2, higher than the desired range. All rehabilitation MUs met the acceptance criteria (<10 and >4).

Soil pH at the reference sites were slightly acidic, returning values of 5.8 and 5.9 for REF01 and REF02 respectively.

Exchangeable Sodium Percentage

Exchangeable Sodium Percentage (ESP) levels greater than 6% are considered potentially detrimental to plant growth and soil stability as they have less stable aggregates and are less productive. Three sites recorded levels that were in the upper range for ideal plant growth with B01 (B Pit) recording 3.9% and J01(Jax Pit) 5%. V07 (Sonoma 2011 No topsoil) had an elevated result of 14.8%. Notably, all sites were within the acceptable criteria range (<30%).

The two reference sites recorded levels lower percentages at 1.6% and 1.1% for REF01 and REF02 respectively.

3.4.1.2 General soil health parameters

Organic carbon

Organic carbon levels were almost uniformly within the acceptable range of 1.00 – 3.00 %w/w. Only three sites returned levels below this range. These were V07 (Sonoma 2011 No topsoil) at 0.53 %w/w, V15 (Sonoma 2012) at 0.99%w/w and V30 (Sonoma 2014) at 0.94%w/w.

Nitrogen

Nitrogen levels were measured as Nitrate and Nitrite-N and all sites, including the reference sites, returned well below the desirable range of 20 - 40 mg/kg. Results ranged from 0.05 mg/kg (the lower limit of detection) for reference site REF02 to a high of 5.9 mg/kg for V08 (Sonoma 2011).

Phosphorus

Pcol at levels between 20 – 35 mg/kg are considered adequate for pasture. The reference sites recorded levels of 30 and 55 mg/kg for REF01 and REF02 respectively. Two sites, V12 (Sonoma 2011) and V28 (Sonoma 2014) recorded levels within this range, while nine sites (the remaining Sonoma Pit MUs) recorded levels above this range. B Pit (B01 and B02), Drake 5 (D03), Jax Pit (J01) and Q Pit (Q01 and Q02) all recorded low levels of Pcol - between <1 to 16 mg/kg. Site V30 (Sonoma 2014) was the single Sonoma Pit site that recorded a low level of Pcol at 8 mg/kg.

Major Cations

Major cations, calcium, magnesium, potassium and sodium, were generally in the high range deemed as necessary for good pasture growth, and as a consequence Total Cation Exchange Capacity (CEC) was also very high in 10 of the sites (40 meq/100g) and high (25 - <40 meq/100g) in another four sites.

Minor Nutrients

Minor nutrients – copper, zinc, manganese, iron and sulphur are all below adequate levels, with the two reference sites being mixed. Sulfur levels are in the very high range (>20 mg/kg) for V07 (Sonoma 2011 No topsoil). Boron levels were recorded as adequate across almost all sites.

Summary

The soils are mainly alkaline and any increase in alkalinity may result in nutrient deficiencies becoming exacerbated as nutrients become adsorbed to soil particles and become unavailable to plants. Overall, the soils across the MUs are of low fertility, especially with low levels of nitrogen and several key micronutrients. The Sonoma 2011 NT MU appears to be especially of concern with regards to soil fertility. Plant Available Water Capacity is generally positive and suggests an adequate soil structure for retention of perennial grass.

3.4.2 Slope

No change in slope was recorded in annual comparison of the MUs. The slope recorded at each MU remains below the completion criteria requirement of 11.5°. No recent slumping was recorded, for further detail or erosion see **Section 3.5.1** (Disturbance).

Table 7: Slope per MU and variation from maximum slope

Management Unit	Slope (°)	Max slope variation (°)
Sonoma Pit 2010	8	-3.5
Sonoma Pit 2011	9	-2.5
Sonoma Pit 2011 NT	10	-1.5
Sonoma Pit 2012	9	-2.5
Sonoma Pit 2013	3	-8.5

Management Unit	Slope (°)	Max slope variation (°)
Sonoma Pit 2014	5	-6.5
Sonoma Cows B Pit	0	-11.5
Q Pit	9	-2.5
Jax Dump	1	-10.5
Drake 5	10	-1.5

3.5 GENERAL OBSERVATIONS

3.5.1 Disturbance

Minimal disturbance was recorded across the MUs. Cattle have been excluded from the revegetation areas until the commencement of grazing trials. There is evidence of macropod grazing, however, no significant impacts were observed.

Disturbance from feral pigs (*Sus scrofa*) was observed throughout the Sonoma Pit MUs (excluding reference sites). Several dead pigs were observed during the monitoring event, as a result of a recent culling event. Feral deer scats were observed at Sonoma Pit 2011.

Disturbance from weed infestations was evident, such weeds compete for space and can diminish preferred species development and composition. In addition to the four restricted weeds identified in **Section 3.1.2.2**, several other species were recorded commonly occurring throughout the MUs. These included *Melinis repens* (Red Natal Grass), *Vachellia farnesiana* (Mimosa Bush) and *Abutilon* species (mallow varieties).

No recently occurring erosion (within the previous 12 months) was evident. Minor erosion (primarily rilling) was recorded at Sonoma Pit 2012 (V15,16) and Sonoma Pit 2013 (V22). Significant rilling was observed at Sonoma Pit 2010 (V10 and V11) (**Plate 3**), Sonoma Pit 2011 (V12 and V31), Sonoma Pit 2011 NT (V05) which had several gullies, some up to 3m deep, and Drake Pit (D03) with rills to 1m deep recorded. Water tunnelling erosion was also found at Sonoma Pit 2011 NT (V06) (**Plate 4**). All erosion had some form of vegetation cover and appeared to have stabilised since the actual event. No fire, slope failure, or leachate disturbance was observed.



Plate 3: Historic erosion near V10 at Sonoma 2010 MU



Plate 4: Tunnelling erosion at Sonoma Pit 2011 NT (V06)

3.5.2 Fauna activity

Twenty-eight native fauna species were identified, during the monitoring event, throughout the study area. Twenty-three of these species were avian fauna, identified through visual observation or by call recognition. These included notable species such as the Wedge-tailed Eagle (*Aquila audax*) and the Brolga (*Grus rubicunda*). Three macropods were recorded either through scats or observation, and one reptile was recorded (Eastern Brown Snake – *Pseudonaja textilis*). Diggings from a Short-beaked Echidna (*Tachyglossus aculeatus*) were found at Jax Dump. The Short-beaked Echidna is a listed animal under the *Nature Conservation Act 1992* (Special Least Concern).

One animal breeding place, an avian nest (wren species), was observed at Sonoma Cows B Pit (**Plate 5**).



Plate 5: Evidence of a fauna utilising the rehabilitation for breeding at Sonoma Cows B Pit

4 DISCUSSION

The results of the QNH rehabilitation monitoring for 2021 have been summarised for discussion against the completion criteria in the sub-section below. Further discussion specific to the attributes and parameters assessed during the field survey and soil sampling are also discussed, where relevant, with regards to achieving the desired post-mining land use.

4.1 SUMMARY

The QCoal Northern Hub rehabilitation was monitored as 11 Management Units. Given that the Sonoma Pit rehabilitation is contiguous it will be discussed as a whole, where possible, with the management units discussed individually only when issues are required to be raised.

In terms of the Acceptance Criteria – Class 4 (**Table 7**), none of the areas monitored were assessed as fully compliant against all 12 of the currently measurable criteria. Note that grazing trials have not yet commenced and therefore, no assessment was made against this criterion.

In summary, four of the Management Units, Sonoma Pit 2010, Sonoma Cows B Pit, Jax Dump and Drake 5 have all been assessed as compliant with 11 of the 12 criteria, with the remainder of the MUs assessed as compliant with ten of the 12 criteria.

Overall the vegetation overall appears to be suitable for grazing and the soils adequate in terms of pH, mineral composition, and PAWC. However, the majority of the individual MUs were rated as non-compliant in two key vegetation acceptance criteria. The first was the “Proportion of non-preferred species not increasing” where the majority of the Sonoma Pit MUs and B Pit MU were non-compliant. The second was the “Proportion of declared plant pest species not increasing”, where all MUs across the QNH were rated as non-compliant. Parthenium has been found to be a key factor influencing this result.

Table 8: Class 4 acceptance criteria per MU (C – compliant, NC – non-compliant, NA – not applicable)

Parameter	Acceptance criteria	Sonoma Pit 2010	Sonoma Pit 2011	Sonoma Pit 2011 NT	Sonoma Pit 2012	Sonoma Pit 2013	Sonoma Pit 2014	Sonoma Cows B Pit	Q Pit	Jax Dump	Drake 5
Plant Available Water Capacity (PAWC)	>50 mm	C	C	C	C	C	C	C	C	C	C
Salinity (Cl 1:5)	EC1:5 <1.2 mS/cm or Cl1:5 <1,500 ppm in the root zone (60 cm depth)	C	C	C	C	C	C	C	C	C	C
Rockiness	<100% (% coarse fragments at soil surface)	C	C	C	C	C	C	C	C	C	C
Soil pH (1:5 $CaCl_2$)	<10 and >4 as measured at any part of the root zone.	C	C	C	C	C	C	C	C	C	C
Exchangeable Sodium Percentage (ESP %)	<30% (0-10 cm depth)	C	C	C	C	C	C	C	C	C	C
Water erosion (a function of slope % and ESP %)	Mean Slope <15% on cracking clay soils Mean Slope <12% on sodic soils (ESP >15% within 500 mm of surface) rigid soils Mean Slope <45% on non-sodic (ESP <15% within 500 mm of surface) rigid soils	C	C	C	C	C	C	C	C	C	C
Grazing Criteria	≥70% of the productivity (or carrying capacity) of non-mined land in the lease area or, Carrying capacity within the range of values reported for the region, taken as 15 ha/head.	C	C	C	C	C	C	C	C	C	C
Groundcover	Mean groundcover ≥50% or > than the reference site mean minus one standard deviation.	C	C	C	C	C	C	C	C	C	C
Grazing Trials	Undertaken following groundcover establishment to confirm carrying capacity.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Parameter	Acceptance criteria	Sonoma Pit 2010	Sonoma Pit 2011	Sonoma Pit 2011 NT	Sonoma Pit 2012	Sonoma Pit 2013	Sonoma Pit 2014	Sonoma Cows B Pit	Q Pit	Jax Dump	Drake 5
Species Mix and Composition – Preferred Species	Proportion of non-preferred species not increasing.	C	NC	NC	NC	NC	NC	NC	C	C	C
	Proportion class will not be more than one class greater than the grazed reference sites.	C	C	C	C	C	C	C	C	C	C
Species Mix and Composition – Declared pest plants	Proportion of declared plant pest species not increasing	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Proportion class will not be more than one class greater than the grazed reference sites.	C	C	C	C	C	C	C	C	C	C
Total parameters achieving compliant status (out of 12)		**11**	**10**	**10**	**10**	**10**	**10**	**10**	**11**	**11**	**11**

4.2 INDIVIDUAL MANAGEMENT UNITS

4.2.1 Sonoma Pit

Sonoma Pit has been divided into individual MUs based on age of rehabilitation. These MUs were rehabilitated between 2010 and 2014, making them considerably older than the other rehabilitated areas and collectively much larger, at 182 ha of contiguous area. Overall, there has been a slight decrease in total ground vegetation cover, as observed during the monitoring visit (≤ 6%), but none of the MUs have fallen below the acceptance criteria requirement. There has been a large increase in Restricted Invasive Plant (RIP) coverage, which has been prevalent across all MUs and is largely attributable to Parthenium, though the woody weeds Rubber Vine and Chinee Apple have also had notable increases and were observed to be in flower or have seed present, indicating the potential for increasing densities in the future. Below average rainfall in the six months preceding the survey could account for both a decrease in ground cover and increased Parthenium germination; Parthenium populations are encouraged by reduced pasture covers particularly in drought situations. The overall stock carrying capacity of this area is generally about the same, with some of the MUs increasing (two MUs) and others decreasing or remaining the same (four MUs) depending on preferred species coverage.

Erosion in the Sonoma 2011 NT MU was deemed to be more prevalent that other MUs at Sonoma, with a single example of tunnelling erosion observed. Tunnelling is of concern as it can lead to much larger erosion issues such as slumping at the exit point. One of the soil samples (V07) indicated a higher level of salinity (0.83 mS/cm) and returned the highest ESP value (14.8%) suggesting an increased risk from dispersion, however a second sample on the MU (V05) returned inconsistent results suggesting further targeted sampling at this location is required. This MU also has some of the steeper rehabilitated slopes assessed that would exacerbate any such dispersion. It is recommended that this site (Sonoma 2011 NT) be monitored in more detail during the next survey e.g., soil samples from all three transects and from more erosion prone areas and a more detailed walk over survey to broadly assess the possible presence of dispersive soils (laterally and vertically) and identify further erosion issues, if present, and erosion potential (unstable soils).

4.2.2 Sonoma Cows B Pit

The Cows B Pit is in good condition and presents a very uniform area of rehabilitated pasture. Despite some decrease in preferred species composition and an increase in RIPs (largely due to increased Parthenium cover), the stock carrying capacity of this area has increased by a calculated 65%. PAWC is also good at 131mm. This area, although relatively small in size (17.5 ha), presents an opportunity for grazing trials to be commenced; though consideration will need to be given to weed control, access, water and fencing given the proximity to operational mining areas.

4.2.3 Q Pit

The Q Pit rehabilitation is a very small area, approximately 1 ha in size, that has recorded an increase in stocking capacity with a large increase in preferred species composition, but also an increase in weed species coverage. The small size of this rehabilitation area probably precludes grazing trials on any meaningful scale.

4.2.4 Jax Dump

The Jax Dump is also a small area of rehabilitation at 1.7 ha and one that demonstrated a positive change in rehabilitation values. This area has increased its ground cover by 6.5% and the preferred species composition has also increased by 8%. This area also recorded a large increase in RIP coverage, primarily Parthenium.

4.2.5 Drake 5 Pit

The Drake 5 Pit is another area showing good promise for grazing trials, with a good size (14 ha), good PAWC (128mm), and substantial improvements in preferred species composition and increase in total ground cover. This area also recorded an increase in RIP cover, again primarily due to Parthenium.

4.3 GENERAL COMMENTS

This monitoring survey was undertaken somewhat later in the season than is desirable for rehabilitation monitoring and, combined with the reduced rainfall that the area received in the months prior to this survey, may have contributed to some of the variations in the results. Parthenium was seen to be the dominant weed of

significance, often being observed as a multitude of seedlings underneath existing pasture cover. Below average rainfall in the six months preceding the survey is likely to have resulted in a reduced groundcover; such disturbance commonly leads to an increase in Parthenium prevalence.

The use of environmental or cool season burns can be considered as a method of controlling weeds, but also as method of stimulating desirable grass and legume species. However, such burns will not reliably control the large woody weed species such as Chinee Apple and Prickly Acacia as this would require a non-beneficial high intensity burn. Woody weeds will require manual weed control, including cut and painting the stump with herbicide. Basal barking is also an option however an environmental risk assessment should be undertaken first as diesel can have broader impacts in rehabilitated environments. Given that many of these individual trees will have set seed, it is further recommended that any contractors or QCoal staff, engaged to undertake this work, locate the position of these trees by GPS so that follow up spraying of seedlings can be conducted at and around these locations where seeds have been deposited.

The Sonoma Pit rehabilitation is older than the revegetation in the other MUs, and the overall impression gained from the monitoring work is that the rehabilitation on the B Pit, Drake 5, Jax and Q Pit MUs is in better condition. Certainly, the quality of the revegetation on B Pit and Drake 5 support this observation.

No slope failure or slumping was observed on any of the rehabilitated areas. No recent erosion was evident from the previous 12 months and since the 2020 monitoring event. The main form of historic erosion was localised rilling that potentially formed in the early stages prior to stabilisation by ground cover. This appears to be mostly stable, and vegetation has covered most exposed soils aside from steep bank faces. Gullies (up to 3m deep) remain on the south-western side of the Sonoma Pit, in the 2010 and 2011 (No Topsoil) MU. Remediation of gully bank faces is recommended to stabilise the flow paths and prevent further erosion occurring. Battering the banks to a more suitable slope would allow topsoil respread or seeding to be undertaken.

Given the large size of the Sonoma Pit, consideration should be given to conducting at least some of the monitoring utilising a drone equipped with high-definition video and mapping technology. Such mapping can more accurately monitor the change in preferred and non-preferred species including RIPs.

Consideration was given to the Class 4 acceptance criteria (being based on the DME 1995 Class 4 beef cattle grazing criteria) as being appropriate and effective in determining successful and self-sustaining rehabilitated pasture. In general, the parameters are suitable and consistent with Queensland agricultural health and sustainability guidelines.

However, soil analysis could be more prescriptive and targeted at topsoil health and functionality e.g., Total Organic Carbon, and macro and micronutrients. Healthy soils are a more reliable indicator of self-sustaining pastures as they are less reactive to seasonal climate fluctuations (such as rainfall) than the vegetation that grows on them.

The classification of preferred species is considered ambiguous and the RMP should more rigidly define palatable and preferred species to ensure accurate and consistent reporting on the progress of this parameter. The approach followed during this monitoring program as outlined in **Section 2.3.1** is considered to be a suitable approach to determining preferred and intermediate species given the reliance on the natural seedbank within the respread topsoil.

5 RECOMMENDATIONS

A summary of recommendations based on the results of the assessment and the associated discussion have been provided in **Table 8**.

Table 9: Recommendations

Aspect	Recommended Actions
Management units	
B Pit	• Consideration of instigating grazing trials.
Q Pit	• No specific recommendations. Consideration given to utilising this area for trials such as controlled burns.
Jax Dump	• No specific recommendations. Consideration given to utilising this area for trials such as controlled burns.
Drake 5	• Consideration of instigating grazing trials. •
Sonoma Pit	• Weed control measures targeting Parthenium and woody weeds. • Consider the use of controlled burns for weed control and pasture enhancement. • Remediation to be considered for large erosion features in the Sonoma 2010 MU (primarily contouring of eroded banks to allow for further revegetation) and the tunnelling erosion observed in Sonoma 2011 (No Topsoil). • Further investigation of the erosion root causes and the distribution/influence of dispersive soils in this area are needed first to inform remedial works and potentially allow proactive erosion prevention • Incorporate re-seeding, with an appropriate seed mix or respreading of topsoil with a viable seedbank, into the remediation approach for those erosion areas addressed. •

Weed control	• The development of a targeted weed control strategy is recommended for all sites that recorded restricted invasive plants.
	• A particular focus of the strategy should be the timely control of Parthenium targeted management prior to seeding.
	• The program should consider the foliar application of registered herbicides approved by DAF.
	• Pre-emergent herbicides for Parthenium will help to manage the seed bank.
	• Consideration should be given to controlled burns on the Sonoma Pit given its large size and prevalence of weeds such as Parthenium.
	• If controlled burns are utilised, they should be followed up as soon as possible with a broadscale seeding program of desirable pasture species mix that includes an increase in tropical pasture legumes to help improve soil nitrogen levels.
	• Follow-up monitoring/control will be necessary for Parthenium for an extended period of time (up to ten years seed viability in the soil medium).
	• Manual woody weed control to be undertaken to control Chinee Apple, Rubber Vine and Prickly Acacia. Mimosa Bush infestations should also be considered, due to their localised invasive nature. Trees and/or areas of infestation to be GPS located to allow for follow up spraying of seedlings
	• Monitoring of large sites e.g., Sonoma Pit by drone to locate large areas of weed infestation.
	• Sites requiring control of significant weeds include:
	  ○ All of Sonoma Pit MUs
	  ○ B Pit
	  ○ Jax Pit

Aspect	Recommended Actions
Future monitoring events	
Monitoring	• Consideration given to aerial mapping and monitoring using drones. Drone monitoring can also help in the development of a targeted weed control strategy. • Given the uniformity of the B Pit and the Drake 5 rehabilitation, it is suggested that monitoring of these sites can be reduced to a single transect each year with the transect survey rotated through the three existing transects on an annual basis. • MU Sonoma 2011 NT to be surveyed in more detail in the next round of monitoring to ascertain what, if any, remedial action is required. • Incorporate more prescriptive soil health analysis into future soil sampling events. • Biennial soil sampling is recommended in general, unless specific sampling in areas of concern has been suggested.
Reporting	• Reporting, including analysis of data, needs to be uniform and consistent, to facilitate improved year on year comparison. Tabulated information should be provided to QCoal per event. • The soils analysis should include a soil textures component, soil descriptions – but only the first time that soil is tested and then as determined necessary at future 5 – 10 year intervals.

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APPENDIX A: MONITORING SITE LOCATIONS







Table 10: Rehabilitation and reference site labels and locations

Site label	Latitude	Longitude
Sonoma Coal Mine		
Q01	-20.6460	147.8605
Q02	-20.6464	147.8608
V01	-20.6123	147.8388
V02	-20.6095	147.8352
V03	-20.6107	147.8422
V09	-20.6143	147.8386
V10	-20.6217	147.8448
V11	-20.6182	147.8418
V04	20.6106	147.8500
V08	-20.6112	147.8473
V12	-20.6172	147.8430
V13	-20.6160	147.8415
V14	-20.6138	147.8392
V18	-20.6133	147.8419
V31	-20.6108	147.8455
V32	-20.6112	147.8435
V15	-20.6163	147.8443
V16	-20.6152	147.8431
V17	-20.6136	147.8435
V22	-20.6110	147.8524
V23	-20.6104	147.8550
V24	-20.6118	147.8506
V25	-20.6145	147.8438
V26	-20.6144	147.8449
V27	-20.6148	147.8463
V28	20.6147	147.8503
V29	-20.6149	147.8493
V30	-20.6162	147.8473
V05	-20.6098	147.8523
V06	-20.6097	147.8538
V07	-20.6092	147.8551
Sonoma / Cows Coal Mine		
B01	-20.6385	147.8361
B02	-20.6391	147.8378
B03	-20.6389	147.8396
Jax Coal Mine		
J01	-20.7126	147.8599
Drake Coal Mine		
D01	-20.7008	147.8047

Site label	Latitude	Longitude
D02	-20.7021	147.8037
D03	-20.7034	147.8032
Reference Sites		
REF 01	-20.607080	147.838604
REF 02	-20.608446	147.837108
REF 03	-20.610162	147.830965
REF 04	-20.625502	147.835417

Coordinates identify the start of the transect.

APPENDIX B: PHOTO MONITORING









Photo 1:
Site B01- Transect



Photo 2:
Site B01 - North



Photo 3:
Site B01-South



Photo 4:
Site B01-East



Photo 5:
Site B01- West



Photo 6:
Site B01- D1



Photo 7:
Site B01- D2



Photo 8:
Site B01-Q1

Site B01

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Photo 9:
Site B02- Transect



Photo 10:
Site B02 - North



Photo 11:
Site B02- South



Photo 12:
Site B02-East



Photo 13:
Site B02- West



Photo 14:
Site B02-West



Photo 15:
Site B02-D1



Photo 16:
Site B02-Q1

Site B02

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Photo 17:
Site B03- Transect



Photo 18:
Site B03 - North



Photo 19:
Site B03-South



Photo 20:
Site B03-East



Photo 21:
Site B03- West



Photo 22:
Site B03- D1



Photo 23:
Site B03- D2



Photo 24:
Site B03-Q1

Site B03

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Photo 25:
Site D01- Transect



Photo 26:
Site D01 - North



Photo 27:
Site D01- South



Photo 28:
Site D01-East



Photo 29:
Site D01- West



Photo 30:
Site D01- D1



Photo 31:
Site D01- D2



Photo 32:
Site D01-Q1

Site D01

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Photo 33:
Site D02- Transect



Photo 34:
Site D02- North



Photo 35:
Site D02-South



Photo 36:
Site D02-East



Photo 37:
Site D02- West



Photo 38:
Site D02- D1



Photo 39:
Site D02-D2



Photo 40:
Site D02-Q1

Site D02

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Photo 41:
Site D03- Transect



Photo 42:
Site D03- North



Photo 43:
Site D03-South



Photo 44:
Site D03-East



Photo 45:
Site D03-West



Photo 46:
Site D03-D1



Photo 47:
Site D03-D2



Photo 48:
Site D03- Q1

Site D03

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Photo 49:
Site J01- Transect



Photo 50:
Site J01- North



Photo 51:
Site J01-South



Photo 52:
Site J01-East



Photo 53:
Site J01- West



Photo 54:
Site J01- D1



Photo 55:
Site J01- D2



Photo 56:
Site J01-Q1

Site J01

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Photo 57:
Site Q01- Transect



Photo 58:
Site Q01 - North



Photo 59:
Site Q01-South



Photo 60:
Site Q01-East



Photo 61:
Site Q01- West



Photo 62:
Site Q01- D1



Photo 63:
Site Q01- D2



Photo 64:
Site Q01-Q1

Site Q01

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Photo 65:
Site Q02- Transect



Photo 66:
Site Q01-- North



Photo 67:
Site Q01-South



Photo 68:
Site Q01-East



Photo 69:
Site Q02-West



Photo 70:
Site Q02-D1



Photo 71:
Site Q02-D2



Photo 72:
Site Q02-Q1

Site Q02

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Photo 73:
Site Reference 1- Transect



Photo 74:
Site Reference 1 - North



Photo 75:
Site Reference 1-South



Photo 76:
Site Reference 1- East



Photo 77:
Site Reference 1- West



Photo 78:
Site Reference 1- D1



Photo 79:
Site Reference 1- D2



Photo 80:
Site Reference 1- Q1

Site REF01

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Photo 81:
Site Reference 2- Transect



Photo 82:
Site Reference 2 - North



Photo 83:
Site Reference 2- South



Photo 84:
Site Reference 2- East



Photo 85:
Site Reference 2- West



Photo 86:
Site Reference 2- D1



Photo 87:
Site Reference 2- D2



Photo 88:
Site Reference 2- Q1

Site REF02

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Photo 89:
Site Reference 3- Transect



Photo 90:
Site Reference 3 - North



Photo 91:
Site Reference 3- South



Photo 92:
Site Reference 3-East



Photo 93:
Site Reference 3- West



Photo 94:
Site Reference 3- D1



Photo 95:
Site Reference 3- D2



Photo 96:
Site Reference 3-Q1

Site REF03

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Photo 97:
Site Reference 4- Transect



Photo 98:
Site Reference 4- North



Photo 99:
Site Reference 4- South



Photo 100:
Site Reference 4- East



Photo 101:
Site Reference 4- West



Photo 102:
Site Reference 4- D1



Photo 103:
Site Reference 4- D2



Photo 104:
Site Reference 4- Q1

Site REF04

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Photo 105:
Site V01- Transect



Photo 106:
Site V01 - North



Photo 107:
Site V01-South



Photo 108:
Site V01-East



Photo 109:
Site V01- West



Photo 110:
Site V01- D1



Photo 111:
Site V01- D2



Photo 112:
Site V02-Q1

Site V01

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Photo 113:
Site V02- Transect



Photo 114:
Site V02 - North



Photo 115:
Site V02-South



Photo 116:
Site V02- East



Photo 117:
Site V02- West



Photo 118:
Site V02- D1



Photo 119:
Site V02-D2



Photo 120:
Site V02-Q1

Site V02

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Photo 121:
Site V03- Transect



Photo 122:
Site V03- North



Photo 123:
Site V03-South



Photo 124:
Site V03- East



Photo 125:
Site V03- West



Photo 126:
Site V03- D1



Photo 127:
Site V03- D2



Photo 128:
Site V03- Q1

Site V03	KLEINFELDER Bright People. Right Solutions.	**Project No: 20220778**	
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Photo 129:
Site V04- Transect



Photo 130:
Site V04- North



Photo 131:
Site V04-South



Photo 132:
Site V04-East



Photo 133:
Site V04-West



Photo 134:
Site V04- D!



Photo 135:
Site V04- D2



Photo 136:
Site V04-Q1

Site V04

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Photo 137:
Site V05- Transect



Photo 138:
Site V05- North



Photo 139:
Site V05-South



Photo 140:
Site V05-East



Photo 141:
Site V05- West



Photo 142:
Site V05- D1



Photo 143:
Site V05- D2



Photo 144:
Site V05-Q1



Photo 145:
Site V06- Transect



Photo 146:
Site V06- North



Photo 147:
Site V06-South



Photo 148:
Site V06-East



Photo 149:
Site V06- West



Photo 150:
Site V06- D1



Photo 151:
Site V06- D2



Photo 152:
Site V06-Q1

Site V06

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Photo 153:
Site V07- Transect



Photo 154:
Site V07 - North



Photo 155:
Site V07-South



Photo 156:
Site V07-East



Photo 157:
Site V07- West



Photo 158:
Site V07- D1



Photo 159:
Site V07- D2



Photo 160:
Site V07-Q1

Site V07

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Photo 161:
Site V08- Transect



Photo 162:
Site V08- North



Photo 163:
Site V08-South



Photo 164:
Site V08-East



Photo 165:
Site V08- West



Photo 166:
Site V08- D1



Photo 167:
Site V08- D2



Photo 168:
Site V08- Q1

Site V08

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Photo 169:
Site V09- Transect



Photo 170:
Site V09- North



Photo 171:
Site V09-South



Photo 172:
Site V09-East



Photo 173:
Site V09- West



Photo 174:
Site V09-D1



Photo 175:
Site V09- D2



Photo 176:
Site V09-Q1

Site V09

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Photo 177:
Site V10- Transect



Photo 178:
Site V10 - North



Photo 179:
Site V10-South



Photo 180:
Site V10-East



Photo 181:
Site V10- West



Photo 182:
Site V10- D1



Photo 183:
Site V10- D2

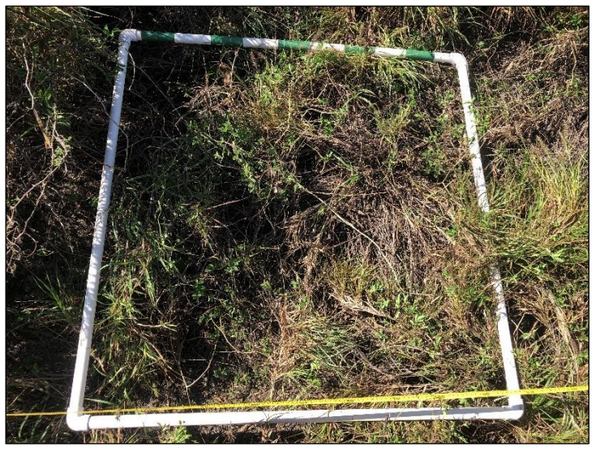


Photo 184:
Site V10-Q1

Site V10

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Photo 185:
Site V11- Transect



Photo 186:
Site V11- North



Photo 187:
Site V11-South



Photo 188:
Site V11-East



Photo 189:
Site V11- West



Photo 190:
Site V11- D1



Photo 191:
Site V11- D2



Photo 192:
Site V11-Q1

Site V11

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Photo 193:
Site V12- Transect



Photo 194:
Site V12- North



Photo 195:
Site V12 -South



Photo 196:
Site V12-East



Photo 197:
Site V12- West



Photo 198:
Site V12- D1



Photo 199:
Site V12- D2



Photo 200:
Site V12-Q1

Site V12	KLEINFELDER Bright People. Right Solutions.	**Project No: 20220778**	
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Photo 201:
Site V13- Transect



Photo 202:
Site V13- North



Photo 203:
Site V13-South



Photo 204:
Site V13-East



Photo 205:
Site V13- West



Photo 206:
Site V13- D1



Photo 207:
Site V13- D2



Photo 208:
Site V13-Q1

Site V13

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Photo 209:
Site V14- Transect



Photo 210:
Site V14- North



Photo 211:
Site V14-South



Photo 212:
Site V14-East



Photo 213:
Site V14- West



Photo 214:
Site V14- D1



Photo 215:
Site V14- D2



Photo 216:
Site V14- Q1

Site V14

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Photo 217:
Site V15- Transect



Photo 218:
Site V15- North



Photo 219:
Site V15-South



Photo 220:
Site V15-East



Photo 221:
Site V15- West



Photo 222:
Site V15- D1



Photo 223:
Site V15- D2



Photo 224:
Site V15-Q1

Site V15

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Photo 225:
Site V16- Transect



Photo 226:
Site V16- North



Photo 227:
Site V16-South



Photo 228:
Site V16-East



Photo 229:
Site V16- West



Photo 230:
Site V16- D1



Photo 231:
Site V16- D2



Photo 232:
Site V16-Q1

Site V16	KLEINFELDER Bright People. Right Solutions.	**Project No: 20220778**	
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Photo 233:
Site V17- Transect



Photo 234:
Site V17- North



Photo 235:
Site V17-South



Photo 236:
Site V17-East



Photo 237:
Site V17- West



Photo 238:
Site V17- D1



Photo 239:
Site V17- D2

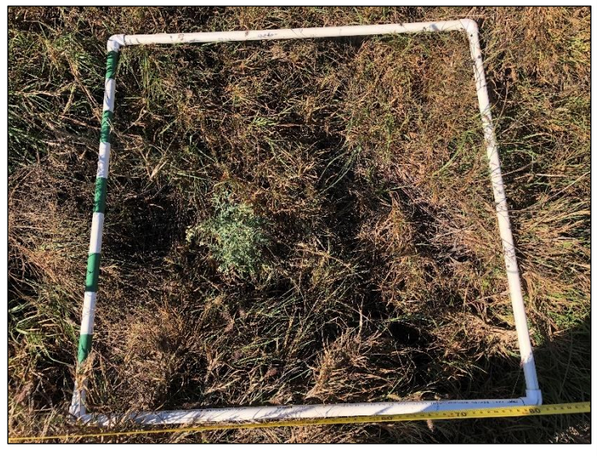


Photo 240:
Site V17-Q1

Site V17

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Photo 241:
Site V18- Transect



Photo 242:
Site V18- North



Photo 243:
Site V18-South



Photo 244:
Site V18-East



Photo 245:
Site V18- West



Photo 246:
Site V18- D1



Photo 247:
Site V18- D2



Photo 248:
Site V18- Q1

Site V18

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Photo 249:
Site V22- Transect



Photo 250:
Site V22- North



Photo 251:
Site V22-South



Photo 252:
Site V22-East



Photo 253:
Site V22- West



Photo 254:
Site V22- D1



Photo 255:
Site V22- D2



Photo 256:
Site V22-Q1

Site V22

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Photo 257:
Site V23- Transect



Photo 258:
Site V23- North



Photo 259:
Site V23-South



Photo 260:
Site V23-East



Photo 261:
Site V23- West



Photo 262:
Site V23- D1



Photo 263:
Site V23- D2

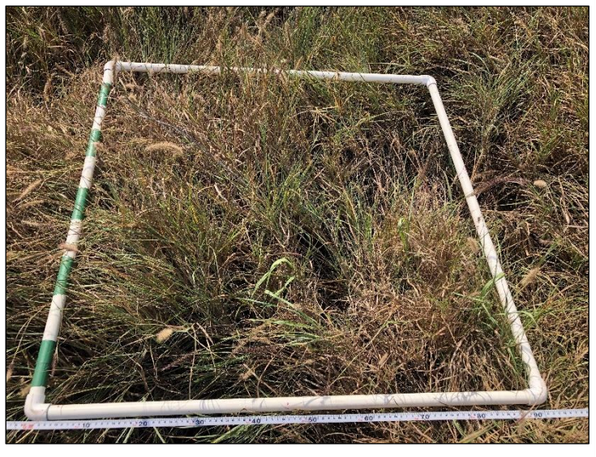


Photo 264:
Site V23-Q1

Site V23

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Photo 265:
Site V24- Transect



Photo 266:
Site V24- North



Photo 267:
Site V24- South



Photo 268:
Site V24- East



Photo 269:
Site V24- West



Photo 270:
Site V24- D1



Photo 271:
Site V24- D2

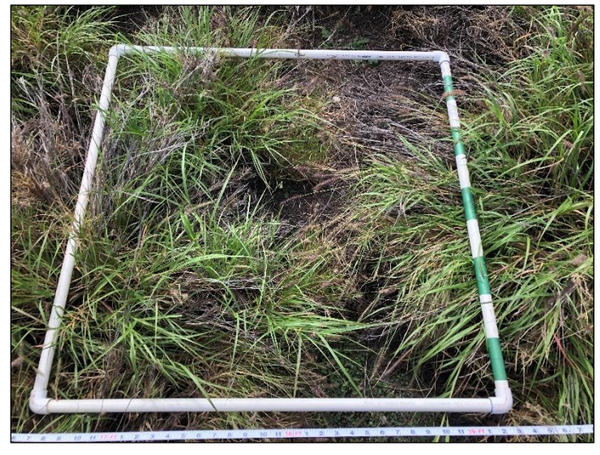


Photo 272:
Site V24- Q1

Site V24

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Photo 273:
Site V25- Transect



Photo 274:
Site V25- North



Photo 275:
Site V25- South



Photo 276:
Site V25- East



Photo 277:
Site V25- West



Photo 278:
Site V25- D1



Photo 279:
Site V25- D2



Photo 280:
Site V25- Q1

Site V25

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Photo 281:
Site V26- Transect



Photo 282:
Site V26- North



Photo 283:
Site V26- South



Photo 284:
Site V26- East



Photo 285:
Site V26- West



Photo 286:
Site V26- D1



Photo 287:
Site V26- D2



Photo 288:
Site V26- Q1

Site V26

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Photo 289:
Site V27- Transect



Photo 290:
Site V27- North



Photo 291:
Site V27- South



Photo 292:
Site V27- East



Photo 293:
Site V27- West



Photo 294:
Site V27- D1



Photo 295:
Site V27- D2

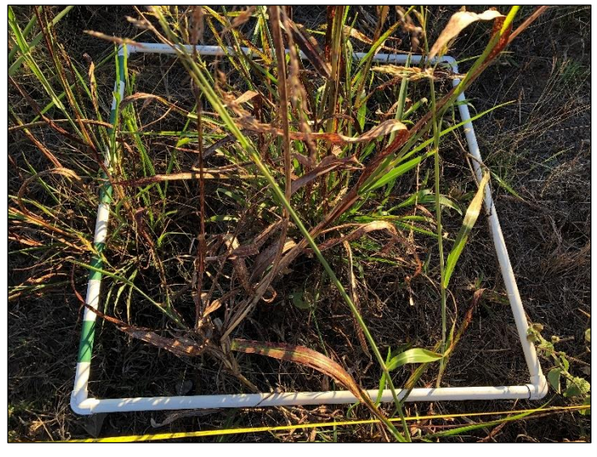


Photo 296:
Site V27- Q1

Site V27	KLEINFELDER Bright People. Right Solutions.	**Project No: 20220778**	
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		10/156 Boundary Street, West End, QLD 4104	**Site Photos**
		Phone +61 7 4957 5036	



Photo 297:
Site V28- Transect



Photo 298:
Site V28- North



Photo 299:
Site V28- South



Photo 300:
Site V28- East



Photo 301:
Site V28- West



Photo 302:
Site V28- D1



Photo 303:
Site V28- D2



Photo 304:
Site V28- Q1

Site V28

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Photo 305:
Site V29- Transect



Photo 306:
Site V29- North



Photo 307:
Site V29- South



Photo 308:
Site V29- East



Photo 309:
Site V29- West



Photo 310:
Site V29- D1



Photo 311:
Site V29- D2



Photo 312:
Site V29- Q1

Site V29

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Photo 313:
Site V30- Transect



Photo 314:
Site V30- North



Photo 315:
Site V30- South



Photo 316:
Site V30- East



Photo 317:
Site V30- West



Photo 318:
Site V30- D1



Photo 319:
Site V30- D2



Photo 320:
Site V30- Q1

Site V30

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Photo 321
Site V31- Transect



Photo 322:
Site V31- North



Photo 323:
Site V31- South



Photo 324:
Site V31- East



Photo 325:
Site V31- West



Photo 326:
Site V31- D1



Photo 327:
Site V31- D2



Photo 328:
Site V31- Q1

Site V31

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Project No: 20220778	
Date: 27/08/2021	QCoal Pty Ltd
10/156 Boundary Street, West End, QLD 4104	Site Photos
Phone +61 7 4957 5036	



Photo 329:
Site V32- Transect



Photo 330:
Site V32- North



Photo 331:
Site V32- South



Photo 332:
Site V32- East



Photo 333:
Site V32- West



Photo 334:
Site V32- D1



Photo 335:
Site V32- D2



Photo 336:
Site V32- Q1

Site V32	KLEINFELDER Bright People. Right Solutions.	**Project No: 20220778**	
		Date: 27/08/2021	**QCoal Pty Ltd**
		10/156 Boundary Street, West End, QLD 4104	**Site Photos**
		Phone +61 7 4957 5036	

APPENDIX C: FAUNA OBSERVATIONS







Table 11: Fauna interaction list

Class	Common Name	Scientific Name	Comments
Aves	Sulphur Crested Cockatoo	*Cacatua galerita*	
Aves	Australian White Ibis	*Threskiornis moluccus*	
Aves	Torresian Crow	*Corvus orru*	
Aves	Black Shouldered Kite	*Elanus axillaris*	
Aves	Willie Wagtail	*Rhipidura leucophrys*	
Aves	Australian Magpie	*Gymnorhina tibicen*	
Aves	Black Kite	*Milvus migrans*	
Aves	Crested Pigeon	*Ocyphaps lophotes*	
Aves	Brolga	*Grus rubicunda*	
Aves	Square-tailed Kite	*Lophoictinia isura*	
Aves	Peregrine Falcon	*Falco peregrinus*	
Aves	Nankeen Kestrel	*Falco cenchroides*	
Aves	Pied Butcherbird	*Cracticus nigrogularis*	
Aves	Magpie-lark	*Grallina cyanoleuca*	
Aves	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	
Aves	Pale-headed Rosella	*Platycercus adscitus*	
Aves	Doubled-barred Finch	*Taeniopygia bichenovii*	
Aves	Rufous Songlark	*Cincloramphus mathewsi*	
Aves	Wedge-tailed Eagle	*Aquila audax*	
Aves	Brown Falcon	*Falco berigora*	
Aves	Rainbow Bee-eater	*Merops ornatus*	
Aves	Welcome Swallow	*Hirundo neoxena*	
Aves	Brown Treecreeper	*Climacteris picumnus*	
Reptilia	Eastern Brown Snake	*Pseudonaja textilis*	
Mammalia (Marsupial)	Eastern Grey Kangaroo	*Macropus giganteus*	
Mammalia (Marsupial)	Swamp Wallaby	*Wallabia bicolor*	
Mammalia (Marsupial)	Rufous Bettong	*Aepyprymnus rufescens*	
Mammalia (Monotreme)	Short-beaked Echidna	*Tachyglossus aculeatus*	Diggings
Mammalia	Deer	*Cervis spp.*	Scats
Mammalia	Pig	*Sus scrofa*	Scats

APPENDIX D: SOIL SAMPLE RESULTS







Table 12: Soil analysis

Analyte Name	Units	Ref 1	Ref 2	B01	B02	D03	JAX	Q01	Q02
pH (CaCl2)	pH Units	5.9	5.8	8.0	7.9	7.9	8.0	7.9	7.9
Conductivity of Extract (1:5 dry sample basis)	mS/cm	0.049	0.029	0.140	0.110	0.170	0.180	0.230	0.160
Chloride (water extractable 1:5)	mg/kg	6	<5	7	10	11	30	<5	<5
Colwell Phosphorus	mg/kg	30	55	16	<1	78	10	5	4
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.75	0.05	1.3	0.13	2.7	1.9	1.0	1.1
Total Organic Carbon	%w/w	1.7	1.2	1.4	1.4	1.1	1.2	1.3	1.2
Exchangeable Sodium, Na	meq/100g	0.29	0.11	2.2	0.78	0.41	2.3	0.82	0.90
Exchangeable Potassium, K	meq/100g	0.54	0.92	0.55	0.60	1.3	0.77	0.89	0.93
Exchangeable Calcium, Ca	meq/100g	9.9	6.0	42	43	35	35	40	40
Exchangeable Magnesium, Mg	meq/100g	7.0	3.2	11	15	5.8	7.9	5.5	5.3
Exchangeable Sodium Percentage	%	1.6	1.1	3.9	1.3	1.0	5.0	1.8	1.9
Cation Exchange Capacity	meq/100g	18	10	56	59	42	46	47	47
Copper, Cu	mg/kg	1.7	0.76	0.64	0.75	0.91	0.90	0.93	0.97
Zinc, Zn	mg/kg	0.54	0.29	0.17	0.23	0.38	0.15	0.11	0.15
Manganese, Mn	mg/kg	28	12	2.7	1.9	3.2	2.4	4.0	3.9
Iron, Fe	mg/kg	62	43	5.6	4.7	6.6	5.5	4.8	4.8
CaCl2-extractable Boron, B	mg/kg	0.53	0.26	1.5	0.96	0.71	1.2	1.4	1.1
KCl-40-extractable Sulphur, S	mg/kg	2	<1	1	2	3	2	1	<1
PBI	No unit	60	29	150	140	86	100	140	140

Analyte Name	Rehab Yr	2010	2011 (No Topsoil)		2011		2012		2013		2014	
	Units	V02	V05	V07	V08	V12	V15	V17	V22	V27	V28	V30
pH (CaCl2)	pH Units	6.6	7.8	8.2	8.0	7.8	7.5	7.8	7.8	7.9	7.9	8.0
Conductivity of Extract (1:5 dry sample basis)	mS/cm	0.063	0.083	0.830	0.170	0.130	0.095	0.180	0.150	0.120	0.160	0.150
Chloride (water extractable 1:5)	mg/kg	<5	<5	920	<5	<5	<5	<5	<5	<5	<5	16
Colwell Phosphorus	mg/kg	51	43	49	65	27	49	58	69	48	25	8
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	1.5	0.21	1.3	5.9	0.82	0.85	3.4	2.5	0.62	0.97	0.73
Total Organic Carbon	%w/w	1.4	2.3	0.53	1.1	1.3	0.99	1.1	1.2	1.1	1.2	0.94
Exchangeable Sodium, Na	meq/100g	0.09	0.07	4.1	0.20	0.26	0.14	0.33	0.09	0.36	1.7	1.9
Exchangeable Potassium, K	meq/100g	1.1	0.38	0.34	0.69	0.80	0.77	1.2	1.4	0.77	0.65	0.58
Exchangeable Calcium, Ca	meq/100g	14	12	13	44	15	11	33	18	18	32	22
Exchangeable Magnesium, Mg	meq/100g	7.8	6.4	10	13	9.1	5.3	7.8	5.3	6.9	12	12
Exchangeable Sodium Percentage	%	0.4	0.4	14.8	0.4	1.1	0.8	0.8	0.4	1.4	3.8	5.2
Cation Exchange Capacity	meq/100g	23	19	28	58	25	18	42	24	26	46	36
Copper, Cu	mg/kg	1.1	1.4	0.66	0.94	0.94	1.0	1.0	0.84	1.2	0.87	0.88
Zinc, Zn	mg/kg	0.71	1.5	1.4	0.27	0.57	0.31	0.24	0.55	0.43	0.16	0.13
Manganese, Mn	mg/kg	7.6	2.1	2.6	3.0	4.9	6.6	2.8	3.0	3.6	2.7	2.2
Iron, Fe	mg/kg	11	7.7	6.3	5.1	8.7	14	6.9	7.4	10	6.5	6.3
CaCl2-extractable Boron, B	mg/kg	0.67	0.18	0.30	1.1	0.78	0.61	0.92	0.67	0.82	0.96	1.2
KCl-40-extractable Sulphur, S	mg/kg	1	4	96	2	3	1	2	1	2	1	2
PBI	No unit	51	67	42	110	66	45	61	47	67	77	89

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ANALYSIS REPORT SOIL

PROJECT NO: EW211213		**Date of Issue:**	**14/09/2021**
Customer:	KLEINFELDER	Report No:	1
Address:	1/95 COVENTRY ST. SOUTH MELBOURNE VIC 3205	Date Received:	2/09/2021
		Matrix:	Soil
Attention:	Nigel Fisher	Location:	
Phone:	0407657583	Sampler ID:	Client
Fax:		Date of Sampling:	26/08/2021
Email:	nfisher@kleinfelder.com	Sample Condition:	Acceptable

Results apply to the samples as submitted. All pages of this report have been checked and approved for release.

Signed:

Stephanie Cameron
Laboratory Operations Manager

ASPAC
PROFICIENT LAB
Visit www.aspac-australasia.com to view our certification details.

East West is certified by the Australian-Asian Soil & Plant Analysis Council to perform various soil and plant tissue analysis. The tests reported herein have been performed in accordance with our terms of accreditation.

This report must not be reproduced except in full and EWEA takes no responsibility of the end use of the results within this report.

This analysis relates to the sample submitted and it is the client's responsibility to make certain the sample is representative of the matrix to be tested.

Samples will be discarded one month after the date of this report. Please advise if you wish to have your sample/s returned.



ANALYSIS REPORT

PROJECT NO: EW211213 Location:

					CLIENT SAMPLE ID	Sample 1 - Reference	Sample 2 - B-Pit	Sample 3 - Drake 5	Sample 4 - Jax Pit
					DEPTH	0-20cm	0-20cm	0-20cm	0-20cm
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**		**211213-1**	**211213-2**	**211213-3**	**211213-4**
PAWC (volumetric)	Shaw & Yule	24.4.1	mm/m	na		119	131	128	128
PAWC (gravimetric)	Shaw & Yule	24.4.1	%	na		9.12	10.1	9.12	9.85
WMAX Field Capacity	Shaw & Yule	24.4.1	%	na		17.5	21.2	18.2	23.2
WMIN Wilting Point	Shaw & Yule	24.4.1	%	na		8.42	11.2	9.03	13.4
Bulk Density	Cylinder	ASTM F 1815-97	g/cm3	na		1.3	1.3	1.4	1.3
Gravel >2.0mm	Sieve	ASTMD422-63	%	na		<0.1	2.6	1.9	7.6
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na		13.0	13.2	14.4	9.7
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na		39.1	26.0	22.1	25.4
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na		7.0	12.9	20.5	16.1
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na		40.9	45.3	41.1	41.2



ANALYSIS REPORT

PROJECT NO: EW211213 Location:

			CLIENT SAMPLE ID		Sample 5 - Q Pit	Sample 6 - Sonoma 2010	Sample 7 - Sonoma 2011 (No Top Soil)	Sample 8 - Sonoma 2011
			DEPTH		0-20cm	0-20cm	0-20cm	0-20cm
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211213-5**	**211213-6**	**211213-7**	**211213-8**
PAWC (volumetric)	Shaw & Yule	24.4.1	mm/m	na	129	115	85.7	108
PAWC (gravimetric)	Shaw & Yule	24.4.1	%	na	9.89	8.18	5.72	8.33
WMAX Field Capacity	Shaw & Yule	24.4.1	%	na	26.9	18.5	13.5	19.7
WMIN Wilting Point	Shaw & Yule	24.4.1	%	na	17.0	10.3	7.79	11.4
Bulk Density	Cylinder	ASTM F 1815-97	g/cm3	na	1.3	1.4	1.5	1.3
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	8.5	1.0	15.1	3.7
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	11.1	17.8	24.0	19.8
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	28.2	29.5	35.3	28.6
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	14.9	20.5	15.5	16.7
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	37.3	31.2	10.1	31.2

ANALYSIS REPORT

PROJECT NO: EW211213 **Location:**

				CLIENT SAMPLE ID	Sample 9 - Sonoma 2012	Sample 10 - Sonoma 2013	Sample 11 - Sonoma 2014	
				DEPTH	0-20cm	0-20cm	0-20cm	
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211213-9**	**211213-10**	**211213-11**	
PAWC (volumetric)	Shaw & Yule	24.4.1	mm/m	na	121	106	154	
PAWC (gravimetric)	Shaw & Yule	24.4.1	%	na	8.62	7.57	11.8	
WMAX Field Capacity	Shaw & Yule	24.4.1	%	na	19.2	18.4	28.9	
WMIN Wilting Point	Shaw & Yule	24.4.1	%	na	10.6	10.8	17.1	
Bulk Density	Cylinder	ASTM F 1815-97	g/cm3	na	1.4	1.4	1.3	
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	1.0	7.6	1.6	
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	16.7	20.0	7.7	
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	32.9	31.3	26.8	
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	15.1	15.6	14.2	
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	34.3	25.5	49.7	

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Soils are air dried at 40^{o}C and ground <2mm.

NB: LOR is the Lowest Obtainable Reading.

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