

TEC COAL PTY LTD

Environmental Investigation Report – Meandu Mine

14 SEPTEMBER 2018



Environmental Investigation Report Meandu Mine

TEC Coal Pty Ltd

WSP

Level 3, Northbank Plaza,

69 Ann Street

Brisbane QLD 4000

GPO Box 2907

Brisbane QLD 4001

Tel: +61 7 3854 6200

Fax: +61 7 3854 6500

wsp.com

REV	DATE	DETAILS
B	11/09/2018	Final

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SUMMARY OF NOTICE REQUIREMENT FINDINGS

S1 BACKGROUND

On 21 December 2016, the former Department of Environment and Heritage Protection (EHP) (now Department of Environment and Science (DES)) issued TEC Coal Pty Ltd with a notice (DES reference CA34208) to conduct or commission an environmental evaluation under Section 326B of the *Environmental Protection Act 1994* (EP Act) (the Notice). TEC Coal Pty Ltd (ABN 55 119 063 900) is the recipient of the Notice. TEC Coal Pty Ltd is a wholly owned subsidiary of Stanwell Corporation Limited (Stanwell). Stanwell is a Queensland Government Owned Corporation under the *Government Owned Corporations Act 1993* and registered under the *Corporations Act 2001*.

The grounds for the environmental evaluation relate to the identification of acid and metalliferous drainage (AMD) at Meandu Mine and the potential for this AMD to cause environmental harm. As the full nature and extent of the AMD was unknown, EHP (now DES) required that an environmental investigation be undertaken to determine whether environmental harm has resulted from AMD at the Meandu Mine. For the purposes of this environmental investigation, the area of interest relates to the surface rights area of Meandu Mine.

AMD was identified as reporting by overland flow to retention dam 7 (RD7) in the retention dam network on the western side of the mine, where it was mixing with other mine affected water. Water from RD7 flows to RD8 where it is either re-used for site purposes or reports to the Meandu Creek Dam via release (compliance) point 3 (CP3). AMD reporting to RD7 is believed to be originating from two closely associated seepage locations:

- 1 Bullgang Corner, located approximately 600 metres (m) south-east of RD7.
- 2 A covered (vegetated) coal rejects area between Ramp 7 and the western side of the North-West A tailings void (North-West A tailings).

To address the requirements of the Notice, Stanwell commissioned an Environmental and Engineering Evaluation into AMD at the Meandu Mine site (environmental investigation). This environmental investigation incorporates studies across of range of technical disciplines and by suitably qualified technical specialists being:

- Mine planning historical and life of mine (future) – Xenith Consulting
- Material classification assessments (geochemical) – RGS Environmental Pty Ltd
- Hydrogeological assessments – JBT Consulting Pty Ltd
- Surface water quality, sediments and aquatic ecology investigations – Ecological Service Professionals Pty Ltd
- Water modelling and development of engineering solutions – Golder Associates Pty Ltd.

S1.1 PURPOSE OF THIS DOCUMENT

The methodology and findings of the studies undertaken to determine the source, extent and potential environmental harm from AMD at the Meandu Mine are outlined in the Environmental Investigation Report and associated technical appendices. These documents have been prepared to address the requirements of the Notice. Proposed monitoring and management measures to mitigate potential environmental impacts associated with AMD are also identified and discussed. This Summary of Notice Requirement Findings has been prepared to provide an overview of the key findings and management recommendations and to outline how each of the individual requirements of the Notice have been addressed. This Summary of Notice Requirement Findings should be read in conjunction with the Environmental Investigation Report and associated technical reports (Appendix D through to Appendix H).

S1.2 KEY FINDINGS FROM THIS ENVIRONMENTAL INVESTIGATION

Based on the environmental investigation undertaken in response to the Notice, there is no evidence of negative impacts to the environmental values of Meandu Creek as a result of AMD from Meandu Mine.

Overall, aquatic ecological communities in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam. Aquatic flora and fauna communities in Meandu Creek downstream of Meandu Creek Dam were in a similar or better condition than would be expected in the broader catchment. The perennial flow regime, resulting from the consistent releases from Meandu Creek Dam, allows for stable and diverse aquatic habitats to occur, which in turn are colonised by a diverse range of macroinvertebrates (including some sensitive and very sensitive taxa), along with aquatic plants, fish and turtles, where habitat is suitable. This confirms that the quality of water released from Meandu Creek Dam, and the sediment quality of the receiving environment, is suitable for protecting the downstream aquatic ecosystem.

Future potential impacts on the environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine are considered unlikely given:

- The information presented in this environmental investigation shows there is no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment.
- The static and kinetic geochemical data combined with the geological model, overburden model and material balances, site-based evaluations and the long-term water quality data, indicate that the potential for acidic drainage to be produced in pits is very low or unlikely (other than from the North-West Backfilled Pit).
- The geochemical characterisation, based on over 14 months data of kinetic leach column testing, established that the AMD issues at Meandu Mine are considered relatively minor and able to be managed through the implementation of changes to mining and the placement of mined materials.
- The commitment to continuation of monitoring measures as outlined in the Environmental Investigation Report.
- The continuation of current management measures along with the implementation of future actions as identified from this environmental investigation.

As a result of the identification of AMD issues at the North-West Backfilled Pit, Stanwell has implemented controls and made a number of infrastructure and mine planning management changes since 2015/2016. These have included:

- initial changes to water management infrastructure
- construction of seepage collection dam RD27, automated lime-dosing and pump and pipework
- installation of solid bowl centrifuges at the coal handling and preparation plant (CHPP) to dewater tailings
- changes to rejects placement
- rehabilitation design changes.

These current management measures which commenced in 2015/2016, have been included in the Integrated Water Model developed for this environmental investigation.

In addition to the controls listed above, Section S7.4.2 of this Summary of Notice Requirement Findings outlines recommendations for ongoing and future management measures as an outcome of this environmental investigation. Some of these recommendations relate to the continuation of existing management measures as summarised below:

- Rejects material placement: with actions focusing on limiting storage exposure time of coarse reject materials, combining rejects and tailings streams and placement of reject materials approximately 6 m beneath the final landform profile.
- Material testing: with actions focusing on ongoing independent geochemical assessment.
- Application of water modelling as a predictive tool: actions to inform optimisation of site water management.

The recommendations for future actions from Section S7.4.2 of this Summary of Notice Requirement Findings are:

- Implementation of dewatering program using installed dewatering system bores (GW48, GW49) in the North-West Backfilled Pit to reduce the water level in the pit to well below the spill elevation for diffuse and resurgent seepage (approximately RL432 mAHD in the western area (Ramp 7) and approximately RL435 mAHD in the area where the North-West Backfilled Pit spills to Bullgang Corner). The predictive model shows that by 2037, if two bores are used for dewatering the water level may be reduced more than 8 m below the diffuse seepage spill point (RL432 mAHD). This reduction is predicted to be in the order of 1,9 m if one bore is used.
- Based on the outcome of the dewatering program, additional improvements to the cover thickness of Rejects Storage Area 1 (RSA1) may need to be considered.
- Continued verification to improve the reliability of modelling predictions, such as, monitoring of water use in the coal handling and preparation plant (CHPP) following installation of solid bowl centrifuge and water quality monitoring of water stored in pits.
- Establishment of groundwater bore(s) to the west of Meandu Creek to monitor the high electrical conductivity recorded at GW78 and to validate data from geophysics investigations.
- Update of the current Meandu Creek Receiving Environment Monitoring Program (REMP) to include key indicators for AMD (i.e. iron and manganese).
- Additional monitoring (i.e. toxicity and bioaccumulation) in sediment at CM2 (in the channel between CP3 and the Meandu Creek Dam) to determine the acute or chronic toxicity of sediment and understand the potential for impacts to downstream reaches. Site CM2 has abundant reeds and fine sediments, and appears to be effectively trapping metals and reducing transportation further downstream to the receiving environment. While there is no evidence of impacts to the environmental values of Meandu Creek under current water conditions, under certain conditions (e.g. low pH and/ or low water hardness), metals in sediment could be mobilised and transported further downstream. It should be noted that where pH and electrical conductivity continue to be monitored and managed to remain within acceptable range, as required by current Environmental Authority (EA) (EPML00709113) water contaminant limits for compliance point CP1, and CP3 respectively, the release of sediment bound contaminants to the water column is not expected to occur.

While no recommendations for closure are identified as an outcome of this environmental investigation, it is acknowledged that the Mineral and Energy Resources (Financial Provisioning) Bill 2018, if passed, will require a Progressive Rehabilitation and Closure Plan. The overall findings from this environmental investigation will inform the Rehabilitation Planning Part of the new Progressive Rehabilitation and Closure Plan for Meandu Mine.

With the implementation of the recommendations from this environmental investigation (Section S7.4.2 of this Summary of Notice Requirement Findings) and continued compliance with current EA water quality limits (both Meandu Mine and Tarong and Tarong North power stations), future impacts on environmental values of surface water (Meandu Creek) are considered unlikely.

S2 REQUIREMENT B1

NOTICE REQUIREMENT B1	SUMMARY REFERENCE	EIR REFERENCE	SPECIALIST REPORT
<i>An appropriately qualified person(s) as defined in this notice must provide background and baseline information for the coal mining activity relevant to the environmental investigation including:</i>			
— <i>a description of Meandu Mine (ML6674) operations and a brief history of operations on Meandu Mine; and</i>	Section S2.1	Section 2	
— <i>a (dedicated) site plan showing the location of key features of the Meandu Mine; and</i>	Figure 2	Figure 1.1a Figure 1.1b	N/a
— <i>a summary of water quality data relevant to the investigation; and</i>	Section S2.2.1	Section 7	Appendix D
— <i>a summary of geochemical data relevant to the investigation; and</i>	Section S2.2.2	Section 3	Appendix E
— <i>a (dedicated) topographic map of the Meandu Mine; and</i>	Figure 3	Figure 6.1	N/a
— <i>a brief history and overview of the AMD at the site (from first known (historic) indicators to current awareness</i>	Section S2.4	Section 1	Appendix E

S2.1 MEANDU MINE – SITE DESCRIPTION AND OVERVIEW OF OPERATIONS

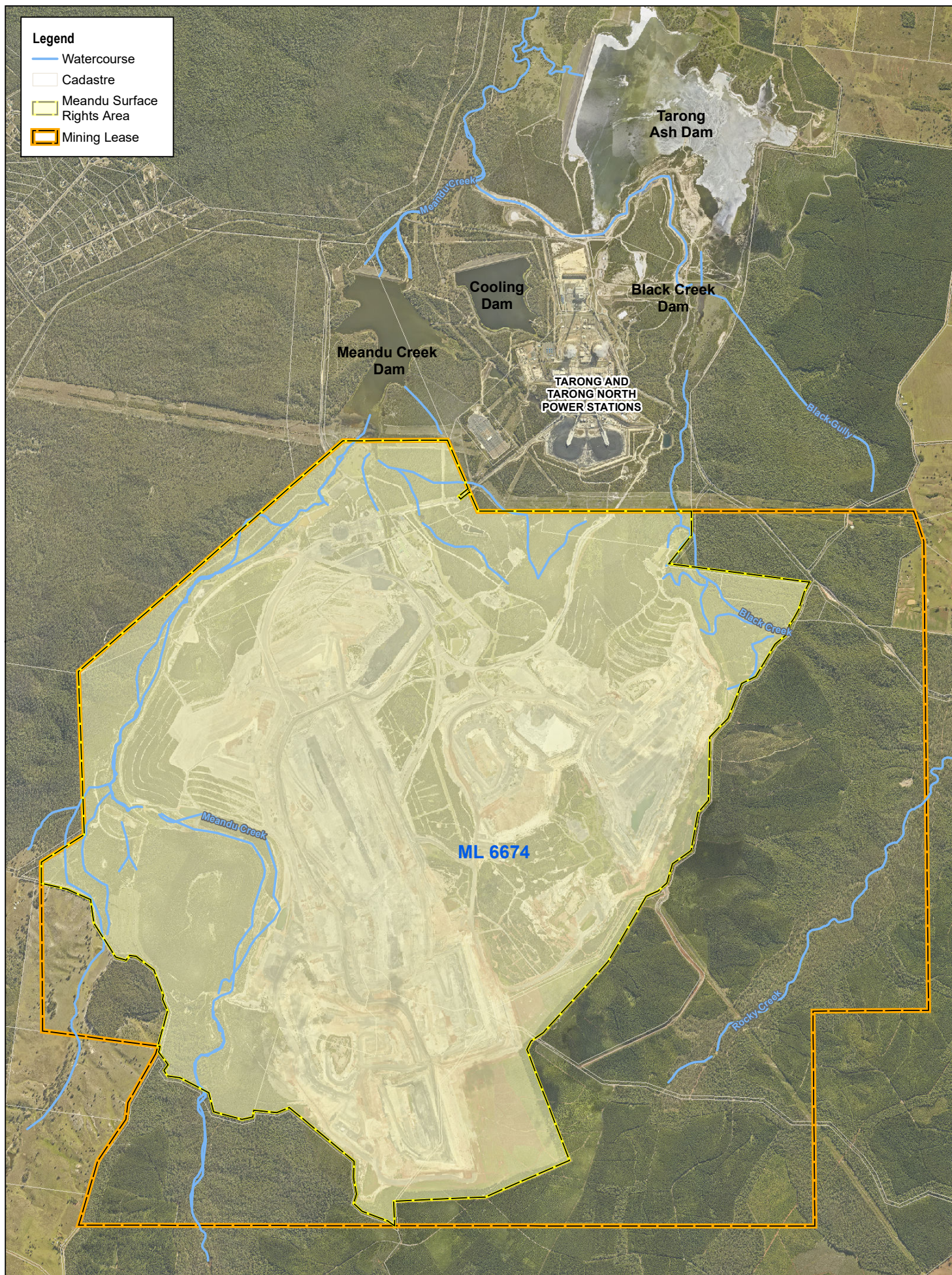
The Meandu Mine is an open-cut coal mine located in Queensland's South Burnett region, approximately 150 kilometres (km) north-west of Brisbane, 14 km south-west of Nanango and 1.5 km to the south of the Tarong and Tarong North power stations.

The nearest town to the mine site is Yarraman, which is located approximately 4 km south-southeast of the Mining Lease (ML) area and approximately 6 km from mining activities. The Meandu Mine supplies black thermal coal only to the Tarong and Tarong North power stations.

The Meandu Mine is located wholly within ML6674. ML6674 occupies an area of 4,267 hectares (ha) within both the South Burnett Regional Council and Toowoomba Regional Council local government areas. TEC Coal currently holds surface rights for 2,638.4 ha of ML6674, most of which is located within the South Burnett Regional Council local government area. The location of ML6674 and existing surface rights area is shown on Figure 1.

Mining at Meandu Mine commenced in 1983 for the purposes of supplying coal to the Tarong Power Station and subsequently the Tarong North Power Station in 2003. The history of Meandu Mine extends back to 1967, when Rio Tinto Coal took out an authority to prospect in the Tarong area near the town of Yarraman. Drilling in subsequent years showed steaming coal occurring at substantial thicknesses, indicating the likelihood of a sufficient coal resource to support power generation.

Ownership of the mine was assumed by Tarong Energy in early 2008. Following a restructure of Queensland Government owned generators, ownership of Meandu Mine was transferred to Stanwell from Tarong Energy in July 2011. TEC Coal Pty Ltd contracts all mining services at the Meandu Mine to a mining contractor. Between 2008 and 2012 this was Thiess Mining Services Pty Ltd. From 2013 mining services have been contracted to Downer EDI Mining Pty Ltd.



Map: PS102396_FigB_LeaseArea_r1v5
 Date: 6/09/2018
 Data source: © State of Queensland (Department of Natural Resources and Mines) 2017.

Author: NK/HC
 Approved by: AOK



0 430 860 m
 1:30,000
 Coordinate system: AGD 1984 AMG Zone 56
 Scale ratio correct when printed at A3



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Figure 1 Meandu Mine lease boundary and surface rights area

All mining operations at Meandu Mine occur within the surface rights area of ML6674 and under EA (EPML00709113). Mining operations currently advance the existing Central; Ramp 5; King 4 East (K4E); and King 4 South (K4S) pits. Waste rock material is moved by dragline and excavator/haul truck fleets to in-pit or ex-pit overburden dumps, appropriate to the mine plan and mining location. Coarse rejects are stockpiled at the CHPP before being trucked to the current rejects dump locations. Since late 2015, all rejects materials are dumped at least 6 m beneath the final landform profile to ensure adequate capping can be constructed over the top of the rejects.

Figure 2a and Figure 2b shows the Meandu Mine site and key areas of interest relevant to this Notice response.

S2.2 DATA RELEVANT TO THIS INVESTIGATION

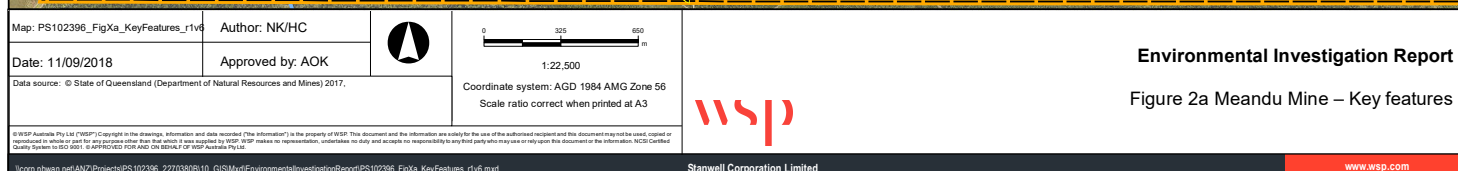
S2.2.1 WATER QUALITY DATA

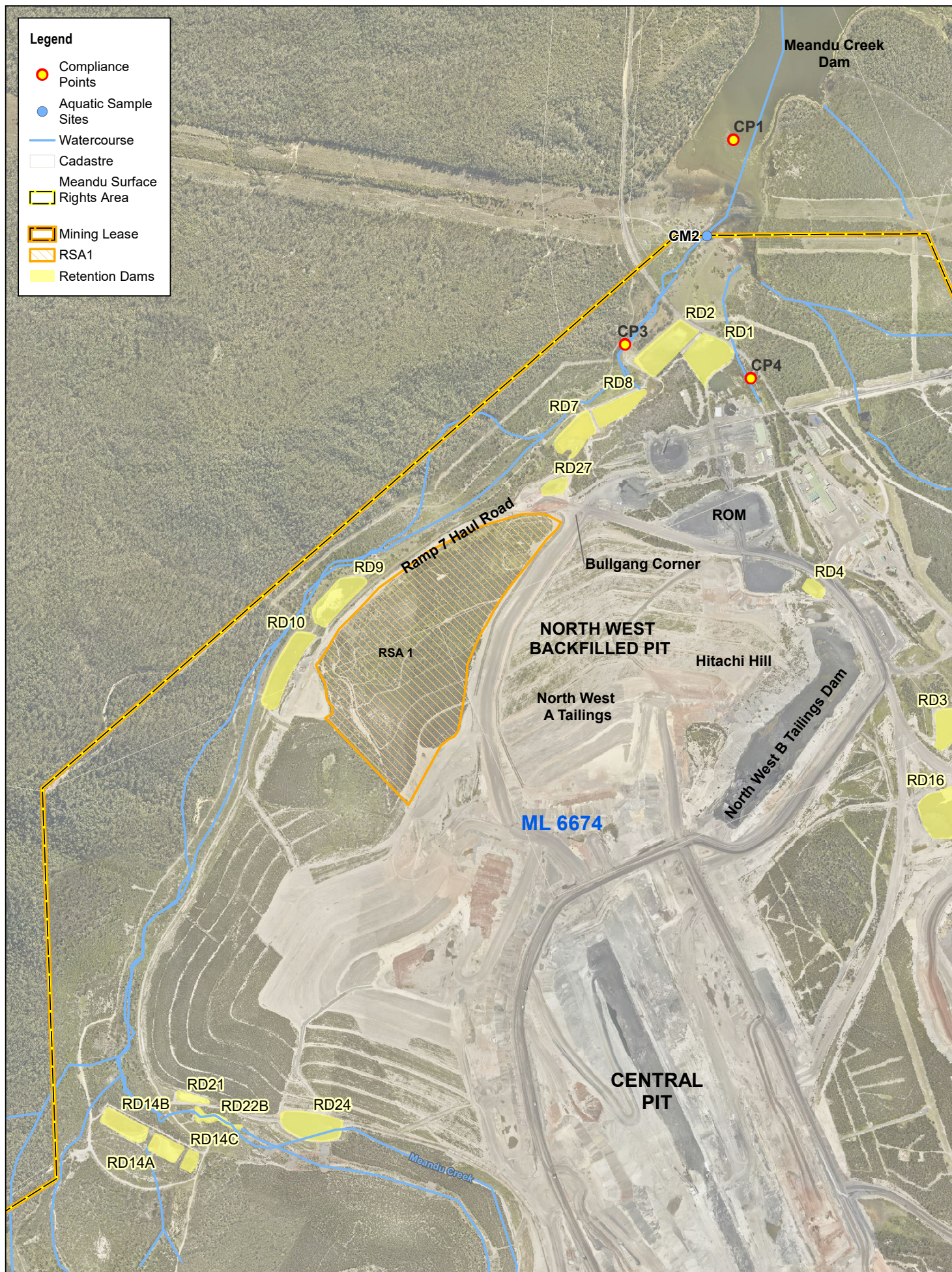
Surface water quality monitoring has been undertaken at Meandu Mine since 1978. Water quality has been monitored at numerous locations throughout the mine water management system and in Meandu Creek, as well as in groundwater bores. The Meandu Mine EA (EPML00709113) specifies compliance points for surface water quality monitoring.

A comprehensive groundwater monitoring bore network exists around Meandu Mine designed to detect any potential impacts. This includes bores located at strategic points downstream of mine operations and the King 2 West (K2W)/King 2 North (K2N) ash disposal facility (K2W/N). The groundwater bore network has been developed on an ongoing basis since 1993. Bores are monitored quarterly by an independent contractor and samples analysed by a NATA-accredited laboratory.

In addition, Stanwell also undertakes surface water quality monitoring to satisfy conditions of EA (EPPR00971913) for the Tarong and Tarong North power stations. This monitoring is undertaken in accordance with the Meandu Creek REMP (previously known as the Meandu Creek Monitoring Protocol). The REMP outlines the sampling requirements (i.e. locations, frequency of monitoring, parameters to be monitored, methods for sampling) for groundwater, surface water, sediment quality and aquatic biota in Meandu Creek downstream of Meandu Creek Dam (and including Meandu Creek Dam).

Water quality sampling data from both the Meandu Mine and Tarong and Tarong North power stations monitoring programs (October 1978 to August 2017) supplied by Stanwell was assessed as part of this investigation.





Map: PS102396_FigXb_KeyFeatures_r1v6

Author: NK/HC

Date: 6/09/2018

Approved by: AOK

Data source: © State of Queensland (Department of Natural Resources and Mines) 2017.



0 180 360
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Coordinate system: AGD 1984 AMG Zone 56

Scale ratio correct when printed at A3



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Figure 2b Meandu Mine – Key features (inset)

S2.2.2 GEOCHEMISTRY DATA

Since 1990, a number of studies have been undertaken relating to the geochemical characterisation of materials from the Meandu Mine. RGS was engaged by Stanwell in 2015 to provide a review of the historical information relating to material classification, establish a characterisation program, and to in-fill data from the previous drilling programs. The program developed by RGS used diamond drill core, reverse circulation drill chips and bulk samples from test pits and included:

- Monthly static CHPP rejects and tailing analysis to track the variability in the chemical parameters and elements in these process waste materials over a 12-month period.
- Sampling of Hitachi Hill rejects from a 4.5 ha rejects area that was being reprofiled to fit into the landform design for Hitachi Hill.
- Rapid screening program (pH and electrical conductivity) of spoil from Central and Ramp 5 pits using existing drill chips which ranged in age from 10 to 20 years.
- Completion of additional indicative non-acid-forming (NAF) and potential acid-forming (PAF) tests on spoil material from Central and Ramp 5 pits using samples from 9 test pits.
- Hitachi Hill soil cover verification program using 9 test pits.
- Ramp 7 seepage test pits.
- Establishment of a kinetic leach column (KLC) program using samples obtained from the K4E Pit for coarse-grade reject samples, fine-grade rejects collected from the CHPP belt, tailings from the CHPP underflow thickener, ash from the K2N ash pit and overburden samples from drill core samples collected from K2E. The samples were evaluated as individual samples and in a variety of mixtures to simulate potential management strategies including co-disposal and the addition of agricultural lime. The KLC program has been ongoing for more than 14 months. Leach cycles are conducted monthly.

An AMD database was developed by RGS for this environmental investigation, which applied historical data points (EGi 2016) and data gained from this environmental investigation. The database includes:

- overburden, interburden and process wastes such as rejects, tailings and ash
- mine domains (including the CHPP)
- mined lithological units.

S2.3 LAND USE AND TOPOGRAPHY

Meandu Mine is located within a rural area where land use is characterised by mining, power generation, forestry, grazing, cropping, and remnant and regrowth vegetation. Immediately to the east and south of the Meandu Mine is the Yarraman State Forest, which is characterised by Hoop Pine plantation interspersed with remnant vegetation. Tarong National Park lies to the west of the Meandu Mine site. There are also swathes of privately owned remnant and regrowth vegetation adjacent to the north-western side of the mine. To the north of the mine are the Tarong and Tarong North power stations (owned and operated by Stanwell) and the Tarong State Forest.

The average altitude of the area surrounding the Meandu Mine is approximately 480 m. The region is predominantly undulating hills of low relief, characterised by steep upper slopes and gentle summits and ridges. These hills are spurs of the Cooyar Range (altitude 600 m), to the south-east of the mining area. Flat-lying basalt flows and associated sediments form the generally subdued scarp of the Cooyar Range. Remnants of sandstones and conglomerates of the coal measures form isolated knobs and subdued hill scarps.

The topography of the mine itself has been altered significantly by mining operations. The topography of the Meandu Mine (based on current operations) is shown in Figure 3.



Map: PS102396_Figxx_MineCont_r1v2

Author: NK/HC

Date: 11/09/2018

Approved by: AOK

Data source: © State of Queensland (Department of Natural Resources and Mines) 2017.



0 325 650
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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3



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Figure 3 Topographic map of Meandu Mine

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S2.4 HISTORY AND OVERVIEW OF AMD AT MEANDU MINE

RGS has undertaken an investigation into the history and occurrence of AMD at Meandu Mine. A summary of events leading up to the identification of AMD at the Meandu Mine based on that investigation, as well as the understanding of AMD at Meandu Mine at the time the Notice was issued in December 2016, is outlined below.

Operations at Meandu Mine commenced in 1984 in the King 1 (K1) and King 2 (K2) open pits and then in the North-West A Pit. Tailings were initially placed into in-pit cells in the North-West A Pit and then into a valley fill tailings dam in the Black Creek catchment (the K2 tailings storage facility (K2 TSF)). Coal rejects were initially placed into small cells and then into RSA1 to the west of the North-West A Pit. Rejects from the CHPP were hauled from the reject stockpile and placed into RSA1. RSA1 was initially constructed on top of natural ground that allows surface runoff and seepage to report onto Ramp 7 haul road, into RD7 and into the upper ephemeral area of Meandu Creek. When the storage capacity on natural ground at RSA1 was reached, spoil and rejects were subsequently placed in-pit at North-West A.

In 1995 a period of above average rainfall events led to an acidic drainage event from RSA1. The pH of the seepage from RSA1 was approximately pH 3 to 3.5, with a measured acidity of 1,530 mg/L, and elevated concentrations of iron and zinc. Following this event, analysis of the water quality data from RD7 (and RD8) verified that acidic water was (mostly) associated with above average rainfall events. Given that pit water quality at that time was mostly circum-neutral it is likely that the acid events recorded in RD7 and RD8 were other seepage events from RSA1.

The North-West B Pit was opened after North-West A had been mined. North-West A was then used to store spoil, rejects and tailings until December 2005. As tailings were placed into North-West A tailings storage facility (TSF), water within the tailings percolated into the adjacent spoil and rejects within the mined open pit. In about 2005, tailings placement in North-West A ceased and rehabilitation commenced in 2008 by placing spoil and rejects on top of the tailings. Due to low geotechnical stability and overloading, the tailings were displaced vertically by some 50 m over about 3 years. From 2005 to December 2017 tailings were placed into North-West B TSF and water from the tailings continued percolating into adjacent spoil and into unsaturated spoil and rejects in North-West A.

In mid-2013 seepage from RSA1 rejects storage area was noted and this water was subsequently identified as AMD and attributed to water seeping from the backfilled North-West A Pit. The seepage continued at about 2 megalitres (ML) per day at two seepage locations known as Ramp 7 and Bullgang Corner (note: based on 2016 data this seepage rate was on average 1.3 ML/day). Initially the AMD seepage at these two locations was attributed to porewater being squeezed directly from the tailings and expressed at the lowest point of the old North-West pit shell (through the spoil). Based on further understanding of the mechanisms for seepage from the North-West Backfilled Pit and the result of static and kinetic leach testing of tailings, RGS now considers this theory to be incorrect. RGS expects that even though the tailings were displaced vertically, their inherent fine-grained, plastic texture and ability to retain moisture meant they would maintain a high moisture content, reducing their potential for oxidation and generation of AMD.

As part of the investigation undertaken into the history and occurrence of AMD at Meandu Mine, RGS has determined that the most probable cause of the historic AMD and ongoing AMD from the North-West Backfilled Pit was oxidation of the sulfide minerals, and subsequent leaching of the AMD weathering products from the rejects stored in RSA1.

At RSA1, aerial imagery and the shape of the landform suggests that the rejects were end-tipped then pushed by dozer during construction and it is probable that the rejects were left exposed to atmospheric conditions for an extended time-period (months and possibly even years). This extended exposure is likely to have contributed to the production of AMD. Occurrences of AMD from RSA1 may not have been readily observed during operations until there was sufficient rain from a large or prolonged rainfall event to wash them onto the Ramp 7 haul road, or into the North-West A Pit, or later, into the spoil and rejects in the North-West A backfilled pit.

The recognition that AMD was occurring on-site resulted in EHP issuing TEC Coal Pty Ltd with the December 2016 Notice to conduct or commission an environmental evaluation into AMD at the Meandu Mine.

S3 REQUIREMENT B2

NOTICE REQUIREMENT B2	SUMMARY REFERENCE	EIR REFERENCE	SPECIALIST REPORT
<i>An appropriately qualified person(s) as defined in this notice must identify and characterise the environmental values that may be impacted by AMD from Meandu Mine.</i> <i>This characterisation must include land and groundwater environmental values that may be impacted by AMD from Meandu Mine.</i> <i>The characterisation of Meandu Creek must:</i>			
— identify any Environmental Values (EVs) and Water Quality objectives (WQOs) scheduled for Meandu Creek under the EPP Water; and	Section S3.1	Section 6	Appendix F Appendix G
— propose default EVs/WQOs where required for Meandu Creek; and	Section S3.2	Section 6	Appendix F Appendix G
— provide a description of the existing qualities, characteristics and resilience of Meandu Creek; and	Section S3.3	Section 8	Appendix G
— with reference to items (i) to (iii) above determine the mine-affected water release quality that must be achieved to protect the relevant EVs of Meandu Creek.	Section S3.4	Section 6	Appendix G

S3.1 MEANDU CREEK ENVIRONMENTAL VALUES AND WATER QUALITY OBJECTIVES

The Environmental Protection (Water) Policy 2009 (EPP (Water)) under the EP Act, establishes Environmental Values (EVs) for natural waters in Queensland. EVs relate to specific values of waterways, determined by physical, biological, social, economic and historical features. Water quality objectives (WQOs) are quantitative measures established to protect the assigned EVs. Achieving the relevant WQOs assists with ensuring that the corresponding EVs and uses of the waterway are protected.

There are currently no assigned EVs in Schedule 1 of the EPP (Water) for Meandu Creek.

Relevant EVs for the purpose of this environmental investigation were assigned from those outlined in Section 6 (2) of the EPP (Water), with reference to other relevant sources, such as the Burnett Mary Water Quality Improvement Plan (WQIP), available literature, previous technical reports and field surveys (refer Section S3.2).

S3.2 PROPOSED ENVIRONMENTAL VALUES AND WATER QUALITY OBJECTIVES

For the purposes of the environmental investigation, Meandu Creek has been separated into the following reaches as shown on Figure 4:

- Meandu Creek upstream of Meandu Mine (ephemeral and upstream of mining operation)
- Meandu Creek upstream of Meandu Creek Dam (direct impact from mining operations)
- Meandu Creek downstream of Meandu Creek Dam (perennial and downstream of mining and power station operations).

Figure 4 also shows Meandu Creek survey sites associated with the April 2017 survey of surface water quality and aquatic biota undertaken to support this environmental investigation.

S3.2.1 MEANDU CREEK UPSTREAM OF MEANDU MINE

Meandu Creek upstream of Meandu Mine is ephemeral and was dry at the time of the 2017 survey. This section of the creek is not impacted by operations at Meandu Mine and as such no EVs or WQOs have been proposed.

S3.2.2 MEANDU CREEK UPSTREAM OF MEANDU CREEK DAM

Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam as well as Black Creek Dam and Black Creek upstream of Black Creek Dam form part of the water management systems for Meandu Mine and the Tarong and Tarong North power stations, and thus, the industrial use EV has been assigned to these sections.

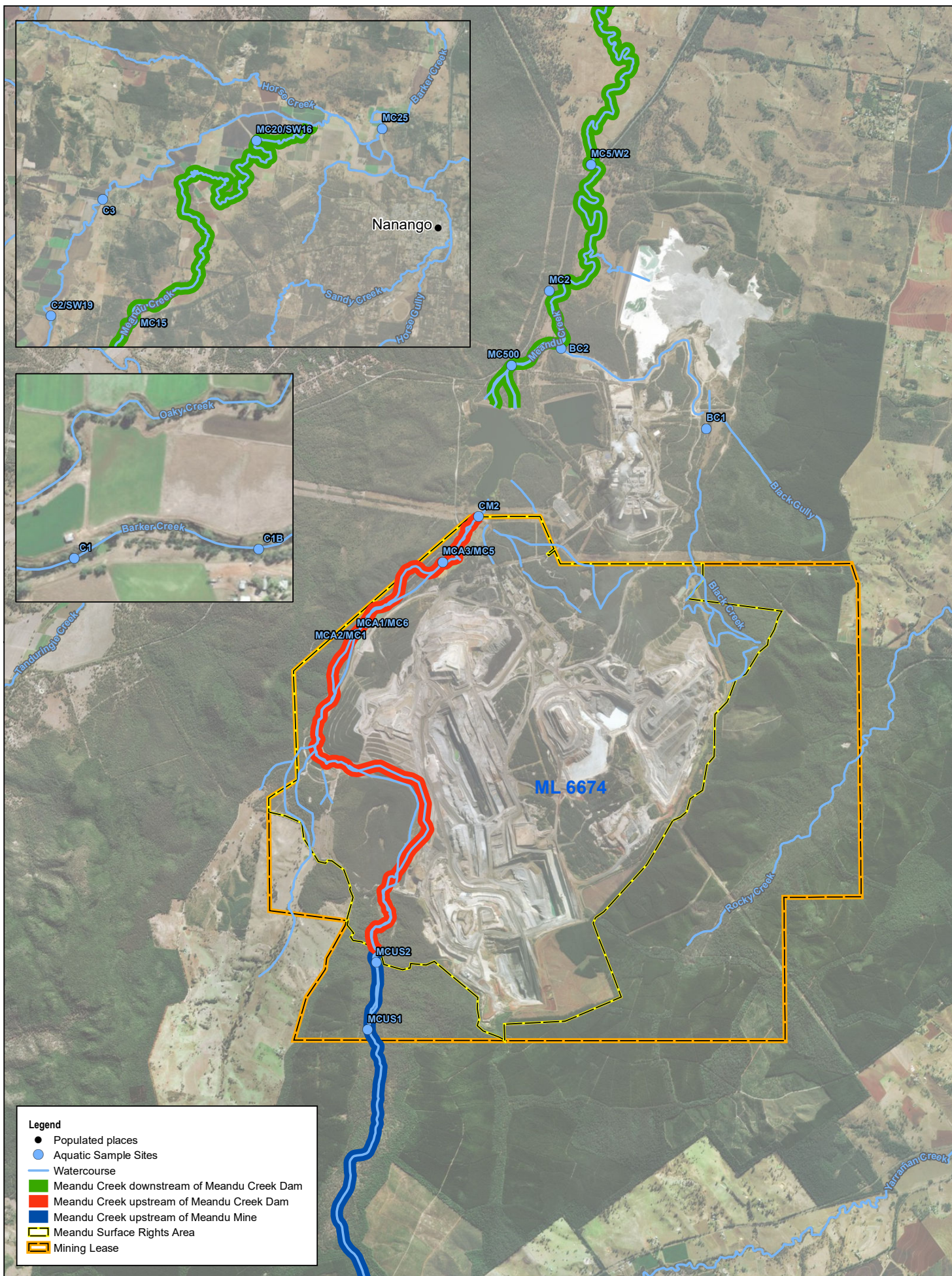
The conceptual model developed for the groundwater system at Meandu Mine considers that groundwater that flows towards Meandu Creek (including groundwater seepage from the North-West Backfilled Pit where AMD has been identified) flows towards and is captured by either the Meandu Creek alluvium upstream of Meandu Creek Dam or by seepage to the ground surface to be collected via site drains and/or retention dams. In terms of groundwater management, it is generally considered that groundwater that occurs within alluvium is managed as surface water; therefore the groundwater EV's for Meandu Creek, as well as for Black Creek, are taken to be the same as the Meandu Creek upstream of Meandu Creek Dam surface waters (i.e. the industrial use EV).

Current compliance limits outlined in the EAs for Meandu Mine (EPML00709113) and Tarong and Tarong North power stations (EPPR00971913) are considered appropriate for management of these waters

S3.2.3 MEANDU CREEK DOWNSTREAM OF MEANDU CREEK DAM

For Meandu Creek downstream of Meandu Creek Dam relevant EVs were assigned from those outlined in Section 6(2) of the EPP (Water), with reference to other relevant sources, such as the Burnett-Mary WQIP, available literature, previous technical reports and field surveys.

The Burnett-Mary WQIP identifies draft EVs relevant to the major waterways in the catchment, including those within the Burnett River Basin. Based on the WQIP as well as findings from available literature, previous technical reports and the current field survey, EVs assigned to Meandu Creek downstream of Meandu Creek Dam were aquatic ecosystems (moderately disturbed), irrigation, farm supply, stock watering, human consumption, primary recreation, secondary recreation, and industrial use.



PS102396_Fig4 Map: MeanduCKSurvey_r1v1	Author: NK/TW/HC		
Date: 11/09/2018	Approved by: LR		
Data source: Mining boundaries from client (2017); Cadastre from © State of Queensland (Department of Natural Resources and Mines) 2017; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.			
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Figure 4 Reaches of Meandu Creek and survey locations

WQOs for the receiving environment (downstream of Meandu Creek Dam) have been derived from the following hierarchy of sources:

- The Burnett-Mary WQIP, which defaults to the Queensland Water Quality Guidelines (QWQG) (EHP 2013) for central east coast upland waters.
- Aquatic ecosystems (physico-chemical parameters and nutrients) from the QWQGs as applied to slightly-moderately disturbed systems such as the receiving environment.
- Aquatic ecosystems EV (toxicants) – the Australian Water Quality Guidelines (AWQG) (ANZECC & ARMCANZ 2000) using the trigger values outlined in the AWQG that are applicable to slightly-moderately disturbed systems (95% level of protection).
- Human consumption, stock watering and farm supply EVs – the AWQG.
- Primary recreation EV – the Guidelines for Managing Risks in Recreational Waters (NHMRC 2008).

In selecting these WQOs consideration has also been given to:

- Release contaminant trigger investigation levels and receiving waters contaminant trigger levels from the Model Water Conditions for Coal Mines in the Fitzroy Basin (Version 6.01, 7 March 2017); to provide a context for the WQOs historically applied to the Meandu Creek, and currently applied to the receiving environment of coal mines in the adjacent basin.
- Site specific data, where no other guideline was available or where other guidelines were considered inappropriate.

In most instances, the most stringent WQO for each parameter was considered appropriate to protect all EVs in the receiving environment. However, in some cases (e.g. pH, percent saturation of dissolved oxygen, electrical conductivity and turbidity), less stringent WQOs were adopted given the known ambient water quality conditions in comparative waterways in the wider region, or long-term water quality values in the receiving environment that have been demonstrated to support diverse and healthy aquatic ecosystems (e.g. electrical conductivity).

S3.3 EXISTING QUALITIES, CHARACTERISTICS AND RESILIENCE OF MEANDU CREEK

S3.3.1 CHARACTERISTICS OF MEANDU CREEK

Meandu Mine is located near the headwaters of Meandu Creek, a tributary of Barker Creek, which flows to the Bjelke-Petersen Dam (Lake Barambah) some 100 km downstream of the Meandu Creek Dam. Meandu Creek is located within the Barker Creek catchment, part of the Burnett Basin. Waterways in the Barker Creek catchment have an ephemeral or intermittent flow regime, only flowing after rainfall. However, the waters of the receiving environment (including Meandu Creek, and Barker Creek downstream of the confluence with Meandu Creek) have a perennial flow regime due to releases from Meandu Creek Dam (except during extreme drought conditions when releases may cease).

Cooling water blowdown is discharged to Meandu Creek Dam from the Tarong and Tarong North power stations in accordance with the power stations' EA licence conditions (EPPR00971913). Meandu Creek Dam also receives stormwater runoff from the power stations as well as stormwater runoff from the Meandu Mine and from the upper Meandu Creek catchment.

Water from Meandu Creek Dam is subsequently released to the receiving environment of Meandu Creek via a release valve at the dam wall (monitoring site W3). Under normal operating conditions, there is a continual release of water; during dry conditions in the absence of rainfall and catchment inflows, these releases are the main source of water for Meandu Creek downstream of Meandu Creek Dam. Release volumes are regulated by water levels within the dam.

Upstream of Meandu Creek Dam, Meandu Creek is an ephemeral watercourse with several disjointed, non-flowing pools. These upper reaches of Meandu Creek (upstream of the mine) are a stream order 2, with poorly defined channels that are naturally ephemeral (i.e. they convey runoff after rainfall, but water rarely pools).

The section of the creek adjacent to Meandu Mine (and within the mining lease) has been significantly modified through the creation of the Meandu Creek Dam and three creek diversions to facilitate mining operations. This section of the creek forms part of the overall water management systems for Meandu Mine.

S3.3.2 RESILIENCE OF MEANDU CREEK

Resilience is the capacity of a system to experience shocks while retaining the same basic function, structure and feedbacks, and therefore identity (Walker et al 2004). The resilience of aquatic communities in Meandu Creek was assessed based on the sensitivity of aquatic communities, values and processes within the waterway to tolerate disturbance events (either long-term permanent changes or to short-term, moderate impacts). Communities consisting of more sensitive taxa are generally less resilient than those comprising more tolerant taxa, as they are more susceptible to changes in the conditions of their environment.

S3.3.3 GENERAL RESILIENCE

S3.3.3.1 MEANDU CREEK UPSTREAM OF MEANDU CREEK DAM (ADJACENT TO THE MINE) AND WITHIN MEANDU CREEK DAM

Aquatic communities in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) and within Meandu Creek Dam are considered to have high general resilience (i.e. as a response to unforeseen disturbance) based on the following attributes:

- Communities present have adapted to changes in the catchment, including dams, diversions, mining and power station activities.
- Macroinvertebrate communities are relatively diverse and include some sensitive taxa, but are generally dominated by tolerant taxa that can withstand harsh environmental conditions.
- Despite a history of disturbance (from dams, diversions, agriculture, mining and power station activities) in the catchment, the aquatic habitat is generally in moderate health, with some sensitive and long-lived species present (fish).
- Species in the region tend to be opportunistic (a typical trait of ephemeral systems) and able to adapt quickly, colonise rapidly and regenerate when conditions are suitable (e.g. local waterholes can 'seed' disturbed areas when conditions are suitable).
- Long lived species (e.g. fish) are present, which tend to be more sensitive to bioaccumulation and habitat changes.

S3.3.3.2 MEANDU CREEK DOWNSTREAM OF MEANDU CREEK DAM

Aquatic communities in Meandu Creek downstream of Meandu Creek Dam are considered to have a moderate general resilience (i.e. as a response to unforeseen disturbance) based on the following attributes:

- Aquatic communities have historically adapted quickly to long-term changes, including the relatively recent change from an ephemeral to perennial system due the continuous releases from Meandu Creek Dam.
- Aquatic communities have colonised the waterway relatively quickly following the long-term change from an ephemeral to perennial system due the continuous releases from Meandu Creek Dam.
- Macroinvertebrate communities are diverse and include many sensitive taxa (making them more sensitive to changes in their environment than communities dominated by tolerant species).
- Despite a history of disturbance (from dams, diversions, agriculture, mining and power station activities) in the catchment, the aquatic habitat is in good health, with many sensitive and long-lived species present (fish and turtles).
- Species in the region tend to be opportunistic and able to adapt quickly, colonise rapidly and regenerate when conditions are suitable (e.g. local waterholes can 'seed' disturbed areas when conditions are suitable).
- A diverse range of long-lived species are present (e.g. fish and turtles) which tend to be more sensitive to bioaccumulation and habitat changes.

S3.3.4 SPECIFIC RESILIENCE

Communities both upstream and downstream of Meandu Creek Dam are resilient to disturbance from the current Meandu Mine and the Tarong and Tarong North power stations activities, with aquatic communities adapted to the ambient water quality, sediment quality and habitat conditions (particularly to high electrical conductivity and high concentrations of some metals in the water and sediment which were recorded in Meandu Creek adjacent to the mine).

Overall, aquatic communities in Meandu Creek downstream of Meandu Creek Dam have a high specific resilience (i.e. as a response to a specific disturbance) to current mining and power station activities as they have previously shown rapid adaption and colonisation following conditions and are generally in a similar or better condition than would be expected in the broader catchment.

S3.4 MINE-AFFECTED WATER RELEASES

This section identifies the mine-affected water release quality that must be achieved to protect the relevant EVs of Meandu Creek based on the information presented in the previous sections.

S3.4.1 SURFACE WATER

The waters of Meandu Creek upstream of Meandu Creek Dam, Meandu Creek Dam and Black Creek Dam (including the Black Creek diversion) are managed for the industrial use EV, which does not include specific limits for the concentration of metals and metalloids designed to protect aquatic ecosystem values. While these reaches support aquatic species and communities, there is no specific management intent with respect to aquatic ecosystems under current operations. Rather, the management intent with respect to aquatic ecosystems is to protect the integrity of aquatic ecosystems in the receiving environment (Meandu Creek downstream of Meandu Creek Dam), which as an outcome of this environmental investigation shows no evidence of negative impacts to environmental values as a result of AMD.

Current compliance limits for mine affected release water quality outlined in the EA for Meandu Mine (EPML00709113) are considered appropriate to protect the environmental values in Meandu Creek. No additional mine water release quality limits are proposed as a result of this environmental investigation.

S3.4.2 GROUNDWATER

As identified in Section S3.2.2 it is generally considered that groundwater that occurs within alluvium is managed as surface water, therefore the groundwater EVs for Meandu Creek (as well as Black Creek) are taken to be the same as the surface waters of Meandu Creek upstream of Meandu Creek Dam (i.e. industrial use EV).

With respect to protecting the relevant EVs of Meandu Creek, groundwater quality is assessed at Meandu Creek alluvium bore GW39 as part of the groundwater monitoring program and compared to the groundwater contaminant trigger levels that are defined within the Meandu Mine EA (EPML00709113). These trigger levels were developed by JBT in parallel to the work undertaken for this environmental investigation and are considered suitable to detect potential for change to groundwater quality values due to Meandu Mine activities. No additional trigger values are proposed as a result of this environmental investigation.

S4 REQUIREMENT B3

NOTICE REQUIREMENT B3	SUMMARY REFERENCE	EIR REFERENCE	SPECIALIST REPORT
<i>An appropriately qualified person(s) as defined in this notice must undertake studies to determine the presence and extent of AMD at MCM, and to determine the acid generating potential of materials at Meandu Mine; the studies must include:</i>			
— <i>geochemical assessments to characterise the chemical and physical properties of any materials at Meandu Mine (soil, overburden, in-pit side cast coal, product coal, rejects, tailings, ash etc.) with potential to generate AMD so these materials can be classified and then managed appropriately; and</i>	Section S4.1	Section 3	Appendix E
— <i>contaminant hydrogeological investigations inclusive of drilling and installation of monitoring bores (if required); and</i>	Section S4.2	Section 4	Appendix F
— <i>studies to identify the extent and locations of potential AMD source materials at Meandu Mine; and</i>	Section S4.3	Section 3	Appendix F
— <i>investigations to identify physical and/or environmental influences relating to storage areas (coal rejects, overburden, waste rock, and topsoil) that may determine the occurrence, rate of progression, or volume of AMD generated at Meandu Mine for example: stockpile location, size, surface area, profile/geometry, water infiltration and drainage characteristics.</i>	Section S4.4	Section 4 Section 5	Appendix E Appendix F
— <i>a dedicated site plan showing the location and extent of AMD at Meandu Mine, including existing seepage flow paths.</i>	Figure 8	Section 4 Section 5	Appendix F – Figure 45

S4.1 GEOCHEMICAL ASSESSMENT TO CHARACTERISE CHEMICAL AND PHYSICAL PROPERTIES

S4.1.1 STATIC AND KINETIC TEST RESULTS

The purpose of the static geochemical test program undertaken by RGS was to characterise and classify mine waste materials (overburden; interburden; coal rejects, tailings and ash) from K2E, K4E, K4S and Central pits into six geochemical classes ranging from acid consuming (AC) to potentially acid forming (PAF). The static geochemical test and classification program was also extended to coal rejects, tailings and coal ash materials. The static geochemical classification system used by RGS for the purpose of this investigation is provided in Table 1.

The neutralisation potential ratio (NPR) values adopted for the criteria are conservative, for example, for PAF-UC, RGS assumes that the ANC levels will at least equal (i.e. balance) the maximum potential acidity (MPA), that is no acid would be returned in the Net Acid Producing Potential (NAPP) test. Kinetic testing can result in a more accurate determination as to whether a material has a significant potential to generate acid. The KLC testing program implemented by RGS used samples obtained from the K4E Pit for coarse-grade reject samples, fine-grade rejects collected from the CHPP belt, tailings from the CHPP underflow thickener, ash from the K2N ash pit and overburden samples from drill core samples collected from K2E. The samples were evaluated as individual samples and in a variety of mixtures to simulate potential management strategies including co-disposal and the addition of agricultural lime.

Table 1 *Geochemical classification system used by RGS for mine waste materials*

MATERIAL TYPE	CLASSIFICATION CRITERIA
Acid Consuming (AC)	TS% < 0.05 and NPR > 10 and > 50 kg H ₂ SO ₄ /t
Non-Acid Forming (NAF)	TS% < 0.05 and NPR > 3
Non-Acid Forming Uncertain (NAF-UC)	TS% < 0.05 and NPR < 3
Potentially Acid Forming Uncertain (PAF-UC)	TS% > 0.05 and < 0.2% and NPR > 1 < 3
Potentially Acid Forming - Low Capacity (PAF-LC)	TS% > 0.05 and < 0.2% and NPR < 1
Potentially Acid Forming (PAF)	TS% > 0.2%

At the time of reporting, the KLC testing program had been ongoing for over 14 months. Leach cycles were conducted monthly. A summary of the main findings from the static and kinetic leach programs is provided in the following subsections.

S4.1.1.1 COARSE-GRADE REJECTS

The coarse-grade rejects sample (KLC12) had a static PAF classification. The sample initially leached neutral drainage, but became acidic within 6 months, and after 14 months leached drainage with pH of 3 to 4. The sample has a lag period of less than 6 months to produce acidic drainage under unsaturated atmospheric conditions. The addition of lime has a positive effect on maintaining the reject sample at neutral pH over 14 months (initial pH 8.2, final pH 7.7).

S4.1.1.2 FINE-GRADE REJECTS

The fine-grade rejects sample (KLC5) had a static PAF-LC classification. The sample initially leached neutral drainage and retained a pH of 7.19 after 14 months of leaching. The sample had low acidity over the program starting at 26 mg/L and ending with 11 mg/L. Compared to the coarse-grade reject samples, the sulfate concentration was initially elevated (1,970 mg/L), but decreased rapidly to 154 mg/L after 14 months. The initially elevated sulfate concentration within the sample was attributed to entrained sulfate from the process water circuit in the CHPP and the high surface area of this sample. The material represented by this sample therefore has a lag period of more than 14 months to produce acidic drainage under unsaturated atmospheric conditions.

S4.1.1.3 TAILINGS

The tailings sample (KLC3) had a static PAF-LC classification. The sample initially leached neutral drainage and retained a pH of 6.2 after 14 months of leaching. The sample had low and consistent acidity and sulfate concentration over the test program of approximately 4 mg/L and 350 mg/L, respectively. Material represented by this sample therefore has a lag period of more than 14 months if it were capable of producing acidic drainage under unsaturated atmospheric conditions. The fine-grained and low permeability nature of the material encouraged moisture retention and limits sulfide oxidation. It is noted that lime [Ca(OH)₂] is added to the tailings stream to maintain the pH of the tailings at about pH 7, because there are times when the tailings has the potential to generate acidity at the CHPP.

S4.1.1.4 ASH

The ash sample (KLC2) had a static PAF-LC classification. The sample initially leached pH 6.7 drainage and retained a pH of 7.4 after 14 months, and had low and decreasing acidity that reduced from 24 mg/L to 2 mg/L. The concentration of dissolved sulfate also decreased rapidly over the 14 months. Due to very low sulfur content and non-detectable sulfide content, it has no potential to produce acidic drainage.

S4.1.1.5 OVERBURDEN / INTERBURDEN

The bulk of the samples in the overburden and interburden are within the NAF mine waste class and this is typical of most coal mines. Basalt and conglomerate are predominantly NAF, with one sample of sandstone having a static and kinetic PAF-LC classification. Ongoing sampling and analysis is being undertaken to reduce uncertainty around the location of PAF mine overburden. PAF materials will be segregated and treated separately in the mine plan.

S4.2 CONTAMINANT HYDROGEOLOGICAL INVESTIGATIONS

The hydrogeological investigations included:

- The installation of an additional 12 groundwater monitoring bores specific to this environmental investigation, to bring the current monitoring network to a total of 63 bores at 50 sites (noting that 6 bores at 4 sites have been decommissioned during this assessment due to pit progression).
- A land-based (July 2015) and airborne (March 2017) geophysics investigation. The land-based survey was undertaken to identify potential seepage pathways from spoil-filled prior voids as well as the overall geophysics response of the area within and adjacent to Meandu Creek. The airborne geophysics investigation comprised 1,107.5 line kilometres of transient electromagnetic (TEM) survey. The survey was undertaken to improve the understanding of geology and potential seepage zones at Meandu Mine, including seepage from site storages and backfilled voids as well as groundwater conditions within and to the west of Meandu Creek.
- Information obtained from the geophysics investigation has been used, in conjunction with other data (geological data, water quality data, location of pre-mining drainage, delineation of the deepest mined surface) to establish the location and extent of seepage pathways as well as the mechanisms for seepage.

The available data for this environmental investigation enabled a comprehensive groundwater conceptual model to be developed that defined key groundwater units, groundwater recharge system, groundwater inflow to mine voids, groundwater seepage paths and groundwater flow direction. This conceptual model then informed the input requirements to the Integrated Water Model (Goldsim) undertaken by Golder. The analysis has enabled conclusions to be reached with respect to the chemistry of AMD seepage at Meandu Mine, zones of existing seepage, mechanisms for seepage, potential impacts on the Meandu Creek environment and recommended control measures.

The hydrogeological investigation focused on the North-West Backfilled Pit as the only known mine domain seeping AMD. Two separate areas with high electrical conductivity groundwater have been identified based on review of water quality data:

- A saline plume that has been identified with an origin close to the Queen West void; groundwater within the plume moves through shallow regolith along a natural drainage line towards retention dams RD1 and RD2
- An area within the Black Creek catchment in the northern area of the lease.

Based on the interpretation of this data, the high electrical conductivity plume along an area that is downgradient of the Queen West void is determined to not be related to AMD and also to not be related to groundwater quality impacts within the Black Creek catchment.

The saline plume extends from an area near the Queen West void (note that the Queen West void is not thought to be the source), with affected groundwater flowing through shallow regolith along a natural drainage line towards RD1 and RD2 (which are both to the east of Meandu Creek). There is no discernible impact on water quality of RD1 and RD2 to date from the high electrical conductivity groundwater within the plume. A potential reason for the apparent lack of water quality impact on RD1 and RD2 is the relatively low rate of seepage within the plume. Based on a preliminary assessment JBT has calculated the groundwater inflow rate to RD1/RD2 to be between 0.3 and 1.3 L/second (0.025 to 0.1 ML/day) (refer Appendix F). This flow rate would be relatively insignificant when compared to surface water inflows to both dams over the course of a year.

From the preliminary assessment, it is concluded that, even if the saline plume has extended to RD1/RD2, the potential rate of inflow to the dams is calculated to be low and based on available water quality data, it is evident that the plume has not made a discernible impact to date on the electrical conductivity of RD1 and RD2. It may be further concluded that, due to the relatively low seepage rates and the presence of retention dams to intercept groundwater flow, the risk to the environmental values of Meandu Creek is also low.

Potential impacts on groundwater quality within the Black Creek catchment are interpreted based on water quality data (note: interpretation of the geophysical data in this area is complicated by the presence of high voltage transmission lines and basaltic clays). Data from the majority of bores in this area is relatively recent (with data available from November 2016 with the exception of GW61_s and GW61_d, where data is available from 2009). The groundwater quality trends (high electrical conductivity, low pH, high aluminium and zinc concentrations) are not consistent between bores in the Black Creek catchment. It is notable that bores GW73 (high electrical conductivity) and GW74 (low pH, high aluminium and zinc concentrations), are constructed within natural material (regolith) that is down-gradient of spoil (a potential source of contaminants). The bores that are constructed within the up-gradient mined spoil and tailings (e.g. GW70, GW72, GW61_s) do not tend to record elevated concentrations of the same parameters (or low pH). It is further noted that water quality data is available from bores GW70, GW72, GW73 and GW74 for a relatively short period (November 2016 to present, at quarterly intervals) and that additional data will assist the interpretation of water quality trends within the catchment. Therefore, additional monitoring to establish trends will be required before conclusions can be made.

It should be noted that both of the areas above have been assessed by JBT as being unrelated to AMD processes and will be monitored by Stanwell as part of the ongoing groundwater monitoring program (EA EPML00709113).

S4.3 IDENTIFICATION OF EXTENT AND LOCATION OF POTENTIAL AMD SOURCE MATERIALS AT MEANDU MINE

Stanwell developed a 3-dimensional (3D) material placement concept model in Vulcan, which identified the placement of ash, rejects, tailings and waste material across the mine site since operations commencement in 1984 through to 2016. The 3D concept model of waste material placement has been used to inform the environmental investigation into AMD at Meandu Mine, particularly the material classification assessment undertaken by RGS and development of the Integrated Water Model by Golder

The concept model of waste material placement particularly focused on the North-West Backfilled Pit, a complex layered domain that contains over 30 years of placement of rejects, tailings and waste material. Construction of the North-West Backfilled Pit has been ongoing since mining commenced in the North-West A Pit. The pit was initially made up of North-West Pit A and North-West Pit B. These pits were eventually linked when the land bridge between them was mined out. Backfilling of North-West Pit commenced immediately with dragline operations dumping mining waste directly into the previous strip void. The dump over the North-West Backfilled Pit currently covers an area of approximately 400 ha. In addition to mining waste the North-West Backfilled Pit includes:

- Ramp 3, North-West A and North-West B TSFs
- Ramp 2 TSF from Central Pit that have been relocated and intermingled with waste rock from Central Pit
- Rejects storage (North-West rejects) constructed in six stages
- North-West waste dump
- Hitachi Hill rejects/waste solids.

Given that the historical data was limited in detail, it was not possible to determine the exact ratio of rejects to tailings to waste in the North-West Backfilled Pit without further monitoring (which will require installation of additional bore(s)). Assumptions around material placement had to be made based off historical flyover images and confirmation with long-term Meandu Mine employees. The locations of material placement within the North-West Backfilled Pit domain based off these investigations is shown in Figure 5.

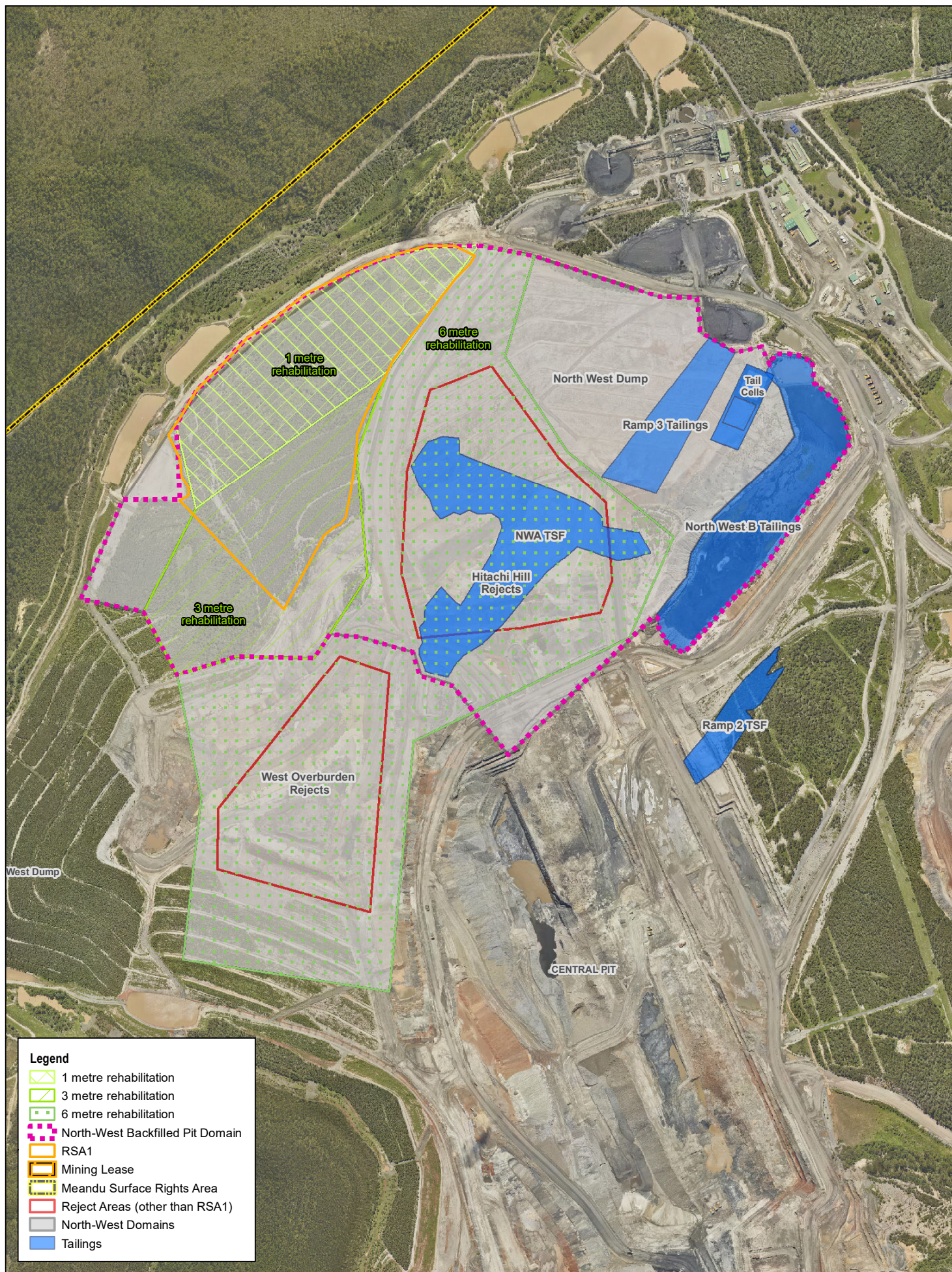
S4.4 PHYSICAL OR ENVIRONMENTAL INFLUENCES RELATING TO STORAGE AREAS

It was originally thought that AMD seepage from Ramp 7 and Bullgang Corner may have been due to porewater being squeezed directly from the tailings. RGS has shown however that this is not the case with over 14 months of kinetic leach testing of tailings verifying that tailings continue to generate neutral pH drainage.

RGS has determined that the most probable cause of historic and ongoing AMD events from North-West Backfilled Pit was oxidation of sulfide minerals and subsequent leaching of AMD weathering products from the reject storage. Reject materials collected from the re-exposed area in Hitachi Hill were initially pH neutral but become acidic within six months of exposure to oxidising conditions. KLC testing of this material confirmed that after oxidation, solute concentrations decrease rapidly. Hence, under free draining conditions it is expected that the weathering products from this material will be removed from the system quite rapidly.

Fresh coarse reject material had a six-month lag period until the onset of acid production. The fine-grade rejects, tailings and ash maintained neutral pH over the test period of 14 months. The weathered clay samples had acid leachate from the first leach cycle but this acidity is due to soluble aluminium and manganese, not sulfide oxidation processes. The PAF sandstone material used in the KLC testing program produced acid leachate within one month. This sample selected for the KLC program is not representative of sandstone in general.

The current Meandu Mine management procedures of limiting storage/exposure time of coarse reject materials at the reject stockpile to less than two weeks appears to be an effective way of controlling the risk of acidic drainage generation. The potential for oxidation will be further reduced through the incorporation of fine-grade rejects and tailings when the dewatering process is implemented at site, whereby pore voids within the coarse rejects will be filled with highly plastic low permeability tailings limiting oxidation and permeability. The combined reject and tailings stream will be placed into the spoil dumps and progressively co-mingled or encapsulated with overburden and interburden. The PAF overburden units identified in the highwall during mining will be segregated and placed at least 6 m under the final landform and covered by NAF material. If acidic drainage is perceived as an ongoing issue, then supplemental liming could be considered, but is unlikely to be required. Ongoing drilling, sampling and analysis will be continued to improve the reliability of the overburden model so that PAF units can be identified ahead of mining and managed appropriately. Sampling of reject, tailings and ash streams is being continued for basic geochemical test parameters to ensure the geochemical nature of the mine waste is tracked over time.



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Figure 5 North-West Backfilled Pit Domain



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S4.5 LOCATION AND EXTENT OF AMD AT MEANDU MINE AND ASSOCIATED SEEPAGE PATHWAYS

S4.5.1 NORTH-WEST BACKFILLED PIT

The North-West Backfilled Pit is the only known mine domain currently seeping AMD. Seepage from the North-West Backfilled Pit has been observed as seepage to Bullgang Corner, as well as relatively diffuse seepage that occurs towards Ramp 7. The North-West Backfilled Pit is a complex layered domain that contains over 30 years of placement of rejects, tailings and waste material. Construction of the North-West Backfilled Pit has been ongoing since mining commenced in the North-West A pit and, in addition to mining waste, the North-West Backfilled Pit includes: Ramp 3, North-West A and North-West B TSFs; Ramp 2 TSF from Central Pit that have been relocated and intermingled with waste rock from Central Pit; and six stages of rejects storage. The dump over the North-West Backfilled Pit currently covers an area of approximately 400 ha.

Figure 6 contains four plots that can be used to understand the location of and mechanisms for seepage from the North-West Backfilled Pit.

The upper left plot shows the location of the North-West Backfilled Pit, which has been filled and rehabilitated. Also shown are the locations of the current North-West B TSF, Bullgang Corner, pre-mining drainage lines and the location of a conceptual section through the North-West Backfilled Pit void (Figure 7 – discussed below) and Meandu Creek.

The upper right plot shows contours of the deepest mined surface for the mine area, focussing on the North-West Backfilled Pit. For areas that have not been mined, the deepest mined surface is the same as the original topographic surface. The plot shows the mined extent of the North-West Backfilled Pit and North-West B TSF. Worth noting is the direct connection (via tailings/spoil) between the North-West B TSF and the North-West Backfilled Pit.

The lower left plot shows the extent and thickness of spoil in the area of the North-West Backfilled Pit. The spoil thickness was generated as the difference between the current topographic surface and the deepest mined void at any location. For areas that have never been mined, or for areas that are currently being mined, the spoil thickness is zero. The spoil reaches a maximum thickness of approximately 150 m beneath the area known locally as “Hitachi Hill”. It is also noted that the spoil thickness reduces to zero near Bullgang Corner.

The lower right plot shows the deepest mined void with the region at or below RL435 mAHD shown in blue shading. This elevation was selected because it is the elevation at which seepage begins to occur from the North-West Backfilled Pit towards Bullgang Corner, with seepage occurring preferentially along a pre-development drainage line. The following observations are made with respect to this plot:

- At RL432 mAHD, seepage via prior drainage channels begins to occur in the western area of the North-West Backfilled Pit. Therefore, at a groundwater elevation of RL435 mAHD (when seepage begins to occur along a prior drainage line towards Bullgang Corner) there will be a ~3 m thickness of saturated spoil above the western wall of the North-West Backfilled Pit along a wide area. In addition, the western wall of the North-West Backfilled Pit is relatively thin at this location (refer conceptual section in Figure 7) and it is conceptualised that this will allow diffuse seepage to occur through the western wall at an elevation slightly below RL432 mAHD when direct seepage via prior drainage lines can occur. This seepage mechanism allows a relatively large area of spoil west of the mined extent of the North-West Backfilled Pit to become saturated, with this seepage expressing at an area where the spoil approaches a zero thickness and the seepage therefore expresses at surface (i.e. along the eastern side of the Ramp 7 haul road).
- At RL435 mAHD seepage commences from the North-West Backfilled Pit along a pre-development drainage line and towards Bullgang Corner. This seepage initially occurs through spoil, with visible seepage occurring at the location where the spoil attains a zero thickness and the seepage therefore expresses at surface (i.e. at the location of Bullgang Corner).
- The most recent water level for spoil monitoring bores within the North-West Backfilled Pit shows that a slight groundwater mound occurs within the void, with the water level at RL438 mAHD in bore NWT (drilled at the top of Hitachi Hill), reducing to RL435.36 mAHD in bore GW49 to the west. Significantly, the water level in all monitoring bores is above RL435 mAHD, which is the elevation at which seepage from the North-West Backfilled Pit towards Bullgang Corner occurs along the pre-development drainage line and seepage over the western wall of the North-West Backfilled Pit (at RL432 mAHD) is already occurring through approximately 3 m of saturated spoil.

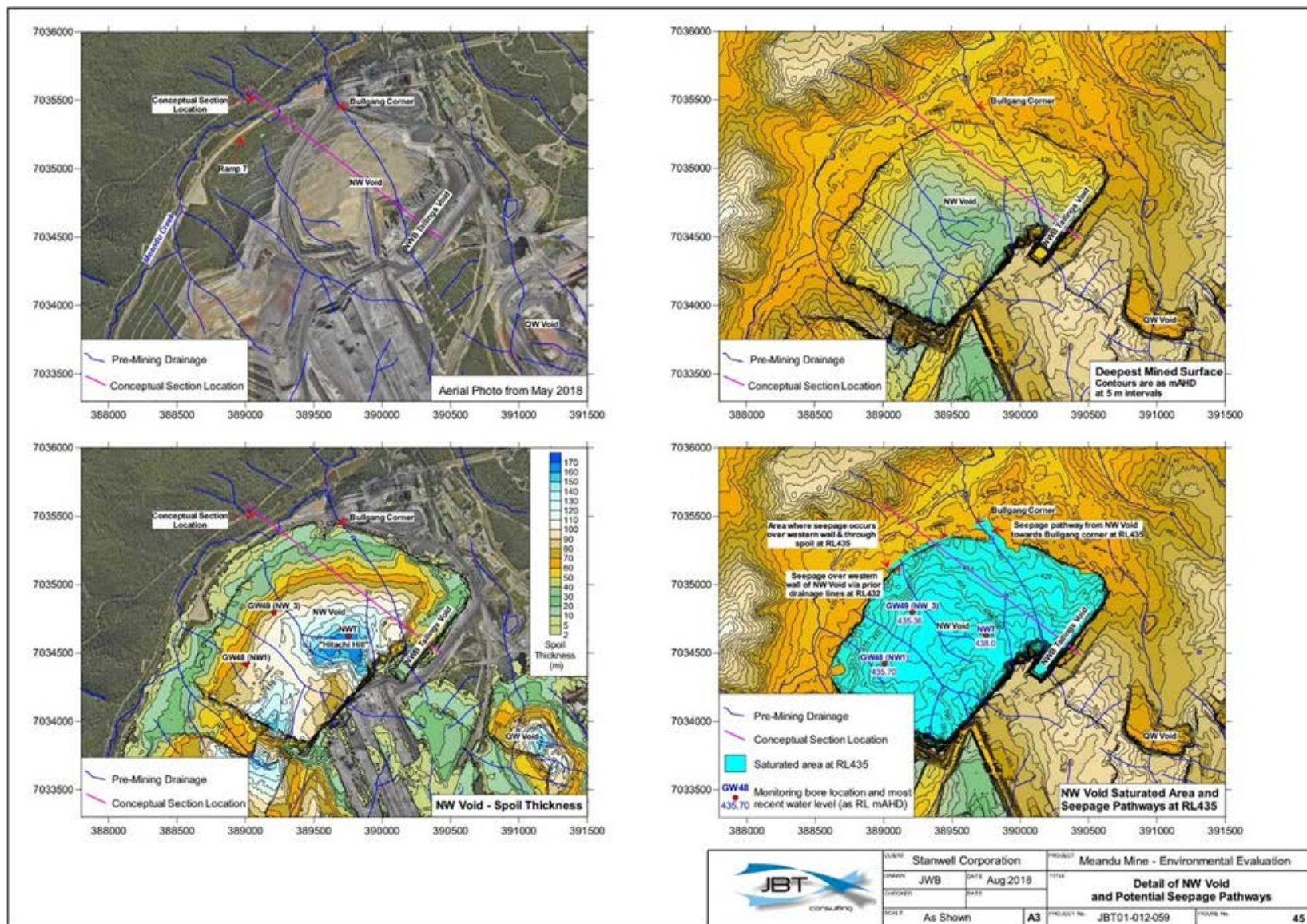


Figure 6 Details of North-West Backfilled Pit and potential seepage pathways

Figure 7 is a conceptual cross section of the North-West Backfilled Pit. The following is shown on this figure:

- The difference between the deepest mined surface and the current topographic surface is the region within the North-West Backfilled Pit that has been filled by mined spoil (a generic term that includes tailings, waste rock, coal rejects etc.).
- At the western limit of the North-West Backfilled Pit, a relatively thin wall of remnant coal measures remains. It is conceptualised that this thin wall of remnant material allows relatively diffuse seepage to occur across a relatively wide area. Seepage occurs initially to the rehabilitated spoil on the western side of the wall of remnant coal measures before reporting as seepage to the Ramp 7 haul road at a location where the spoil approaches a zero thickness.
- The predicted water level within the spoil is shown as a blue dashed line, with water level data available from bores NWT and GW49 and an assumption has been made that the water level within the North-West B TSF is at or close to surface. Available water level data indicates that the groundwater flow direction is from east to west (i.e. towards Meandu Creek) and that water within the North-West B TSF seeps to the North-West Backfilled Pit due to a direct connection between the two features.

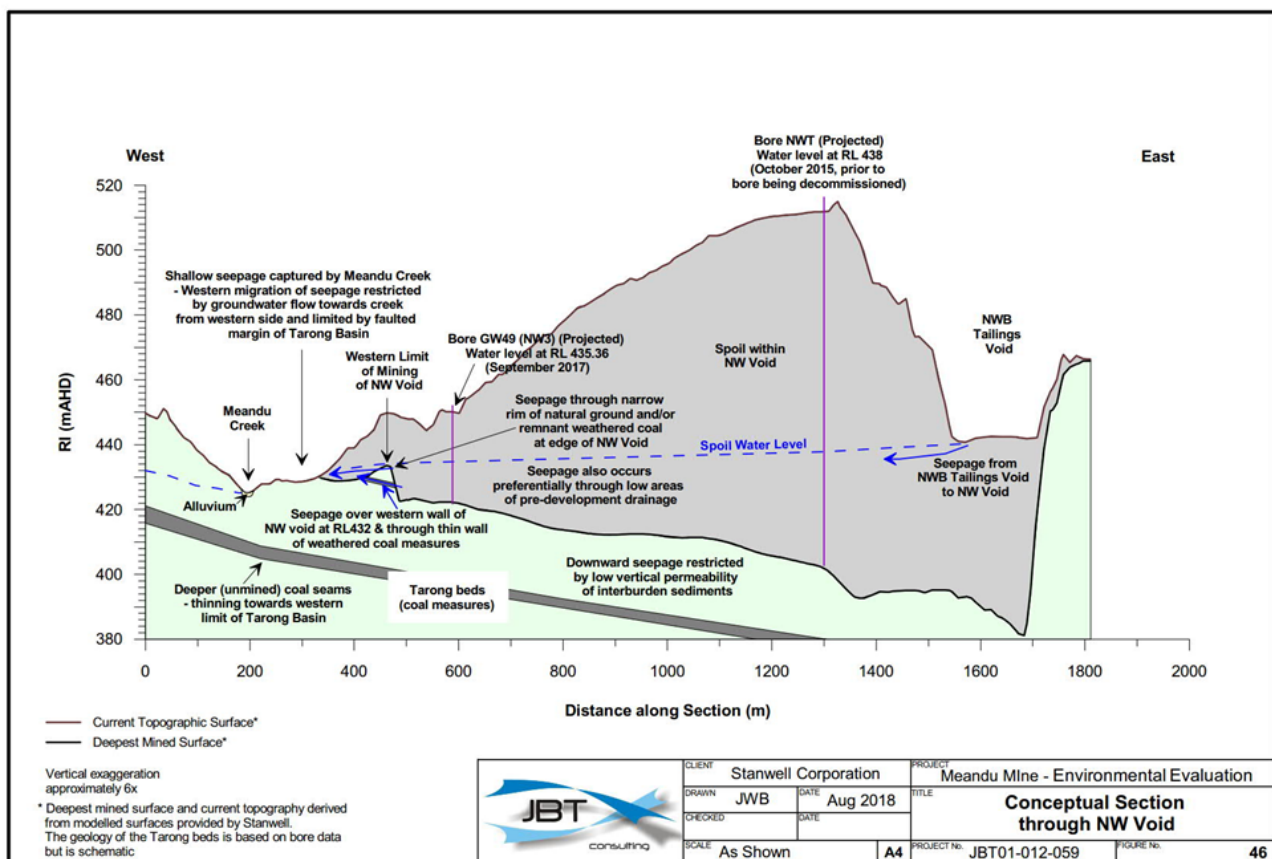


Figure 7 Conceptual section through North-West Backfilled Pit

In summary, it is concluded that groundwater flow direction within the North-West Backfilled Pit is towards the west and north-west and exits the North-West Backfilled Pit by either:

- Seepage along a prior drainage channel at RL435 mAHD towards Bullgang Corner, where seepage is expressed at surface at a location where the spoil thickness approaches zero (i.e. Bullgang Corner).
- Seepage through and over the western wall of the North-West Backfilled Pit, commencing along prior drainage lines at RL432 mAHD and through saturated spoil at higher elevations. Seepage via the western wall also occurs as diffuse seepage through remnant natural material at locations where this material forms a relatively thin barrier to seepage.

The floor of the North-West Backfilled Pit is low permeability interburden material and it is conceptualised that this will restrict downward seepage due to the low vertical permeability of the interburden. However, groundwater movement to the west of the North-West Backfilled Pit (towards Meandu Creek) is interpreted to be possible, via the mechanisms discussed above.

Groundwater flow to the west of Meandu Creek is assessed to be unlikely for the following reasons:

- In the area adjacent to the North-West Backfilled Pit, the deepest seam mined (Queen Seam) does not occur beneath Meandu Creek due to the dip of the coal measures (i.e. the coal measures become more shallow beneath Meandu Creek).
- The lower coal seams (seams below the Queen Seam) also dip from west to east (i.e. the occurrence of the coal seams gets shallower to the west), with the coal measures discontinued to the west against the faulted margin of the Tarong Basin. Therefore, the dip of the strata and the shallow depth of coal measures beneath Meandu Creek combine to result in Meandu Creek acting as a capture zone for groundwater flow within the coal measures.
- It is conceptualised that there will be a natural flow of groundwater towards Meandu Creek on the western side of the creek (because generally, the water table is a subdued reflection of topography and the topography is elevated to the west of Meandu Creek. In other words, it is conceptualised that Meandu Creek is a capture zone for groundwater flow from the west and east.

Figure 8 is presented as a dedicated site plan to show the location and extent of AMD at Meandu Mine, including existing seepage flow paths.



S5 REQUIREMENT B4

NOTICE REQUIREMENT B4	SUMMARY REFERENCE	EIR REFERENCE	SPECIALIST REPORT
<i>An appropriately qualified person(s) as defined in the notice must undertake studies to determine whether AMD at Meandu Mine has impacted on or has the potential to impact on the environmental values of groundwater and/or surface waters including Meandu Creek. The studies must include:</i>			
— water quality investigations to determine any impacts on environmental values of groundwater and surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine; and	Section S5.1	Section 7 Section 8	Appendix F
— water quality investigations to determine future potential impacts on environmental values of groundwater and surface waters (Meandu Creek) resulting from AMD at Meandu Mine; and	Section S5.2	Section 7 Section 8	Appendix F
— identify short term and long-term measures including (if relevant) further lines of investigation, monitoring requirements, and operational or mine planning measures that should be developed and/or implemented to prevent environmental harm occurring from AMD at Meandu Mine.	Section S5.3	Section 8 Section 10	Appendix F

S5.1 ASSESSMENT OF CURRENT IMPACT ON RECEIVING ENVIRONMENT DUE TO AMD

S5.1.1 SURFACE WATER

As a response to the December 2016 Notice, a detailed surface water, sediment and aquatic biota field survey was completed from 23 to 29 March 2017. Aquatic ecology surveys were completed at 33 locations distributed throughout the region, including potentially impacted sites as well as comparative (control) sites. An additional sediment quality survey was also completed from 11 to 14 April 2018, to assess within-site variation and the bioavailability of metals in the sediment. Samples were collected from a sub-set of sites sampled in March 2017. Surface site locations from the March 2017 survey are shown on Figure 4.

S5.1.1.1 MEANDU CREEK UPSTREAM OF AND WITHIN MEANDU CREEK DAM

The results of historical and current (2017) surface water monitoring demonstrate that electrical conductivity levels and the concentrations of major ions (including sulfate), nitrate and some dissolved metals are higher in Meandu Creek adjacent to Meandu Mine (and upstream of Meandu Creek Dam) than at comparative sites within the region.

The March 2017 survey, also identified a general trend of higher concentrations of some metals in sediments that may be influenced by AMD (cobalt, manganese, nickel and zinc), particularly at site CM2. In the April 2018 survey, concentrations of dilute acid extractable nickel and zinc (representative of the bioavailable fraction) exceeded the sediment quality guideline-high value (SQG-high) at CM2; there are no sediment quality guideline values (SQGVs) for cobalt and manganese. Results of the 2018 survey indicated metals in sediments at CM2 may be bioavailable to aquatic flora and fauna. This is discussed further in Section S5.2.1

A similar range of macroinvertebrate taxa were generally recorded at sites in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) and at the ephemeral comparative sites. However, there were some sensitive taxa recorded at comparative sites not found at sites on Meandu Creek upstream of Meandu Creek Dam. Diversity and abundance of fish, and diversity of aquatic plants were also lower at sites upstream of Meandu Creek Dam than at comparative sites.

Differences at these sites may also be due to a range of other factors including the upstream location in the catchment and a lack of connectivity with downstream reaches (particularly due to the presence of Meandu Creek Dam); along with poorer habitat quality as a result of the construction of diversions and mine water management systems.

S5.1.1.2 MEANDU CREEK DOWNSTREAM OF MEANDU CREEK DAM

The results of historical and current (2017) surface water monitoring demonstrated that electrical conductivity levels and the concentrations of major ions (including sulfate) and some dissolved metals are higher in the water at sites in Meandu Creek downstream of Meandu Creek Dam than at comparative sites within the region.

Although the flow regime and water quality have been substantially modified due to the construction of the Meandu Creek Dam in 1982 (and subsequent licensed water discharges), it is likely that the aquatic floral and faunal communities inhabiting downstream reaches have adapted to these altered conditions over time. More continuous flows and altered water quality conditions may have changed the composition of these communities; however, results from the current field surveys in March 2017 indicate that aquatic habitats in Meandu Creek are in moderate to good condition and support a diverse assemblage of aquatic flora and fauna. That is, the aquatic ecosystems of the receiving environment downstream of Meandu Creek Dam are not significantly degraded or of a lower ecological value than surrounding waters (as would be the case for highly disturbed waters). Therefore, the system is currently considered to meet the definition of ‘moderately disturbed’ (i.e. the biological integrity of the water is adversely affected by human activity to a relatively small but measurable degree).

Results of the surveys completed in March 2017 and April 2018 indicate some areas in Meandu Creek downstream of Meandu Creek Dam had sediment-bound metals. However, this was restricted to reaches close to (i.e. within 500 m of) Meandu Creek Dam (site MC500). While this site had relatively high levels of some metals in sediment that are indicative of AMD (cobalt, manganese, nickel and zinc) or power station activities (e.g. nickel and zinc) compared to comparative sites, further assessment indicated that these metals are unlikely to be bioavailable. Furthermore, the results of aquatic flora and fauna surveys demonstrate that the presence of these metals is not resulting in negative impacts to the aquatic ecosystem EVs of the receiving environment.

Aquatic flora and fauna communities in Meandu Creek downstream of Meandu Creek Dam were in a similar or better condition than would be expected in the broader catchment. The perennial flow regime, resulting from the consistent releases from Meandu Creek Dam, allows for stable and diverse aquatic habitats to occur, which in turn are colonised by a diverse range of macroinvertebrates (including some sensitive and very sensitive taxa), along with aquatic plants, fish and turtles, where habitat is suitable. This confirms that the quality of water released from Meandu Creek Dam, and the sediment quality of the receiving environment, is suitable for protecting the downstream aquatic ecosystem.

- Overall, aquatic communities of Meandu Creek downstream of Meandu Creek Dam are highly resilient to current mining and power station activities as they have previously shown rapid adaptation and colonisation to changing conditions and are generally in a similar or better condition than would be expected in the broader catchment.
- Thus, current release conditions within Meandu Mine’s EA (EPML00709113) and the monitoring requirements outlined in the Meandu Creek REMP are considered sufficient to protect the relevant EVs of Meandu Creek.

There is currently no evidence of negative impacts to the environmental values of Meandu Creek as a result of AMD from Meandu Mine. Overall, aquatic ecological communities in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam. Water quality conditions, including hardness and pH, are likely to be reducing the toxicity of metals in water. Further, metals in sediments in some areas of Meandu Creek downstream of Meandu Creek Dam are likely to be immobilised by the availability of sulfides and are unlikely to cause acute or chronic toxicity to aquatic flora and fauna.

S5.1.1.3 CURRENT IMPACTS ON RECEIVING ENVIRONMENT

Elevated conductivity levels and concentration of major ions (including sulfate) and some dissolved metals in Meandu Creek (both adjacent to Meandu Mine and within and downstream of Meandu Creek Dam) may be indicative of an AMD-related impact. Other factors such as operation of the Tarong and Tarong North power stations and/or catchment

inputs also influence some of these parameters. Regardless of this, based on the information from this environmental investigation, there is no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment. Overall, aquatic ecological communities in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam.

S5.1.2 GROUNDWATER

From a review of groundwater chemistry data it is concluded that the primary indicators of AMD seepage are:

- pH
- sulfate, which is assessed to be the most reliable indicator of AMD-impacted groundwater as well as the most reliable general indicator of mining-impacted groundwater
- metals/metalloids including cobalt, iron, manganese, nickel and zinc.

AMD-impacted groundwater is assessed to be present at a number of groundwater monitoring sites that are adjacent to the North-West Backfilled Pit and Meandu Creek. These sites are shown on Figure 8 and include GW25, GW34, GW35, GW36 and GW75. To date, AMD impacts are not evident in groundwater monitoring bores that monitor the Meandu Creek alluvium, which include GW40 and EA (EPML00709113) compliance monitoring bore GW39.

S5.2 IDENTIFICATION OF POTENTIAL IMPACTS DUE TO AMD

S5.2.1 SURFACE WATER

Future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine are considered unlikely. The information presented in this investigation shows there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment.

While a build-up of metals in sediment within 500 m downstream of Meandu Creek Dam has occurred, no impact to biological communities is evident, and water and sediment quality conditions are such that metals are not bioavailable. Provided discharges from Meandu Creek Dam do not cause sudden and drastic increases or decreases to the electrical conductivity in Meandu Creek downstream of Meandu Creek Dam, it is unlikely that the aquatic ecosystem within the receiving environment (that has adapted to the current electrical conductivity range) will experience any acute or chronic effects. Provided current management measures continue to be implemented and future monitoring of key water quality parameters (e.g. pH, electrical conductivity, hardness) occurs in accordance with the Meandu Mine EA (EPML00709113) and Tarong and Tarong North power stations EA (EPPR00971913) including the Meandu Creek REMP, no future environmental harm to Meandu Creek is expected.

The following sections specifically address the potential for AMD related environmental harm from:

- build-up of metals in sediment downstream of Meandu Creek Dam
- elevated metal concentrations in Meandu Creek waters
- alteration of the pH of Meandu Creek Dam waters and release of sediment bound contaminants to the downstream environment
- elevated salinity levels in Meandu Creek waters.

S5.2.1.1 BUILD-UP OF METALS IN SEDIMENT

The results of the current assessment suggest that the greatest build-up of metals in sediment is occurring at site CM2 within Meandu Creek upstream of Meandu Creek Dam (in the channel between Meandu Mine CP3 and the dam) and within Meandu Creek Dam. Currently at site CM2, these metals may be bioavailable to aquatic flora and fauna, as indicated by results from the April 2018 survey. This site is located in the reach of Meandu Creek that widens into Meandu Creek Dam, it also contains a high abundance of instream Cumbungi rushes. A combination of these factors is likely resulting in the baffling of fine sediments and particles out of the water column and into the creek bed at this site. Further downstream of Meandu Creek Dam, while sediment-bound metals are settling in some areas, this is restricted to

reaches close to Meandu Creek Dam (i.e. within 500 m), and the results of April 2018 survey indicated these metals are unlikely to be bioavailable to aquatic flora and fauna. The results of aquatic flora and fauna surveys also demonstrate that sediment bound metals are not resulting in negative impacts to the environmental values of the receiving environment.

The chemistry of the water overlying the sediment plays a large role in determining whether sediment-bound metals are released into the water column; in particular, the pH, electrical conductivity and hardness of water. Under current water chemistry condition, there is no evidence of negative impacts to the environmental values of Meandu Creek. Therefore, ongoing monitoring of relevant water quality parameters in line with the Meandu Mine EA (EPML00709113) and Tarong and Tarong North power stations EA (EPPR00971913) including the Meandu Creek REMP, will be sufficient to protect the environmental values of Meandu Creek.

S5.2.1.2 ELEVATED METAL CONCENTRATIONS IN MEANDU CREEK SURFACE WATERS

The concentrations of dissolved metals in the Meandu Creek receiving environment were equal to or below the relevant WQOs during the field assessment, and are therefore unlikely to be toxic to aquatic flora and fauna. The results of aquatic flora and fauna surveys confirm this, with no impacts detected to communities in the receiving environment.

Provided that water quality is monitored into the future, and concentrations of metals and metalloids remain below the relevant WQOs and/or within the historical range, no future impacts from elevated metal concentrations in Meandu Creek surface waters are expected.

S5.2.1.3 CHANGES TO THE PHYSICAL WATER QUALITY IN MEANDU CREEK DAM

The Notice refers to the potential for *alteration of the pH of Meandu Creek Dam waters and release of sediment-bound contaminants to the downstream environment*. Long-term impacts to pH as a result of AMD from Meandu Mine have not been identified to date in the surface waters of Meandu Creek upstream of Meandu Creek Dam, or in the Meandu Creek Dam. This is as a result of the current monitoring and management of pH on-site. Further, as release water from Meandu Mine moves downstream, it is diluted with the large volume of water in Meandu Creek Dam. The pH of water downstream of Meandu Creek Dam is thus likely to be mainly influenced by the Tarong and Tarong North power stations.

The very high hardness of water in Meandu Creek (including upstream of, within and downstream of Meandu Creek Dam) is likely having a protective effect on aquatic flora and fauna, by reducing the toxicity of some metals. While the water hardness continues to be monitored and managed to remain within the historical range in Meandu Creek downstream of Meandu Creek Dam), an increase in the toxicity of metals in water is not expected to occur.

While pH, electrical conductivity and water hardness continue to be monitored and managed to remain within the acceptable range (i.e. EA limits / WQO range), the release of sediment-bound contaminants to the water column in Meandu Creek downstream of Meandu Creek Dam is not expected to occur.

S5.2.1.4 ELEVATED SALINITY LEVELS IN MEANDU CREEK SURFACE WATERS

Provided that discharges from Meandu Creek Dam do not cause sudden and drastic increases or decreases to the electrical conductivity in Meandu Creek downstream of Meandu Creek Dam, it is unlikely that the aquatic ecosystem (that has adapted to the current electrical conductivity range) will experience any acute or chronic effects. Electrical conductivity levels in the water released from Meandu Creek Dam are currently monitored and managed through the EA for the Tarong and Tarong North power stations (EPPR00971913). Gradual increases in the electrical conductivity of water released from Meandu Creek Dam are permitted under this EA in response to drought conditions, when the electrical conductivity of water sourced from Wivenhoe and Boondoomba dams is expected to increase. A number of studies and investigations have been completed to confirm that a gradual increase in electrical conductivity levels in the receiving environment will not result in environmental harm, and that releases of water with high electrical conductivity under drought conditions are more beneficial to the environmental values of this reach than ceasing releases altogether (IMEMS 2016). Further, increased monitoring is triggered during drought conditions to assess any impacts to receiving environment values associated with elevated electrical conductivity levels.

S5.2.2 GROUNDWATER

From review of geophysics data from surface to the full depth of investigation (~300 m depth) it is concluded that there is no evidence of flow paths to the west of Meandu Creek, with Meandu Creek acting as a capture zone for groundwater flow from the east (mining area) and west (with groundwater flow direction honouring topography in this area).

Groundwater flow to the west of Meandu Creek is also assessed to be unlikely for the following reasons:

- In the area adjacent to the North-West void, the deepest seam mined (Queen Seam) does not occur beneath Meandu Creek due to the dip of the coal measures from west to east in this area.
- The lower coal seams also dip from west to east (i.e. the occurrence of the coal seams gets shallower to the west), with the coal measures discontinued to the west against the faulted margin of the Tarong Basin. The dip of the strata (which shallows to the west) will also encourage the upward movement of groundwater as coal seams pinch out and/or get shallower beneath Meandu Creek.
- It is conceptualised that there will be a natural flow of groundwater towards Meandu Creek on the western side of the creek (because generally, the water table is a subdued reflection of topography and the topography is elevated to the west of Meandu Creek. In other words, it is conceptualised that Meandu Creek is a capture zone for groundwater flow from the west and east.

Ongoing review of groundwater monitoring bores will be required, with reference to AMD-indicator parameters and assessment with respect to the EA (EPML00709113) water quality triggers for Meandu Creek alluvium monitoring bore GW39.

S5.3 IDENTIFICATION OF SHORT-TERM AND LONG-TERM MEASURES TO PREVENT ENVIRONMENTAL HARM

S5.3.1 SURFACE WATER

Where water quality conditions remain unchanged, (i.e. remain within the historical range and/or comply with WQOs where applicable, and are monitored and managed in accordance with the current EA (EPML00709113) and/or Meandu Creek REMP), no further lines of investigation are considered necessary to prevent environmental harm on aquatic environmental values from AMD at Meandu Mine.

Stanwell will undertake ongoing monitoring in accordance with compliance requirements of the Meandu Mine EA (EPML00709113) and the Tarong and Tarong North power stations EA (EPPR00971913), as well as monitoring requirements of the Meandu Creek REMP, to ensure conditions specified remain unchanged. Stanwell will update the Meandu Creek REMP to include key AMD indicators (including concentrations of iron and manganese; Note: cobalt, nickel and zinc are already included). In the event that a change in the water quality conditions of key parameters is detected (e.g. pH falls below the WQO or hardness decreases so that water is no longer extremely hard), the procedures outlined in the Meandu Mine EA (EPML00709113) and the existing Meandu Creek REMP are sufficient to ensure environmental values in the receiving environment are protected.

Upstream of Meandu Creek Dam, site CM2 has abundant reeds and fine sediments, and appears to be effectively trapping metals and reducing transportation further downstream to the receiving environment. Further monitoring (e.g. toxicity and bioaccumulation) at site CM2 will be implemented to understand the potential impacts at this site. This monitoring will be aimed at determining the acute or chronic toxicity of sediment at site CM2. In accordance with the Revision of the Sediment Quality Guidelines (Simpson et al 2013), the following lines of evidence will be undertaken:

- Direct toxicity tests (three tests, including one whole sediment test).
- The concentration of metals in local biota tissue to assess bioaccumulation (this has been previously completed at Meandu Creek Dam, however metal concentrations in sediment at site CM2 are higher than those in the dam).

S5.3.2 GROUNDWATER

Potential short-term and long-term control measures for the groundwater seepage from the North-West Backfilled Pit and additional monitoring of groundwater for water level and water quality are set out below.

To maintain the water level in the North-West Backfilled Pit below the spill point of approximately RL432 mAHD in the western area and approximately RL435 mAHD in the area where the North-West Backfilled Pit spills to Bullgang Corner, Stanwell will implement a dewatering program (refer further to Section S7.4). It is noted that a number of trial groundwater extraction bores already exist (GW48, GW49), though these have not been pumped regularly to date. It is recommended that pumping occur initially from these bores, with additional bores added if/as required. Groundwater pumping would ideally be reduced or phased out over time as passive control measures become increasingly effective. The installation of additional monitoring bores may be required to assess the efficacy of pumping, for example, bores within the spoil at the locations where seepage has been assessed to occur. The number and locations of monitoring bores should be established as part of the design of the pumping bore network.

Dependent on the outcomes of the dewatering program, additional improvements may be considered in RSA1. A long term control may be considered to reduce the rate of recharge to the spoil in RSA1 through additional rehabilitation of the North-West Backfilled Pit to in line with current practices such as:

- contouring the spoil to encourage runoff of rainfall and discourage pooling of water that could report to the spoil as recharge
- revegetating the spoil to further reduce the potential for recharge to the spoil.

In addition, Stanwell will progressively phase out and rehabilitate the North-West B TSF, which is currently interpreted to seep directly to the North-West Backfilled Pit.

The installation of additional groundwater monitoring bore(s) to the west of Meandu Creek is recommended as a means of determining whether the high electrical conductivity recorded at GW78 is indicative of water quality to the west of Meandu Creek and to validate data from geophysics investigations. A separate assessment will be required to identify bore sites as there are limiting factors which include, steep terrain, limited access, and land access that need to be established.

Stanwell will undertake additional monitoring in the Black Creek Catchment and the area of the Queen West Backfilled Pit to provide further understanding of elevated electrical conductivity levels (non-AMD related) in these areas. Further information is provided in the Environmental Investigation Report and the Groundwater Technical Report (Appendix F).

S6 REQUIREMENT B5

NOTICE REQUIREMENT B5	SUMMARY REFERENCE	EIR REFERENCE	SPECIALIST REPORT
An appropriately qualified person(s) as defined in the notice must develop a predictive model for Meandu Mine in relation to potential AMD impacts to provide information relevant to development of: — Mine material management plans — Mine water management plans — Landform and rehabilitation management plans. The predictive model must include:			
— a material model (based on geochemical characterisation); and	Section S6.1	Section 9	Appendix G
— mine water modelling that takes into account surface water, ground water and in pit and in mine spoil water; and			
— potential contaminant pathways; and			
— capacity to predictively model acid production at Meandu Mine; and			
— capacity to predictively model the dissolution and transport of metals to the receiving environment from Meandu Mine; and			
— capacity to predictively model water quality impacts from AMD on groundwater and Meandu Creek.			

S6.1 PREDICTIVE MODEL

This section summarises development of and results from the Integrated Water Model (the model) developed by Golder Associates Pty Ltd (Golder) to predict potential AMD impacts from the Meandu Mine. Components of the model have been developed as a collaborative process using input from technical specialists as outlined in Table 2.

Table 2 Technical specialist input into development of the Integrated Water Model

NOTICE REQUIREMENT	TECHNICAL SPECIALIST INPUT
B5i) a material model (based on geochemical characterisation)	RGS
B5ii) mine water modelling that takes into account surface water, groundwater and in pit and in mine spoil water	JBT Consulting; Stanwell
B5iii) potential contaminant pathways	JBT Consulting; RGS
B5iv) capacity to predictively model acid production at Meandu Mine	RGS
B5v) capacity to predictively model water quality impacts from AMD on groundwater and Meandu Creek	Golder
B5vi) capacity to predictively model the dissolution and transport of metals to the receiving environment from Meandu Mine.	RGS; Stanwell

S6.1.1 LIFE OF MINE

Results of the material characterisation assessment have been used to inform the preparation of the 2017 Life of Mine Plan developed by Xenith Consulting for this environmental investigation. The 2017 Life of Mine Plan has been developed within the parameters of Meandu Mine continuing to provide coal to the Tarong and Tarong North power stations until 2037, while specifically modelling the placement at the mine of waste materials within a range of geochemical properties. The 2017 Life of Mine Plan with its final landforms and modelled placement of waste materials forms the base case of the Integrated Water Model and environmental assessments assessed throughout this environmental investigation.

S6.1.2 MINE INTEGRATED WATER MODEL

The Integrated Water Model has been developed in GoldSim (Version 12.0) (GoldSim Technology Group, 2018). The spatial extent of the model, defined in collaboration with Stanwell to inform the environmental investigation, includes all the elements of Meandu Mine bounded by Meandu Creek Dam and CP2 to the north, Meandu Creek to the west, the extent of the mine catchment to the east and the extent of the Meandu Creek catchment to the south.

Model elements represented within the model boundaries include:

- Water reservoirs (dams, tailings storage areas, ash storage areas, operating pits, decommissioned pits, backfilled pits)
- Inflows (rainfall, catchment runoff, water in tailings, water in ash, pumped water between mine dams, pumped inflows across model boundaries, seepage, groundwater inflow to deep pits, mine impacted water expressed from backfilled pits)
- Outflows (evaporation, overflows from water storages, seepage, pumped water between mine dams, pumped outflows across model boundaries, truck-fill water use, mine impacted water expressed from backfilled pits)
- Meandu Creek streamflow.

The model simulations use a daily time-step for the period 2016 to 2050 (post closure) for three scenarios using a low rainfall data record, a median rainfall data record and a high rainfall data record (based on SILO data drill 120-year synthetic rainfall data records for the location of Meandu Mine).

Changes in the model components from progression of the mine (such as, changes in material placement and related changes in catchments or rehabilitation) are applied according to the 2017 Life of Mine Plan in a step-wise manner for the years 2016, 2018, 2019, 2020, 2022, 2024, 2027, 2029, 2032, and 2037 (model reference years).

Prior to development of the Integrated Water Model in Goldsim, three model conceptualisations (representing surface water, groundwater and materials/ water quality) were prepared in collaboration with JBT Consulting, RGS and Stanwell. The conceptual models are shown as arbitrary two-dimensional (2D) cross-section of the modelled 3D network. Schematics of the inflows and outflows represented in each conceptual model are provided in Figure 9. The integration of the conceptual models provided the framework for subsequent development of the Integrated Water Model.

The Integrated Water Model was developed in Goldsim following confirmation of the conceptual models and model specification. Elements representing climate, global parameters and parameters specific to surface water, groundwater and materials/water quality modules have been incorporated, referenced and linked.

Calibration and validation simulations were conducted using measured site data for the period 2016 (calibration) and 2017 (validation). Sensitivity analysis was undertaken for selected results that are influenced by input parameters that are either assumed or uncertain.

The base case model incorporates any control measures that have been implemented by Stanwell prior to 2018 including:

- construction of RD27 and associated infrastructure including lime-dosing from the beginning of 2018
- the change to high density tailings from 2018 removing the tailings slurry flow input into the North-West B TSF and reducing water demand at the CHPP.

Additionally, the base case includes anticipated changes to water infrastructure required during the life of mine to support the 2017 Life of Mine Plan.

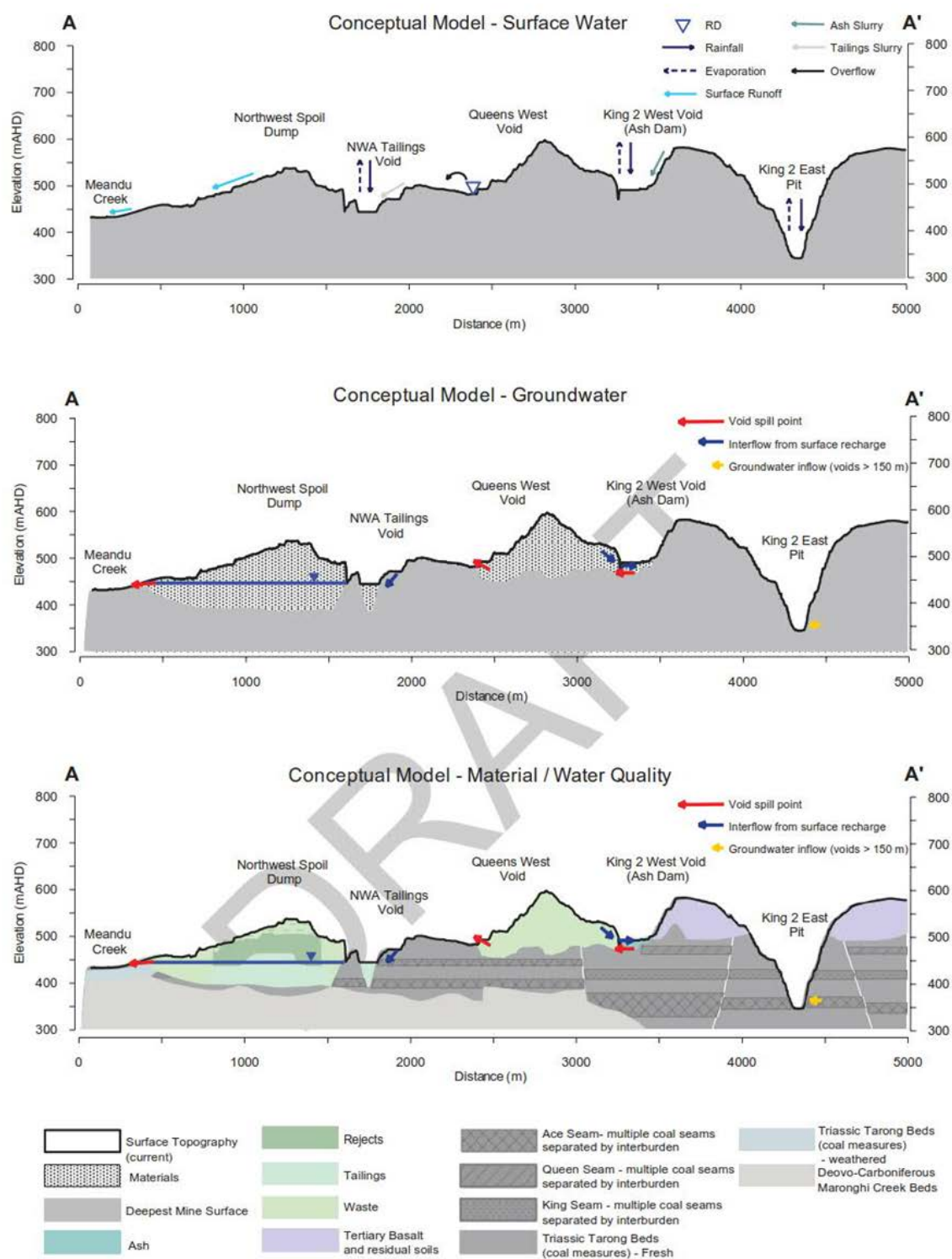


Figure 9 Surface water, groundwater and materials/water quality conceptual models

S6.1.3 GENERAL CAPABILITY AND USE

The model estimates the quantity and quality of water stored, transferred and discharged, over the life of mine up to and including closure. It provides a water balance within the model boundary which is the extent of the catchments reporting to the model components along with an indication of changes in water quality (mass balance of key analytes).

The model has the capacity to forecast:

- water containment in pits and water storages reported in terms of volume and water level
- rates of water transfer and water quantity transferred between storages
- quantity of water released at key discharge locations and compliance points
- quantity of groundwater intercepted by mining pits
- water quality (mass balance of key analytes) of retained water within pits and water storages
- water quality (mass balance of key analytes) at compliance points
- runoff from catchments in response to rainfall and evaporative losses
- changes in flow quantities to the Meandu Mine water infrastructure as a result of operational change and at closure
- the reliability of water supply to the CHPP
- water used at truck fill points.

S6.1.4 MODEL CALIBRATION AND VERIFICATION

Quantity parameters calibrated included:

- water flow rate at CP3
- water level in Meandu Creek Dam
- pit water level
- Australian Water Mass Balance (AWMB) parameters
- CHPP water demand (i.e. based on introduction of the solid bowl centrifuge)
- CHPP water use (i.e. water demand identified in the CHPP)
- seepage at Ramp 7 and Bullgang Corner
- pump efficiency of return water from the decant pond on the North-West B TSF and K2W-N ash dam.

2016/2017 measured data has been used for the calibration process where available.

S6.1.5 RESULTS

Simulations were run on daily time-steps for the period 2016 to 2050 for the base case simulation and two scenario trials of engineering controls. In most cases, three climate scenarios were used for this assessment; that is the low, median and high rainfall data records.

S6.1.5.1 BASE CASE

The base case scenario incorporates control measures that have been implemented at the Meandu Mine prior to 2018 including:

- construction of RD27 with continuous lime dosing of low flow inflows to RD27
- the change to high density tailings, removing the tailings slurry flow input to North-West B TSF and reducing water demand at the CHPP.

Additionally, the base case includes anticipated changes to water infrastructure required during the life of mine that will be required to support the 2017 Life of Mine Plan.

The sensitivity of modelled seepage at Bullgang Corner to North-West Backfilled Pit hydraulic parameters was examined by varying the hydraulic conductivity values of the materials in the groundwater (SEEP/W) model. As discharge from the North-West Backfilled Pit continues to be released, in all cases trialled and without further controls in place for the

duration of the simulation period that includes operations and post closure period (refer to Section S7, Table 4 for proposed control measures).

Flow at CP3 was simulated using three climate scenarios. There are periodic high and low flows in both operational and closure periods in all scenarios, as well as periods of no flow. Periods of no flow are more frequent during mining operations, but there is also an increase in background low flow during operations when compared to the post closure period.

Two scenarios were simulated for the operational and post closure period at Meandu Creek Dam.

- 1 The first, stops continuous low flow discharge when operations cease, and Meandu Creek Dam remains close to capacity during operations and the post closure period.
- 2 The second, allows a continuation of low flow discharge at current rates which results in a marked decline in storage volume of the Meandu Creek Dam.

As simulated in the 2017 Life of Mine Plan, once K2E Pit is dewatered, in preparation for mining that pit, the model indicates there may be periods of insufficient water supply available to the CHPP; particularly during extreme dry periods. Stanwell would monitor water requirements and availability in the lead up to this period and adjust water management practices.

In all climate scenarios simulated there are frequent high flow bypasses of inflow to RD27. Approximately half of the catchment and other flow to RD27 will bypass RD27 and go to RD7. This occurs during high flow events and does not appear to impact on water quality at CP3.

There is good confidence in the representation of electrical conductivity at CP3 in the modelled system. Exceedances of electrical conductivity occurred in the modelled system at periods of low flow. There was only a small, if any, change in electrical conductivity at CP3 in response to high flows of resurgent seepage from Bullgang Corner and Ramp 7 haul road drain.

There is less confidence in the representation of pH at CP3 and subsequently at Meandu Creek Dam (CP1) in the modelled system. Lower pH events in the modelling appear to be related to pit dewatering activities. Once pumping from pits ceases at closure, the pH as modelled returns to neutral conditions. pH is represented in the model based on the concentration of hydrogen ions only and may need revision to incorporate a hydroxide component. Undertaking more frequent in-pit pH sampling is recommended to assist in further verification of the model.

S6.1.5.2 ENGINEERING CONTROLS

Following a review of the base case results and source and extent information gathered from other technical specialists' studies; two engineering controls were identified for further assessment using the model.

- 1 Scenario 1: Dewatering of the North-West Backfilled Pit using 1 bore (at 6 L/s) or 2 bores (at 12 L/s).
- 2 Scenario 2: Improving (thickening) the rehabilitation cover to an area of 1 m – 3 m cover on the north-east surface and embankment of the North-West Backfilled Pit referred to as RSA1.

For the Scenario 1 case, four dewatering control measures were modelled which varied pump rate and pump end (i.e. either pump end at closure or limit of model run), as outlined in Table 3.

Table 3 *Dewatering scenarios*

SCENARIO	PUMP RATE (L/S)	PUMP START (YEAR)	PUMP END (YEAR)
1A	6	2019	2050
1B	12	2019	2050
1C	6	2019	2037
1D	12	2019	2037

Without dewatering (the base case) the water level gradually declines to below the spill elevation for resurgent seepage at Bullgang Corner (RL435 mAHD) by May 2028 (median of 100 model realisations); but remains above the diffuse seepage to Ramp 7 spill elevation (RL432 mAHD) at closure, indicating that resurgent seepage will continue to occur to Ramp 7 up until and beyond closure.

With dewatering at 6 L/s (Scenarios 1A and 1C) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by August 2021 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by July 2029 (median of 100 model realisations).

With dewatering at 12 L/s (Scenarios 1B and 1D) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by June 2020 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by September 2024 (median of 100 model realisations). By 2037, if two bores are used for dewatering, the water level may be reduced to RL424.3 mAHD, that is, approximately 8 m below the diffuse seepage spill point. The reduction is predicted to be in the order of 1.9 m if one bore is used.

However, with North-West Backfilled Pit dewatering bores in operation (to reduce water levels in the North-West Backfilled Pit), there was a marked increase in electrical conductivity at CP3 during the closure period due to continuous overflow of treated water from RD27 (i.e. water no longer being used on-site). The primary inflow to RD27 during this period is low flow seepage from the North-West Backfilled Pit that, when treated, has a modelled electrical conductivity of 3700 $\mu\text{S}/\text{cm}$. Alternatively, if dewatering is discontinued at the end of mining the electrical conductivity at CP3 remained below 2100 $\mu\text{S}/\text{cm}$. As a result, the Integrated Water Model Report (Golder 2018) (Appendix H) recommends that the North-West Backfilled Pit dewatering bores are switched off at the end of mining in 2037. There is a slight rise in water elevation in Scenarios 1C and 1D after dewatering ceases at the end of mining (of less than 0.5 m by 2050 for Scenario 1D and less than 1 m by 2050 for Scenario 1D) as the model assumes (conservatively) that there is zero outflow through the floor of the pit.

Seepage from the North-West Backfilled Pit reporting to Bullgang Corner and diffuse seepage at Ramp 7 is comprised of resurgent seepage as well as interflow. The resurgent seepage is the constant low flow component and interflow occurs in response to rainfall. The low flow component of the seepage ceases to occur with dewatering, however, discharge from the North-West Backfilled Pit will continue due to infiltration and interflow in response to rainfall events.

In the dewatering scenarios trialled, as the water level in the North-West Backfilled Pit is drawn down the resurgent seepage rate declines. The faster the drawdown the lower the resurgent seepage rate. The quantity of high flow diverted around RD27 does not change between scenarios, because there is capacity in RD27 low flow inlets sufficient to manage the constant rate dewatering flow.

A second engineering control has been simulated using the model, that is, application of an improved cover system to RSA1. On average, there is a 13% reduction in infiltration to the North-West Backfilled Pit; however, this change is insufficient to make a significant change to the water surface elevation in the North-West Backfilled Pit.

Section S7.4.2.1 outlines recommendations as an outcome of this environmental investigation for the North-West Backfilled Pit.

S6.2 MANAGEMENT RECOMMENDATIONS

As a result of the identification of AMD issues at the North-West Backfilled Pit, Stanwell has implemented controls and made a number of infrastructure and mine planning management changes since 2015/2016. These include:

- initial changes to water management infrastructure
- construction of seepage collection dam RD27, automated lime-dosing and pump and pipework
- installation of solid bowl centrifuges at the CHPP to dewater tailings
- changes to rejects placement
- rehabilitation design changes.

These current management measures which commenced in 2015/2016, have been included in the Integrated Water Model developed for this environmental investigation. In addition to these management measures, Section S7.4.2 outlines recommendations for future management measures as an outcome of this environmental investigation. To assist with future preparation of these documents (as required) the management actions and recommendations have been separated into the following categories:

- Mine management
- Mine water management
- Landform and rehabilitation
- Closure.

This is discussed further in Section S7 to address Requirement B6 of the Notice.

S7 REQUIREMENT B6

NOTICE REQUIREMENT B6	SUMMARY REFERENCE	EIR REFERENCE	SPECIALIST REPORT
<i>An appropriately qualified person(s) as defined in the notice must develop a report detailing and evaluating the findings from requirements (1) to (5) above and prepare a report based on these findings for submission to the department. The report must:</i>			
— Summarise the findings of requirements (1) to (5) above; and	Section S7.1	Section 11	
— Identify the level of impact AMD from Meandu Mine has had on environmental values of receiving environments; and	Section S7.2	Section 8	Appendix E Appendix F
— Identify potential impacts of AMD from Meandu Mine on environmental values of receiving environments; and	Section S7.3	Section 8	Appendix E Appendix F
— Provide recommendations in regard to management and treatment of AMD at Meandu Mine.	Section S7.4	Section 10	Appendix E Appendix F

S7.1 ENVIRONMENTAL INVESTIGATION REPORT – SUMMARY OF FINDINGS

The Environmental Investigation Report (EIR) addresses the requirements of the December 2016 Notice as summarised in this Summary of Notice Requirement Findings.

As required by Section B7 of the Notice, over the course of the investigation, Stanwell has progressively updated EHP (now DES) on the actions and outcomes of the investigations. Progress updates were provided on:

- Progress update 1: 31 May 2017
- Progress update 2: 13 September 2017
- Progress update 3: 22 May 2018.

The current and potential impact from AMD has been addressed under Requirement B4 (Section S5 of this Summary of Notice Requirement Findings).

The static and kinetic geochemical data combined with the geological model, overburden model and material balances, site-based evaluations and the long term (circa 1986) water quality data indicate that the potential for acidic drainage to be produced in pits (other than the North-West Backfilled Pit) is very low or unlikely. Based on the outcome of the environmental investigation, the AMD issues at Meandu Mine are considered by RGS to be relatively minor and able to be managed through the implementation of changes to the mining and placement of mined materials. The removal and treatment (with lime) of water from the North-West Backfilled Pit will reduce the water level at this location and remove the accumulated weathering products from the groundwater. Because tailings water will no longer be placed into the North-West B TSF when it is decommissioned, recharge to the groundwater system in this pit will be limited to surface infiltration of rain through the backfilled spoil.

S7.2 LEVEL OF ENVIRONMENTAL HARM FROM AMD

The level of environmental harm from AMD has been addressed under Requirement B4 (Section S5 of this Summary of Notice Requirement Findings).

Based on this environmental investigation, there is no evidence of negative impacts to the environmental values of Meandu Creek as a result of AMD from Meandu Mine. Overall, aquatic ecological communities in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam. Water quality conditions, including hardness and pH, are likely to be reducing the toxicity of metals in water. Further, metals in sediments in some areas of Meandu Creek downstream of Meandu Creek Dam are likely to be immobilised by the availability of sulfides and are unlikely to cause acute or chronic toxicity to aquatic flora and fauna.

Where water quality conditions remain unchanged (i.e. remain within the historical range and/or comply with WQOs where applicable, and are monitored and managed in accordance with the current EA (EPML00709113) and/or Meandu Creek REMP), no further lines of investigation are considered necessary to prevent environmental harm on aquatic environmental values occurring from AMD at Meandu Mine.

S7.3 POTENTIAL IMPACTS OF AMD FROM MEANDU MINE

The potential for future environmental harm from AMD has been addressed under Requirement B4 (Section S5 of this Summary of Notice Requirement Findings).

Future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine are considered unlikely. The information presented in this investigation shows there is no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment.

While a build-up of metals in sediment within 500 m downstream of Meandu Creek Dam has occurred, the results of the April 2018 survey indicated these metals are unlikely to be bioavailable to aquatic flora and fauna. Provided discharges from Meandu Creek Dam do not cause sudden and drastic increases or decreases to the electrical conductivity in Meandu Creek downstream of Meandu Creek Dam, it is unlikely that the aquatic ecosystem within the receiving environment (that has adapted to the current electrical conductivity range) will experience any acute or chronic effects. Provided current management measures continue to be implemented and future monitoring of key water quality parameters (e.g. pH, electrical conductivity, hardness) occurs in accordance with Meandu Mine EA (EPML00709113) water quality limits, no future environmental harm to Meandu Creek is expected.

The chemistry of the water overlying the sediment plays a large role in determining whether sediment-bound metals are released into the water column; in particular, the pH, electrical conductivity and hardness of water. Under current water chemistry conditions, there is no evidence of negative impacts to the environmental values of Meandu Creek. Therefore, ongoing monitoring of relevant water quality parameters in line with the Meandu Mine EA (EPML00709113) and Tarong and Tarong North power stations EA (EPPR00971913), including the Meandu Creek REMP, will be sufficient to protect the environmental values of Meandu Creek and no impacts to environmental values are anticipated.

S7.4 RECOMMENDATIONS FOR MANAGEMENT AND TREATMENT OF AMD AT MEANDU MINE

S7.4.1 CURRENT MANAGEMENT MEASURES

As a result of the identification of AMD issues at the North-West Backfilled Pit, Stanwell has implemented a number of interim controls and made a number of infrastructure and mine planning management changes since 2015/2016. These have included:

- initial changes to water management infrastructure (lime-dosing and water reuse) to minimise the amount of Ramp 7 and Bullgang Corner seepage water reporting to CP3 and Meandu Creek Dam
- construction of seepage collection dam RD27, automated lime-dosing and pump and pipework
- installation of solid bowl centrifuges at the CHPP to dewater tailings and decommissioning of North-West B TSF over coming years
- changes to rejects placement
- rehabilitation design changes - introducing 6 m of NAF cover as design criteria in the final cover over rejects areas in Hitachi Hill and future areas rehabilitated from 2016 onwards.

S7.4.2 FUTURE MANAGEMENT MEASURES

The current management measures presented in Section S7.4.1 have played an important role in development of engineering AMD control options as an outcome of this environmental investigation. As the short-term measures were established at commencement of this environmental investigation, they have been implemented on-site and incorporated into the predictive model base case simulations. This has enabled a more targeted list of management measures that are detailed in Table 4 and Table 5. The management measures presented below have focused on continuation of existing practices and where appropriate, new recommendations for future management.

Note: additional groundwater monitoring is recommended (refer JBT 2018 – Appendix F) in relation to the saline plume close to the Queen West void and high electrical conductivity in an area within the Black Creek catchment. This monitoring will be undertaken in line with requirements for the groundwater monitoring program outlined in the EA (EPML00709113). As neither of these areas are determined at this stage to be related to AMD, they are not discussed further in the management actions presented in Table 4 and Table 5, but are discussed in the Section S4.2 of this Summary of Notice Requirement Findings, the Environmental Investigation Report and the Groundwater Technical Report (Appendix F).

S7.4.2.1 DOMAIN SPECIFIC RECOMMENDATIONS AS AN OUTCOME OF THE EIR

NORTH-WEST BACKFILLED PIT

Objective: Stanwell will implement a dewatering program using installed dewatering system bores (GW48, GW49) in the North-West Backfilled Pit to reduce the water level in the pit to well below the spill elevation for diffuse and resurgent seepage (approximately RL432 mAHD in the western area of the North-West Backfilled Pit (Ramp 7) and approximately RL435 mAHD in the area where the North-West Backfilled Pit spills to Bullgang Corner). Refer to Recommendation A1, Table 4. The results of the Integrated Water Model have indication that with dewatering at 6 L/s (Scenario 1A) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by August 2021 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by July 2029 (median of 100 model realisations). With dewatering at 12 L/s (Scenario 1B) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by June 2020 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by September 2024 (median of 100 model realisations).

Note: A second engineering control has been simulated using the model, that is, application of an improved cover system to the RSA1. On average, there is a 13% reduction in infiltration to the North-West Backfilled Pit however, this change is

insufficient to make a significant change to the water surface elevation in the North-West Backfilled Pit and should not be considered as an engineering control on its own. Based on the performance monitored from the dewatering program, additional improvements to the cover thickness may be considered as a long-term control measure. *Refer to Recommendation A2, Table 4.*

Deposition of tailings to the North-West B TSF, which is currently interpreted to seep directly to the North-West Backfilled Pit, is planned to cease by end of calendar year 2019 (*Refer to Recommendation A3, Table 4*).

Progressive rehabilitation of the North-West B TSF will then commence as per Condition G8 of the EA (EPML00709113) (*Refer to Recommendation A4, Table 4*).

Table 4 Proposed recommendations as an outcome of the Environmental Investigation Report for the North-West Backfilled Pit

RECOMMENDATION FROM EIR		STATUS	ACTION REQUIRED	PROPOSED TIMING	SOURCE
A1	Implementation of dewatering program	NEW	Development and implementation of a dewatering program for the North-West Backfilled Pit. Based on the recommendations from Golder and JBT (2018), this program is to include as a minimum: — Utilisation of current extraction bores (i.e. GW48 and GW49) for pumping test to monitor efficiency of pumping for reduction of water level in spoil. — Recommendations to monitor flow rate and water quality at the Bullgang Corner and Ramp 7 intakes to RD27 to validate head-seepage relationships and interflow parameters in the model. — Consideration to install instrumentation (i.e. Lysimeter or vertical series of vibrating wire piezometers) or other methods for measuring rainfall infiltration to the North-West Backfilled Pit. — (if required) Proposed installation of additional groundwater extraction bores in spoil within the areas where seepage has currently been identified (JBT 2018). — As an outcome of the program, recommendations in relation to monitoring water level in the North-West Backfilled Pit required to validate or refine parameters used for determining interflow and recharge in the pit. Note: Groundwater extraction is an engineering solution that would ideally be reduced or phased out over time as passive control measures become increasingly effective.	Establishment in FY18/19	JBT Golder
A2	Improvement of cover system (target area RSA1)	NEW	(if required) Based on the effectiveness of Recommendation (A1), additional improvements may be considered in the RSA1 area, such as: — Change to the cover thickness. — Contouring the spoil to encourage runoff of rainfall and discourage pooling of water that could report to the spoil as recharge (current practice). — Revegetating the spoil to further reduce the potential for recharge to the spoil (current practice).	Long-term measure to be developed (if required) after results of dewatering program are known.	Golder JBT

RECOMMENDATION FROM EIR		STATUS	ACTION REQUIRED	PROPOSED TIMING	SOURCE
A3	Cease tailings deposition in North-West B TSF	PLANNED	Decommissioning of North-West B TSF, which is currently interpreted to seep directly to the North-West Backfilled Pit.	Cease of tailings deposition by end of calendar year 2019	Stanwell
A4	Rehabilitation of North-West B TSF	PLANNED	Progressive rehabilitation of the North-West B TSF, as per Condition G8 of the EA (EPML00709113).	To commence after tailings deposition ceases (refer to A3)	Stanwell

S7.4.2.2 GENERAL RECOMMENDATIONS AS AN OUTCOME OF THE EIR

LANDFORM AND REHABILITATION

No additional landform and rehabilitation actions have been identified other than those identified previously for the North-West Backfilled Pit.

While no recommendations are identified as an outcome of this environmental investigation, it is acknowledged that the Mineral and Energy Resources (Financial Provisioning) Bill 2018, if passed, will require a Progressive Rehabilitation and Closure Plan. The overall findings from this environmental investigation will inform the Rehabilitation Planning Part of the new Progressive Rehabilitation and Closure Plan for Meandu Mine.

CLOSURE MANAGEMENT

No additional closure management actions have been identified as an outcome of this Environmental Investigation Report.

While no recommendations are identified as an outcome of this environmental investigation, it is acknowledged that the Mineral and Energy Resources (Financial Provisioning) Bill 2018, if passed, will require a Progressive Rehabilitation and Closure Plan. The overall findings from this environmental investigation will inform the Rehabilitation Planning Part of the new Progressive Rehabilitation and Closure Plan for Meandu Mine.

MINE MATERIAL MANAGEMENT

Objective: In addition to short-term management actions itemised in Section S7.4.1, the potential for oxidation will be further reduced through the incorporation of fine-grade rejects and tailings when the dewatering process is implemented at site, whereby pore voids within the coarse rejects will be filled with highly plastic low permeability tailings limiting oxidation and permeability. *Refer to Recommendations B1 and B2, Table 5.*

MINE WATER MANAGEMENT

Objective: In addition to short-term management actions itemised in Section S7.4.1, site water modelling will be applied to test and confirm future water management changes as required. *Refer to Recommendation B3, Table 5.*

RECEIVING ENVIRONMENT

Objective: The current study is considered sufficient to confirm that AMD is not having a negative impact on the environmental values of Meandu Creek. Long-term, ongoing monitoring of water quality parameters (as such pH, water hardness and electrical conductivity) in line with current procedures is recommended, in order to detect potential impacts in future. *Refer to Recommendations B4, B5 and B6, Table 5.*

Table 5 General site recommendations as outcome of the EIR

RECOMMENDATION FROM EIR		STATUS	ACTION REQUIRED	TIMING	SOURCE
B1	Rejects materials placement	EXISTING	This method is established as part of mine planning at Meandu Mine and the performance of this method will be monitored over the life of mine. For example: — Rejects material from the CHPP is being dumped approximately 6 m beneath the final landform profile to allow adequate capping to be constructed over the top of the rejects. When the reject dumps reach their final landform capacity, they will be regraded, capped with a minimum 6 m NAF cover material, and rehabilitated as per EA (EPML00709113) requirements. — Continue with current Meandu Mine management practice of limiting storage/exposure time of coarse reject materials at the reject stockpile to less than two weeks that appears to be an effective way of controlling the risk of acidic drainage generation. — The combined reject and tailings stream will be placed into the spoil dumps and progressively co-mingled or encapsulated with overburden and interburden.	In place since 2016	Xenith/ Stanwell RGS
B2	Materials testing (ongoing)	EXISTING	Ongoing independent geochemical assessment and advise on material management to minimise the likelihood of future occurrence of AMD.	Current	RGS/ Stanwell
B3	Application of Integrated Water Model as a predictive tool	EXISTING	In addition to current application of the Integrated Water Model for this environmental investigation, the following actions will be continued to assist in improving the reliability of modelling predictions: — Monitoring of water use in the CHPP following installation of solid bowl centrifuge, including separate monitoring of water from retention dams and raw water use. — Water quality monitoring of water stored in pits (including pH) either directly or indirectly via dewatering lines.	Current	Golder

RECOMMENDATION FROM EIR		STATUS	ACTION REQUIRED	TIMING	SOURCE
B4	Groundwater monitoring	NEW	Stanwell will establish additional monitoring bore(s) to the west of Meandu Creek to monitor the high electrical conductivity as recorded at GW78 and to validate data from geophysics investigations.	Establishment in FY18/19	JBT
B5	Update of Meandu Creek REMP	NEW	Meandu Creek REMP is updated to include: — Key indicators for AMD (e.g. including concentrations of iron and manganese – Note cobalt, nickel and zinc are already included). Where a change is detected and are outside the WQOs or historical range, an additional investigation procedure will be triggered, as per the Meandu Creek REMP.	Establishment in FY18/19	ESP
B6	Further monitoring of toxicity of sediment between CP3 and Meandu Creek Dam (detected at site CM2)	NEW	Monitoring of toxicity and bioaccumulation of the build-up of metals in sediment at site CM2 in the channel between CP3 and the Meandu Creek Dam. While Meandu Creek upstream of Meandu Creek Dam is not managed to protect aquatic ecosystem values, further monitoring to determine the acute or chronic toxicity of sediment at site CM2 will be undertaken to understand the toxicity at this site. In accordance with the Revision of the Sediment Quality Guidelines (Simpson et al 2013), the following testing will be undertaken: — Direct toxicity tests (three tests including one whole sediment test). — The concentration of metals in local biota tissue to assess bioaccumulation (Note: this has previously been completed at Meandu Creek Dam, however metal concentrations in sediment at site CM2 are higher than those in the dam).	Establishment in FY18/19	ESP

GLOSSARY OF TERMS AND ACRONYMS

AC	<u>Acid consuming</u> : Mine waste that has the potential to consume substantial acidity.
ABA	<u>Acid base account</u> : An analytical technique applied to mine waste and geological materials that evaluates the balance between acid-generating processes (oxidation of sulfide materials) and acid-neutralising processes. It is used to predict the potential of that material to be acid-producing or acid-neutralising.
Administering Authority	The agency that administers the environmental authority (EA) provisions under the <i>Environmental Protection Act 1994</i> (EP Act).
Acid forming	Acid forming mine material typified as having an existing pH < 5.
Al	Aluminium
Alluvium	Soil, clay, silt or gravel deposited by flowing water as it slows in a river bed, delta, estuary or floodplain.
AMD	<u>Acid and metalliferous drainage</u> from mine waste materials characterised by low pH, elevated metal concentrations, high sulfate concentrations and high salinity.
ANC	<u>Acid-neutralising capacity</u> : A measure of a sample's maximum potential ability to neutralise acid. Expressed as kg H ₂ SO ₄ equivalent per tonne of sample.
ANZECC	Australian and New Zealand Environment Conservation Council
Appropriately qualified person	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.
Aquifer	Rock or sediment capable of holding and transmitting groundwater; a layer of water-bearing material which is permeable and can transmit significant quantities of water.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
Ash	Inorganic residue (fly and bottom ash) after incineration of coal from the Tarong and Tarong North power stations. It is considered to be non-acid forming (NAF).
AWBM	Australian Water Balance Model
Backfill	Geologic materials returned to an open pit or placed back into an underground mine, after desirable minerals have been removed, to bring a surface mine back to original contour, partially refill an open pit, or to improve stability of underground workings.
Background	Natural concentrations of an element in natural materials that exclude human influence.
BoM	Bureau of Meteorology
Catchment	The total area draining into a river, reservoir, or other body of water.
Ca(OH) ₂	Calcium hydroxide
CEnvP	Certified Environmental Practitioner
Circum-neutral	A pH value that is close to neutral.

Co	Cobalt
Coal	Carbon-based sedimentary rock formed by the accumulation and decomposition of plant material in layers, which can be used as a combustible fuel. Main types, in order of highest rank to lowest rank, are black coal (anthracite, bituminous, sub-bituminous), brown coal (lignite) and peat (considered to be a precursor to coal).
Coal reject	Solid waste produced during the processing of coal, typically from a Coal Handling and Preparation Plant (CHPP). Coal reject typically comprises crushed siltstone, mudstone and fine-grained sandstone, which is mined as coal seam roof, parting or floor material during the extraction of Run-of-Mine (RoM) coal. Coal reject is commonly produced in different size fractions – fine and coarse reject.
Coal seam	A layer of coal within the geological strata.
Coarse reject	Coarse solid waste material (typically greater than 1.5 mm grain size) produced from the CHPP as part of the processing of coal.
CRS	Chromium reducible sulfur
DES	Department of Environment and Science (Queensland)
Dewatering	Draining, permanently or temporarily, a wet area of land or an aquifer.
DNRM	Department of Natural Resources and Mines (Queensland) (former)
DNRME	Department of Natural Resources, Mines and Energy (Queensland)
EA	<u>Environmental Authority</u> : A licence to operate, issued in accordance with the <i>Environmental Protection Act 1994</i> (EP Act) (Queensland), that imposes conditions on environmentally relevant activities to reduce or avoid potential environmental impacts.
EHP	Department of Environment and Heritage Protection (Queensland) (former)
EC	<u>Electrical conductivity</u> : The ability of water or soil solution to conduct an electrical current; a measure of salinity. Expressed as $\mu\text{S}/\text{cm}$.
Environmental harm	An adverse effect, or potential adverse effect (whether temporary or permanent and of whatever magnitude, duration or frequency) on an environmental value, and includes environmental nuisance. Environmental harm may be caused by an activity: (i) whether the harm is a direct or indirect result of the activity; or (ii) whether the harm results from the activity alone or from the combined effects of the activities or factors (Section 14: <i>Environmental Protection Act 1994</i>)
EP Act	<i>Environmental Protection Act 1994</i> (Queensland)
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Commonwealth)
EPP (Water)	Environmental Protection (Water) Policy 2009 (Queensland)
Ephemeral	Relates to the amount of time that surface water persists in a watercourse or wetland; ephemeral watercourses flow only during significant rainfall events and for a short-time following rainfall events.

EV	<u>Environmental Value:</u> a) A quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or b) another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation (Section 9: <i>Environmental Protection Act 1994</i>).
Fault	Zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust.
Fe	iron
Fe ²⁺	Ferrous iron
Fe ³⁺	Ferric iron
Fe(OH) ₃	Ferrous hydroxide
Fe ₂ O ₃	haematite
Groundwater	Water that is present in the pores and cracks of the saturated or capillary zone and water that has been present in caves.
H	hydrogen
H ₂ CO ₃	Carbonic acid
H ₂ O	water
H ₂ SO ₄	Sulfuric acid
ha	hectares
ISOG	Interim Sediment Quality Guidelines
JORC	Joint Ore Reserves Committee
KLC	<u>Kinetic leach column</u> : Procedure used to measure the geochemical/weathering behaviour of a sample of mine material over time.
km	kilometres
Leachate	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.
LoR	<u>Limit of reporting</u> : Laboratory detection limit for the reporting
L/s	Litres per second
m	metres
mAHD	metres Australian Height Datum
mBGL	metres below ground level
mg/kg	milligram per kilogram

mg/L	milligrams per litre
Mine-affected water	Means the following types of water: — pit water, tailings dam water, processing plant water — 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 — 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 — groundwater which has been in contact with any area disturbed by mining activities which have not yet been rehabilitated — groundwater from the mine's dewatering activities — a mix of mine affected water (listed above) and other water. It 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: — 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 — land that has been partially 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: — areas that have been capped and have monitoring data demonstrating hazardous material adequately contained with the site — evidence provided through monitoring that the relevant surface water would have met the water quality parameters for mine affected water release limits in the environmental authority, if those parameters had been applicable to the surface water runoff.
ML	megalitre
ML	Mining lease
mm	millimetres
Mn	<u>M</u> anganese
MPA	<u>Maximum potential acidity</u> : Calculated by multiplying the total sulfur or sulfide sulfur (CRS) content of a sample by 30.6 (stoichiometric factor) and expressed as kg H ₂ SO ₄ per tonne.
Mtpa	million tonnes per annum
NaCl	Sodium chloride
NAF	<u>Non-acid forming</u> : Geochemical classification criterion for a sample that will not generate acid conditions.

NAF-UC	<u>Non-acid forming uncertain</u> : Material that is essentially geochemically inert and may produce circum-neutral drainage in the range of pH 5 to 6.
NAPP	<u>Net acid producing potential</u> : Calculated by subtracting the ANC from the MPA. Expressed as kg H ₂ SO ₄ per tonne.
NATA	National Association of Testing Authorities
NC Act	<i>Nature Conservation Act 1992</i> (Queensland)
NHMRC	National Health and Medical Research Council
Ni	Nickel
NPR	<u>Neutralisation potential ratio</u> :
NTU	<u>Nephelometric Turbidity Unit</u> : measurement of turbidity
PAF	<u>Potentially acid forming</u> : Geochemical classification criterion for a sample that has the potential to generate acid conditions.
PAF-LC	<u>Potentially acid forming – Low capacity</u> : material which has the potential to produce minor acid
PAF-UC	Potentially acid forming uncertain:
PET	Plecoptera / Ephemeroptera / Trichoptera
Permeability	The ability of a rock to transmit water.
pH	A measure of hydrogen ion (H ⁺) concentration; generally expressed as pH.
PhD	Doctor of Philosophy
PIMS	Plant Information Management System
PSD	Particle size distribution
QWQG	Queensland Water Quality Guidelines
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; or c) an area of land that is not specified as “surface rights areas” in the environmental authority (EA).
Recharge	The entry into the saturated zone of water made available at the water table surface, together with the associated flow away from the water table within the saturated zone
Rehabilitation	The process of reshaping and revegetating land to restore it to a stable landform.
Representative	A sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activity.
RL	<u>Reduced level</u> : Relative to mean sea level as distinct from depths to water (EA EPML00709113).

RoM	<u>Run-of-Mine</u> : Coal as it comes from the mine prior to screening or processing.
RPEQ	Registered Professional Engineer of Queensland
S	Sulfur
SILO	Scientific Information for Land Owners
SMD	<u>Slightly to moderately disturbed</u> : ecosystems where aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity (EPP (Water))
SO ₄ ²⁻	Sulfate
Spoil	Waste rock material overlying and between coal seams. Spoil overlying a mined coal seam is called overburden. Spoil between mined coal seams is called interburden.
SQG-high	Sediment Quality Guideline – high value
SQGV	<u>Sediment Quality Guideline Values</u> : as outlined in the Revision of the Sediment Quality Guidelines (Simpson et al. 2013)
Static test	Procedure for characterising the geochemical nature of a sample at a single point in time. Static tests may include measurements of mineral and chemical composition of a sample and the Acid Base Account.
Sulfide	Sulfates that can oxidise and produce acidity.
Tailings	Finely ground materials from which the desired mineral values have been largely extracted. At coal mines, tailings represent the coarse and fine rejects from the coal processing plant.
TDS	<u>Total dissolved solids</u> : A measure of the inorganic salts (and organic compounds) dissolved in water.
TEM	Transient electromagnetic
TS	<u>Total sulfur</u> : content of a sample generally measured using a ‘LECO’ analyser expressed as TS%.
TSF	<u>Tailings storage facility</u> : Facility designed for the storage of unsaturated tailings material produced during ore processing.
Trigger level	The point at which some form of action is begun, such as exceedance of guidelines.
Turbidity	The cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye. The measurement of turbidity is a key test of water quality.
Void	Any constructed, open excavation in the ground.
Waste rock	Material such as soils, barren or uneconomic mineralised rock that surrounds a mineral or coal or body and must be removed in order to mine the ore. Generally referred to as overburden, interburden, interseam or spoil in coal mines.
Water table	The level of groundwater; the upper surface of the zone of saturation for underground water.
Water quality	The chemical, physical and biological condition of water in terms of suitability of the water for various intended uses.

Watercourse	A river, creek or other stream, including a stream in the form of an anabranch or a tributary, in which water flows permanently or intermittently, regardless of the frequency of flow events: — in a natural channel, whether artificially modified or not — in an artificial channel that has changed the course of the stream — it also includes weirs, lakes and dams (<i>Water Act 2000</i>).
WQOs	<u>Water Quality Objectives</u>: long-term goals for water quality management. They are measures, levels or narrative statements of particular indicators of water quality that protect EVs. They define what the water quality should be to protect the Environmental Values—after consideration of the socio-economic assessment of protecting the water quality.
Zn	zinc
µg/L	micrograms per litre
µS/cm	micro Siemen per centimetre.

ABBREVIATIONS SPECIFIC TO MEANDU MINE

CHPP	Coal Handling and Preparation Plant
CP	Compliance point
K1	King 1
K2	King 2
K2E	King 2 East
K2N	King 2 North
K2W	King 2 West
K4E	King 4 East
K4S	King 4 South
RD	Retention dam
REMP	<u>Receiving Environment Monitoring Program</u> : Relates specifically to Meandu Creek Receiving Environment Monitoring Program
RSA	Rejects Storage Area
Stanwell	Stanwell Corporation Limited
TEC	Tarong Energy Corporation

1 PROJECT OVERVIEW

1.1 INTRODUCTION

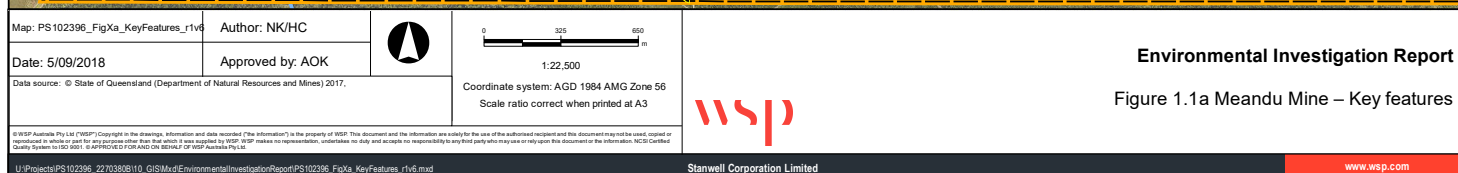
On 21 December 2016, the former Department of Environment and Heritage Protection (EHP) (now Department of Environment and Science (DES)) issued TEC Coal Pty Ltd (a subsidiary of Stanwell Corporation Limited (Stanwell)) with a notice (DES reference cA34208) to conduct or commission an environmental evaluation under Section 326B of the *Environmental Protection Act 1994* (EP Act) (the Notice). A copy of this Notice is attached as Appendix A.

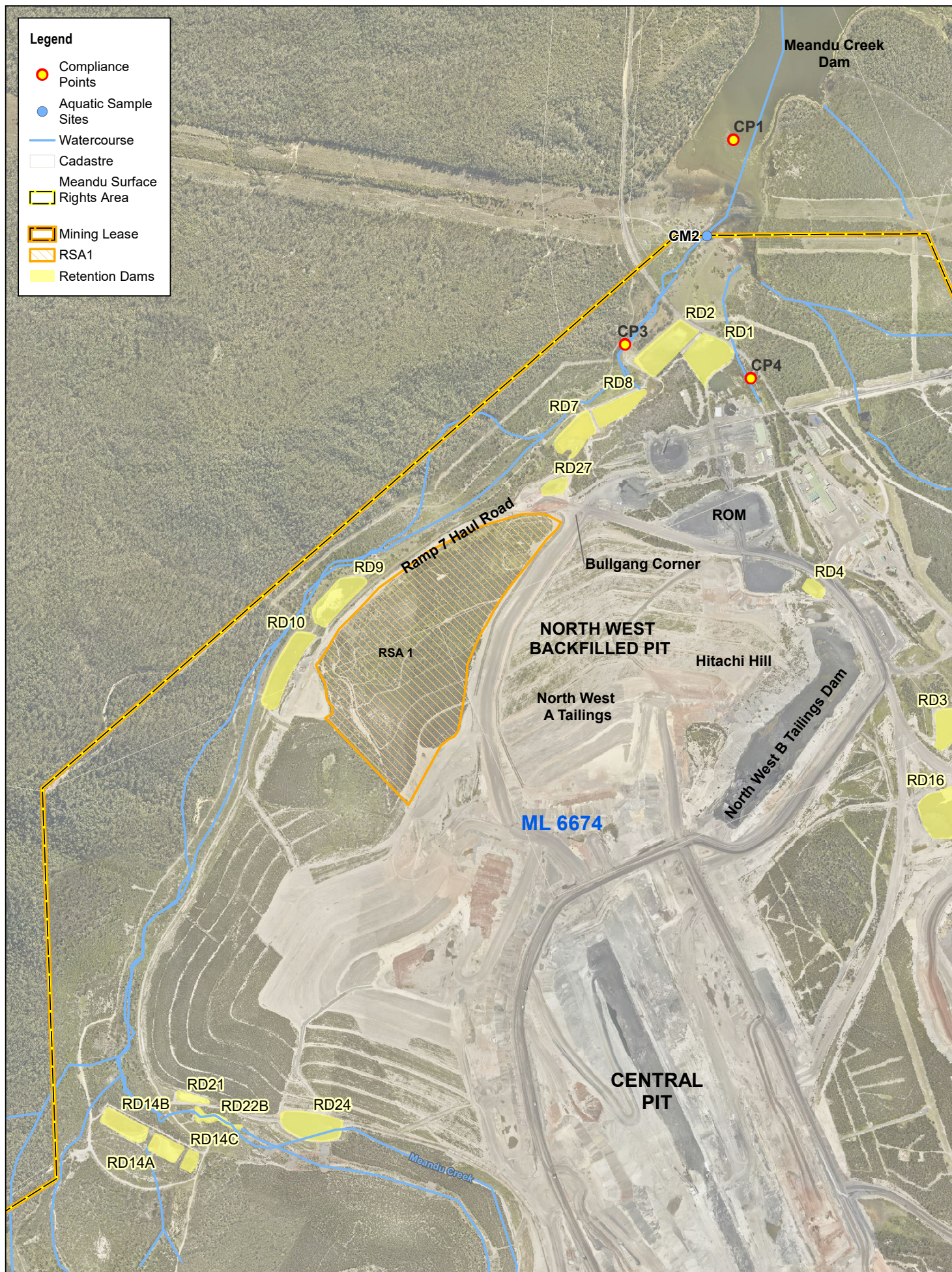
The grounds for the environmental evaluation relate to the identification of acid and metalliferous drainage (AMD) at Meandu Mine and the potential for this AMD to cause environmental harm. As the full nature and extent of the AMD was unknown, EHP (now DES) required that an environmental investigation be undertaken to determine whether environmental harm has resulted from AMD at the Meandu Mine. AMD was identified as reporting by overland flow to retention dam (RD) 7 in the retention dam network on the western side of the mine, where it was mixing with other mine affected water. Water from RD7 flows to RD8 where it is either re-used for site purposes or reports to the Meandu Creek Dam via release (compliance) point 3 (CP3). AMD reporting to RD7 is believed to be originating from two closely associated seepage locations (refer Figure 1.1a and b for locations):

- 1 Bullgang Corner (Bullgang Drain), located approximately 600 metres (m) south-east of RD7.
- 2 A covered (vegetated) coal rejects area between Ramp 7 and the western side of the North-West A tailings void (North-West A tailings).

Specifically, the Notice requires that investigations are undertaken to:

- 1 Determine whether environmental harm has occurred as a result of AMD at Meandu Mine.
- 2 Identify and characterise the AMD and material with potential to generate AMD in the North-West tailings void/spoil dump and rehabilitated rejects to assess the extent of environmental harm likely to be caused by the AMD; and to determine the effects of AMD ingress to stored historical tailings (e.g. potential dissolution of metal contaminants in the tailings which may be transported to the receiving environment in the seepage).
- 3 Identify other locations at Meandu Mine where AMD is occurring; and to identify potential AMD source materials at Meandu Mine.
- 4 Determine the potential for AMD-related environmental harm (acute and/or chronic impacts on the aquatic ecosystem and other relevant water quality objectives (WQOs)) that could occur from future (ongoing) activities at Meandu Mine, including potential impacts from:
 - a build-up of metals in sediment downstream of Meandu Creek Dam
 - b elevated metal concentrations in Meandu Creek waters
 - c alteration of the pH of Meandu Creek Dam waters and release of sediment bound contaminants to the downstream environment
 - d elevated salinity levels in Meandu Creek waters.





Map: PS102396_FigXb_KeyFeatures_r1v6
 Date: 6/09/2018
 Data source: © State of Queensland (Department of Natural Resources and Mines) 2017.

Author: NK/HC
 Approved by: AOK



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 Coordinate system: AGD 1984 AMG Zone 56
 Scale ratio correct when printed at A3



Environmental Investigation Report

Figure 1.1b Meandu Mine – Key features (inset)

To address the requirements of the Notice, Stanwell has commissioned an Environmental and Engineering Evaluation into AMD at the Meandu Mine site. This investigation incorporates studies across a range of technical disciplines including:

- mine planning historical and life of mine (future)
- material classification assessments (geochemical)
- hydrogeological assessments
- surface water quality, sediments and aquatic ecology investigations
- water modelling and development of engineering solutions.

Based on the environmental investigations undertaken in response to the Notice, there is currently no evidence of negative impacts to the environmental values of Meandu Creek as a result of AMD from Meandu Mine. Overall, aquatic ecological communities in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam.

Future potential impacts on the environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine are considered unlikely given:

- The information presented in this environmental investigation shows there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment.
- The static and kinetic geochemical data combined with the geological model, overburden model and material balances, site-based evaluations and the long-term water quality data, indicate that the potential for acidic drainage to be produced in pits is very low or unlikely (other than from the North-West Backfilled Pit).
- The geochemical characterisation, based over 14 months data of kinetic leach column testing, established that the AMD issues at Meandu Mine are considered relatively minor and able to be managed through the implementation of changes to mining and the placement of mined materials.
- The commitment to continuation of monitoring measures as outlined in this Environmental Investigation Report.
- The continuation of current management measures along with the implementation of future actions as identified from this environmental investigation.

Based on the identification of AMD issues at the North-West Backfilled Pit, Stanwell has implemented controls and made a number of infrastructure and mine planning management changes in 2015/2016 to address AMD issues occurring on site. These have included:

- initial changes to water management infrastructure
- construction of seepage collection dam RD27, automated lime-dosing and pump and pipework
- installation of solid bowl centrifuges at the coal handling and preparation plant (CHPP) to dewater tailings
- changes to rejects placement
- rehabilitation design changes.

These current management measures which commenced in 2015/2016, have been included into the Integrated Water Model developed for this environmental investigation.

This environmental investigation report outlines the methodology and findings of the studies undertaken to determine the source and extent of AMD at the Meandu Mine as well as the potential for AMD-related environmental harm resulting from historical or future activities at the mine. Proposed monitoring and management measures to mitigate potential environmental impacts associated with AMD are identified and discussed.

1.2 NOTICE RECIPIENT DETAILS

TEC Coal Pty Ltd (ABN 55 119 063 900) is the recipient of the Notice. TEC Coal Pty Ltd is a wholly owned subsidiary of Stanwell Corporation Limited (Stanwell). Stanwell is a Queensland Government Owned Corporation under the *Government Owned Corporations Act 1993* and registered under the *Corporations Act 2001*. Stanwell is the largest electricity generator in Queensland and owns coal, gas and water assets for the purposes of generating electricity, including the Meandu Mine and Tarong and Tarong North power stations. Through these and other assets, Stanwell has a generation capacity of more than 4,000 megawatts.

TEC Coal Pty Ltd owns the Meandu Mine and is the holder of mining lease (ML6674) and Environmental Authority (EA) EPML00709113 (1 August 2018). The registered address for the recipient is:

TEC Coal Pty Ltd
Level 2, 180 Ann Street
Brisbane, Queensland, Australia, 4000.

1.3 SITE DESCRIPTION (MEANDU MINE)

1.3.1 LOCATION AND MINING TENEMENTS

The Meandu Mine is an open-cut coal mine located in Queensland's South Burnett region, approximately 150 kilometres (km) north-west of Brisbane, 14 km south-west of Nanango and 1.5 km to the south of the Tarong and Tarong North power stations (refer to Figure 1.2).

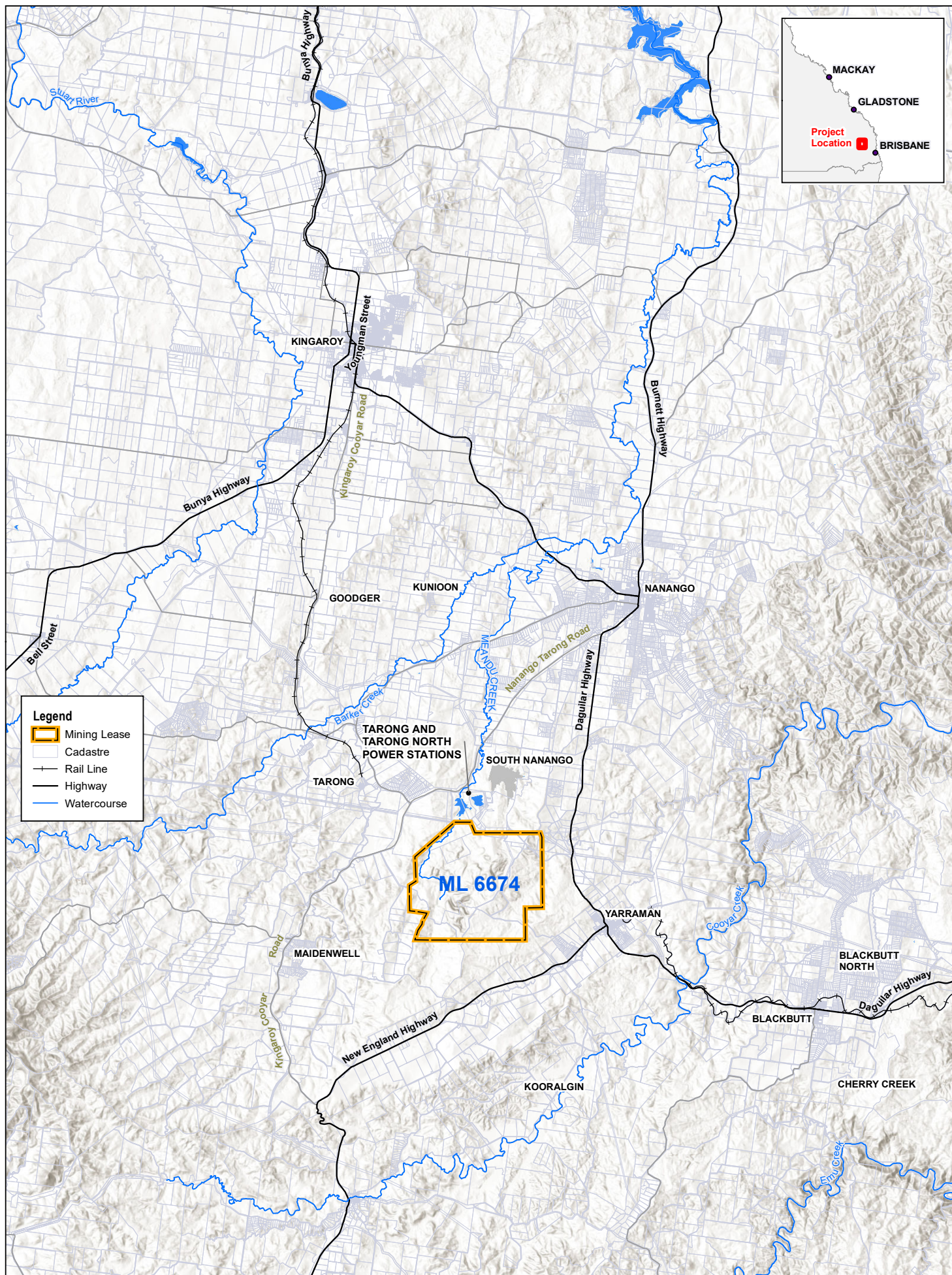
The nearest town to the mine site is Yarraman, which is located approximately 4 km south-southeast of the mining lease (ML) area and approximately 6 km from mining activities. The Meandu Mine only supplies black thermal coal to the Tarong and Tarong North power stations.

The Meandu Mine is located wholly within ML6674, which was granted on 19 February 1981. ML6674 occupies an area of 4,267 hectares (ha) within both the South Burnett Regional Council and Toowoomba Regional Council local government areas. TEC Coal currently holds surface rights for 2,638.4 ha of ML6674, most of which is located within the South Burnett Regional Council local government area. The location of the existing surface rights area within ML6674 is shown on Figure 1.3.

1.4 BACKGROUND TO THE ENVIRONMENTAL EVALUATION

RGS Environmental Pty Ltd (RGS) has undertaken an investigation into the history and occurrence of AMD at Meandu Mine. A summary of events leading up to the identification of AMD at the Meandu Mine based on that investigation, as well as the understanding of AMD at Meandu Mine at the time the Notice was issued in December 2016, is outlined below.

Meandu Mine commenced operations in 1984 in the King 1 (K1) and King 2 (K2) open pits and then in the North-West A Pit. Tailings were initially placed into in-pit cells in the North-West A Pit and then into a valley fill tailings dam in the Black Creek catchment (the K2 tailings storage facility (K2 TSF)). Coal rejects were initially placed into small cells and then into Reject Storage Area (RSA) 1 to the west of the North-West A Pit. Rejects from the CHPP were hauled from the reject stockpile and placed into RSA1. RSA1 was initially constructed on top of natural ground that allows surface runoff and seepage to report onto Ramp 7 haul road, into RD7 and into the upper ephemeral area of Meandu Creek. When the storage capacity on natural ground at RSA1 was reached, spoil and rejects were subsequently placed in-pit at North-West A.



Map: PS102396_FigA_Locality_r1v5

Author: HC/TW

Date: 6/09/2018

Approved by: AOK



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Coordinate system: AGD 1984 AMG Zone 56

Scale ratio correct when printed at A3

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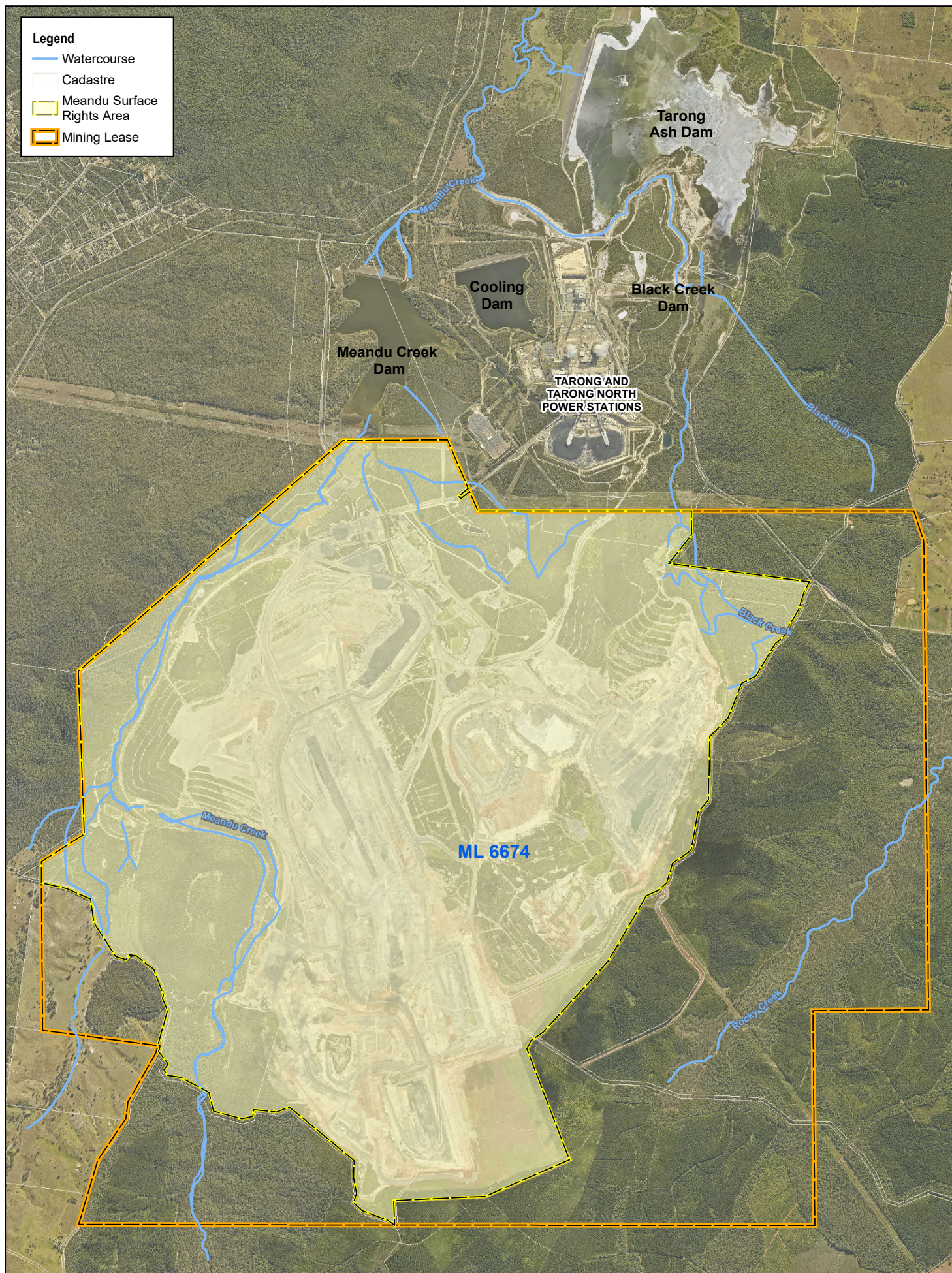


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Environmental Investigation Report

Figure 1.2 Regional location of Meandu Mine

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Map: PS102396_FigB_LeaseArea_r1v5

Author: NK/HC

Date: 6/09/2018

Approved by: AOK

Data source: © State of Queensland (Department of Natural Resources and Mines) 2017.



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Coordinate system: AGD 1984 AMG Zone 56

Scale ratio correct when printed at A3



Environmental Investigation Report

Figure 1.3 Meandu Mine lease boundary and surface rights area

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In 1995 a period of above average rainfall events led to an acidic drainage event from RSA1. The pH of the seepage from RSA1 was approximately pH 3 to 3.5, with a measured acidity of 1,530 milligram/litre (mg/L), and elevated concentrations of iron and zinc. Following this event, analysis of the water quality data from RD7 (and RD8) verified that acidic water was (mostly) associated with above average rainfall events. Given that pit water quality at that time was mostly circum-neutral, it is likely that the acid events recorded in RD7 and RD8 were other seepage events from RSA1.

The North-West B Pit was opened after North-West A Pit had been mined. North-West A was then used to store spoil, rejects and tailings until December 2005. As tailings were placed into North-West A tailings storage facility (TSF), water within the tailings percolated into the adjacent spoil and rejects within the mined open pit. In about 2005, tailings placement in North-West A ceased and rehabilitation commenced in 2008 by placing spoil and rejects on top of the tailings. Due to low geotechnical stability and overloading, the tailings were displaced vertically by some 50 m over about 3 years. From 2005 to December 2017 tailings were placed into North-West B and water from the tailings continued percolating into adjacent spoil and into unsaturated spoil and rejects in North-West A.

In mid-2013, seepage from RSA1 was noted and this water was subsequently identified as AMD. The seepage continued, and this was attributed to water seeping from the backfilled North-West A Pit. The seepage continued at about 2 megalitres (ML) per day at two seepage locations known as Ramp 7 and Bullgang Drain (note based on 2016 data this seepage rate was on average 1.3 ML/day). Initially the AMD seepage at these two locations was attributed to porewater being squeezed directly from the tailings and expressed at the lowest point of the old North-West pit shell (through the spoil). Based on further understanding of the mechanisms for seepage from the North-West Backfilled Pit and the result of static and kinetic leach testing of tailings, RGS now considers this theory to be incorrect. RGS expects that even though the tailings were displaced vertically, their inherent fine-grained, plastic texture and ability to retain moisture would maintain them at a high moisture content, reducing their potential for oxidation and generation of AMD.

Investigation of the historic incidents of AMD at the site by RGS has determined that the most probable cause of the historic AMD events and ongoing AMD from the North-West Backfilled Pit was oxidation of the sulfide minerals, and subsequent leaching of the AMD weathering products from the rejects stored in RSA1.

At RSA1, aerial imagery and the shape of the landform suggests that the rejects were end-tipped then pushed by dozer during construction. It is probable that the rejects were then left exposed to atmospheric conditions for an extended time-period (months and possibly even years). This extended exposure is likely to have contributed to the production of AMD. Occurrences of AMD from RSA1 may not have been readily observed during operations until there was sufficient rain from a large or prolonged rainfall event to wash them onto the Ramp 7 haul road, or into the North-West A Pit, or later, into the spoil and rejects in the North-West A Backfilled Pit.

Non-compliant water releases occurred at Meandu Mine's CP3 during 2014 and 2015. The non-compliances were in relation to electrical conductivity being above the maximum limit of 2,800 $\mu\text{S}/\text{cm}$ allowed by the EA (EPML00709113) for Meandu Mine. The non-compliances were reported by Stanwell to EHP and occurred on the following occasions between June 2014 and January 2015:

- 7 July 2014 (between 8:00pm and midnight, electrical conductivity range: 2,811 $\mu\text{S}/\text{cm}$ and 2,886 $\mu\text{S}/\text{cm}$)
- 7 and 8 November 2014 (between 3pm 7 November and 1:15am 8 November, electrical conductivity range: 3,434 $\mu\text{S}/\text{cm}$ and 4,055 $\mu\text{S}/\text{cm}$)
- 20 and 21 November 2014 (between 4:45pm 20 November and 0.15am 21 November, electrical conductivity range: 2,806 $\mu\text{S}/\text{cm}$ and 4,069 $\mu\text{S}/\text{cm}$)
- 8 and 9 January 2015 (electrical conductivity readings: 7.56am 9 January of 3,130 $\mu\text{S}/\text{cm}$ and the 24-hour average to 9:00am 9 January as 3,068 $\mu\text{S}/\text{cm}$).

The recognition that AMD was occurring on-site resulted in EHP (now DES) issuing TEC Coal Pty Ltd with the December 2016 Notice to conduct or commission an environmental evaluation into AMD at the Meandu Mine.

1.5 PURPOSE OF ENVIRONMENTAL INVESTIGATION REPORT

The purpose of this Environmental Investigation Report is to address the requirements of EHP (now DES) as set out in the Notice (December 2016).

Specifically, the Notice requires (Section A: Grounds) that investigations are undertaken to:

- 1 Determine whether environmental harm has occurred as a result of AMD at Meandu Mine.
- 2 Identify and characterise the AMD and material with potential to generate AMD in the North-West tailings void/spoil dump and rehabilitated rejects to assess the extent of environmental harm likely to be caused by the AMD; and to determine the effects of AMD ingress to stored historical tailings (e.g. potential dissolution of metal contaminants in the tailings which may be transported to the receiving environment in the seepage).
- 3 Identify other locations at Meandu Mine where AMD is occurring; and to identify potential AMD source materials at Meandu Mine.
- 4 Determine the potential for AMD-related environmental harm (acute and/or chronic impacts on the aquatic ecosystem and other relevant water quality objectives (WQOs)) that could occur from future (ongoing) activities at Meandu Mine, including potential impacts from:
 - a build-up of metals in sediment downstream of Meandu Creek Dam
 - b elevated metal concentrations in Meandu Creek waters
 - c alteration of the pH of Meandu Creek Dam waters and release of sediment bound contaminants to the downstream environment
 - d elevated salinity levels in Meandu Creek waters.

To address these requirements Stanwell has commissioned an Environmental and Engineering Evaluation into AMD at the Meandu Mine site. This investigation incorporates studies across a range of technical disciplines including:

- mine planning historical and life of mine (future)
- material classification assessments (geochemical)
- hydrogeological assessments
- surface water quality, sediments and aquatic ecology investigations
- water modelling and development of engineering solutions.

An overview of the scope of works for these studies is provided in Table 1.1.

Table 1.1 *Scope of works undertaken for this environmental investigation*

TECHNICAL STREAM	SCOPE	RESPONSIBILITY
Mine Planning (Historic)	— Identification of the historic location of tailing, rejects and waste placement and the development of the mine from 1983 to December 2015. — Provision of a 3-dimensional (3D) Digital Terrain Model of the Meandu Mine as of end August 2016.	Stanwell
Life of Mine Planning (Future)	— Preparation of a Predictive Life of Mine Plan to model the dump strategy at Meandu Mine, incorporating current knowledge of AMD. — Results to be used as inputs into the integrated water quality and mass balance water model (Golder).	Xenith Consulting

TECHNICAL STREAM	SCOPE	RESPONSIBILITY
Material characterisation – Geochemistry	— Characterisation of the geochemical and physical properties of mined materials to improve deposit knowledge. — Identification of major rehabilitation material types, produce bulk material balances, for all major material types as input into the water quality and mass balance model.	RGS Environmental Pty Ltd
Hydrogeology	— Preparation of a conceptual site model to describe groundwater occurrence and movement at Meandu Mine and the interaction of groundwater with the receiving environment. — Preparation of geological/hydrogeological cross sections. — Review of airborne geophysics and incorporation of results into site conceptual model and geological/hydrogeological cross sections.	JBT Consulting
Geophysics (aerial)	— Delineation of water table depth. — Mapping of water flow direction by imaging groundwater salinity differences. — Measure depth of weathering. — Provision of detailed lithological information including faulting and folding, where present, which may provide additional conduits for saline water.	SkyTEM/Stanwell JBT Consulting (interpretation)
Off-site surface waters	— Characterisation of the surface water values that may be impacted by AMD from the Meandu Mine. — Characterisation of the exiting qualities and resilience of Meandu Creek.	Ecological Service Professionals Pty Ltd
Water Model	— Development of an integrated numerical water quality and mass balance water quality model covering Meandu Mine. The model will be inclusive of clean stormwater and mine impacted water in surface water dams, backfilled voids, open pits and groundwater within unmined ground. The purposes of the model is to simulate the surface water, groundwater and geochemical components of the of the Meandu Mine environment to estimate the AMD potential given the current Plan of Operations to closure (the base case). — Development of a 2-dimensional (2D) groundwater modelling using SEEP/W. — Once the base case AMD potential is estimated using the model, the model will then be used as a tool to trial engineering controls and management measures, where required, to mitigate potential AMD impacts (scenario trials).	Golder Associates Pty Ltd
Engineering Solutions	— Identification of potential engineering options to manage tailings and rejects that could be implemented at Meandu Mine to reduce environmental impacts associated with AMD.	Golders Associates Pty Ltd

1.6 REPORT STRUCTURE

The structure of the Environmental Investigation Report is outlined in Table 1.2. A checklist against the Notice requirements is provided in Appendix B.

Table 1.2 *Report structure*

SECTION	NOTICE REQUIREMENT	DESCRIPTION
Section 0: Project overview	General B1(ii) and (vi)	Provides an overview of the purpose of the Environmental Investigation and outlines the structure of the Environmental Investigation Report. Provides a brief history and overview of AMD at the site (from first known (historic) indicators to current awareness.
Section 2: Meandu Mine Operations	B1(i)	Provides a background and baseline information of both historical and current operations at the Meandu Mine (1983 to 2016). Introduces short-term water management actions to address AMD that have been undertaken at the mine.
Section 3: Mine materials placement and characterisation	B3(i) and (iii)	Presents the outcomes of the geochemical assessments undertaken by RGS to characterise the chemical and physical properties of material at the Meandu Mine with the potential to generate AMD (e.g. soil, overburden, in-pit side cast coal, product coal, rejects, tailings, ash etc). Presents the outcomes of the studies undertaken to identify the extent and location of potential AMD source materials at the Meandu Mine.
Section 4: Hydrogeology investigations	B3(ii) (iv) (v) and B5(iii)	Presents the outcomes of the hydrogeological investigations undertaken by JBT to inform the environmental investigation, including the development of a conceptual groundwater model to inform the Integrated Water Model, and interpretation of data from groundwater monitoring as well as land and aerial geophysical surveys.
Section 5: Mine domains of interest	B3(iv) and B3(v)	Identified the known source and extent of AMD at Meandu Mine.
Section 6: Characterisation of the receiving environment	B2(i), (ii) and (iv)	Identifies and characterises the environmental values (land, groundwater and surface waters) that have the potential to be impacted by AMD from the Meandu Mine. It includes: — the identification of any Environmental Values (EVs) and Water Quality Objectives (WQOs) for Meandu Creek — determination of the mine-affected water release quality that must be achieved to protect the relevant EVs of Meandu Creek.
Section 7: Surface water investigations relevant to this EIR	B4(i) and (ii)	Describes the surface water assessments (water quality, aquatic ecology and sediment sampling) undertaken by ESP to investigate the potential for AMD-related environmental harm from operations at Meandu Mine.
Section 8: Impact to the receiving environment	B2(iii) B4(i), (ii) and (iii) B6(ii) and (iii)	Presents the outcomes of the surface water assessments (water quality, aquatic ecology and sediment sampling) to determine current and future impacts on Meandu Creek from AMD at Meandu Mine Describes the existing qualities, characteristics and resilience of Meandu Creek.
Section 9: Integrated water model	B5	Summaries development of and results from the Integrated Water Model developed by Golder Associates to predict potential AMD impacts from Meandu Mine.

SECTION	NOTICE REQUIREMENT	DESCRIPTION
Section 10: Management recommendations	B4(iii) and B6(iv)	Identifies the management actions which Stanwell has committed to resulting from the investigations into AMD at Meandu Mine.
Section 11: Conclusions	B6(i)	Provides a summary of findings that is also presented in the Summary Report.

1.7 LEGISLATIVE REQUIREMENTS

The Notice to conduct or commission an environmental evaluation is issued by the administering authority pursuant to Section 326B of the EP Act.

1.7.1 APPROPRIATELY QUALIFIED PERSONS

The environmental investigation must be carried out, and the Environmental Investigation Report prepared by, appropriately qualified persons. An 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.

Table 1.3 outlines the appropriately qualified persons involved in the environmental investigations and compilation of this Environmental Investigation Report.

Table 1.3 *Appropriately qualified persons*

NAME	ORGANISATION	POSITION	QUALIFICATIONS	YEARS OF EXPERIENCE
Environmental Investigation Report				
Amanda O’Kane	WSP Australia	Technical Executive – Environment	Bachelor of Science (Applied Geology); CEnvP	25
Allison Rushton	WSP Australia	Principal Environmental Scientist	Bachelor of Economics (Honours); Graduate Diploma Environmental Science; CEnvP	22
Material classification (geochemical)				
Dr Greg Maddocks	RGS Environmental Pty Ltd	Principal Hydrogeochemist	PhD in Geochemical Engineering	20
Alan Roberston	RGS Environmental Pty Ltd	Director and Principal Geochemist	PhD Pure and Applied Chemistry	25
Groundwater (geophysical)				
John Bradley	JBT Consulting Pty Ltd	Principal Hydrogeologist	Bachelor of Applied Science (Geology) (Honours) Master of Science (Hydrogeology and Groundwater Management)	27

NAME	ORGANISATION	POSITION	QUALIFICATIONS	YEARS OF EXPERIENCE
Life of Mine Planning				
Matthew Clarke	Xenith Consulting	Manager	Master of Engineering Bachelor of Engineering (Civil) Bachelor of Business Management (Economics)	15
John Cawte	Xenith Consulting	Manager – Mining Solutions	Bachelor of Engineering (Mining) Diploma of Business	26
Water modelling and engineering solutions				
Michael Gowan	Golder Associates Pty Ltd	Principal	Bachelor of Science (Engineering); Master of Science (Engineering)	45
Dr. Scott Weeks	Golder Associates Pty Ltd	Senior Numerical Modeller	Bachelor of Science (Honours1) PhD	20
Marian Hart	Previous Golder Associates Pty Ltd (now Sunwater)	Senior Water Resources Engineer	Bachelor of Engineering (Environmental) (Honours); CPEng RPEQ	10+
Receiving environment water quality, sediment and aquatic investigations				
Lauren Thorburn	Ecological Service Professionals Pty Ltd	Principal Ecologist	Bachelor of Science (Ecology and Marine Biology) (Honours) CEnvP	15
Kate Keating	Ecological Service Professionals Pty Ltd	Senior Ecologist	Bachelor of Marine Studies (Ecology and Biology) (Honours)	7
Dr Liz West	Ecological Service Professionals Pty Ltd	Principal Ecologist	Bachelor of Science (Honours), PhD	14

As required by the Notice (Section B7), a statutory declaration (EM494) signed by the appropriate representative from TEC Coal Pty Ltd is attached as Appendix C, along with statutory declarations for the appropriately qualified persons preparing this Environmental Investigation Report. Statutory declarations for appropriate qualified persons preparing specialists studies are included within the relevant technical reports in the appendices.

1.7.2 PROGRESS UPDATES

As required by Section B7 of the Notice, over the course of the investigation, Stanwell has progressively updated EHP (now DES) on the actions and outcomes of the investigations. Table 1.4 overleaf provides an overview of these progress updates.

Table 1.4 *Progress updates to EHP (now DES)*

PROGRESS UPDATE DATE / LOCATION	SCOPE	ATTENDANCE
Progress Update 1 31 May 2017 EHP Maryborough	Overview of works undertaken to date Outline upcoming project activities Seek clarifications and feedback from EHP on methodology and approach.	DES: (Maryborough) Coal and Central Queensland Compliance Centre Stanwell Specialist consultants: WSP Australia.
Progress Update 2 13 September 2017 Meandu Mine Site	Update on progress against delivery schedule Discussion of preliminary findings Outline upcoming project activities.	DES: (Maryborough) Coal and Central Queensland Compliance Centre Stanwell Specialist consultants: WSP Australia.
Progress Update 3 22 May 2018 DES Maryborough	Update on progress against delivery schedule Discuss finding and proposed management actions Confirm final delivery of Notice requirements.	DES: (Maryborough) Coal and Central Queensland Compliance Centre Stanwell Specialist consultants: WSP Australia, Ecological Service Professionals Pty Ltd, JBT Consulting.

2 MEANDU MINE OPERATIONS

SECTION OVERVIEW

This section provides an overview of the current mining operations undertaken at the Meandu Mine.

It specifically addresses requirement B1(i) of the Notice:

B1 An appropriately qualified person(s) as defined in this notice must provide background and baseline information for the coal mining activity relevant to the environmental investigation including:

(i) A description of Meandu Mine (ML6674) operations and a brief history of operations on Meandu Mine

Based on the identification of AMD issues at the North-West Backfilled Pit, Stanwell has implemented controls and made a number of infrastructure and mine planning management changes since 2015/2016 to address AMD issues occurring on site. These actions are also outlined in this section.

2.1 OWNERSHIP AND OPERATIONS

Mining at Meandu Mine commenced in 1983 for the purposes of supplying coal to the Tarong Power Station and subsequently the Tarong North Power Station in 2003. The history of Meandu Mine extends back to 1967, when Rio Tinto Coal took out an authority to prospect in the Tarong area near the town of Yarraman. Drilling in subsequent years showed steaming coal occurring at substantial thicknesses, indicating the likelihood of a sufficient coal resource to support power generation.

Operations at Meandu Mine commenced in 1983, and in 1984, the mine began regular deliveries to the power station using a 1.5 km conveyor, increasing supply to Tarong Power Station as more generators were commissioned.

Ownership of the mine was assumed by Tarong Energy in early 2008 from Rio Tinto. Following a restructure of Queensland Government owned generators, ownership of Meandu Mine was transferred to Stanwell from Tarong Energy in July 2011. TEC Coal Pty Ltd has historically contracted all mining services at the Meandu Mine to a mining contractor. Between 2008 and 2012 this was Thiess Mining Services Pty Ltd. From 2013, mining services have been contracted to Downer EDI Mining Pty Ltd.

2.2 TENEMENTS

All mining operations at Meandu Mine occur within the surface rights area of ML6674. Table 2.1 outlines the property (Lot on Plan numbers) underlying this surface rights area.

Table 2.1 Lot on Plan numbers for existing surface rights area of ML 6674

MINING LEASE	LOT ON PLAN
ML 6674	— Lot 10 on FY2980 — Lot 111 on FY817 — Lot 1 on SP181280 — Lot 11 on SP280476 — Lot 2 on RP169258 — Lot 3 on RP176969 — Lot 289 on FTY1859 Temporarily closed sections of Ridge Road, Tarong-Yarraman Road and Unnamed Road

The location of these properties is shown on Figure 2.1.

2.3 SURFACE GEOLOGY

The Meandu Mine is located within an area where the Late Triassic Tarong Beds (the host unit for the coal seams mined at Meandu Mine) occur at the surface. Figure 2.2 shows the surface geology of the Meandu Mine and surrounds at a 1:100,000 scale.

ML6674 overlies part of the Triassic-aged Tarong Basin, a north - northwest – south - southeast trending elongate pull-apart basin, the maximum dimensions of which are approximately 80 km long and 30 km wide (Pegrem 1986). In the area of the Meandu Mine the maximum width of the Tarong Basin is approximately 10 km. The approximate western and eastern limits of the Tarong Basin are shown on Figure 2.2. These limits are based on interpretation of the boundary between the Boondooma Igneous Complex (Permo-Triassic intrusives) to the west, the Maronghi Creek beds to the east, and sediments of the Tarong Beds in the Meandu Mine area. Formation of the Tarong Basin is discussed in Section 4.1.1.

The Tarong Basin has been in-filled by the Tarong Beds which have a preserved thickness of approximately 450 m and comprise predominantly coarse grained, clastic sediments and thick coal accumulations (Pegrem 1995). Sediments stratigraphically near to the coal seams are mostly fine grained sandstone, siltstone and mudstone. The coal seams are inter-bedded with fine grained stone bands that are often highly variable in both thickness and composition. In Jell, 2013, the coal within the basin was referred to as “high-ash, high-volatile, bituminous, low-sulphur, steaming coal with poor coking properties”.

In the southern area and central-eastern area of Meandu Mine, deposits of Tertiary basalt occur at surface. In the central-eastern area of the Meandu Mine lease, the basalt occurs as remnant ridge-top deposits. Quaternary alluvial deposits are associated with ephemeral creeks including Barker Creek and Meandu Creek (which are part of the Burnett River catchment) and Rocky Creek and Yarraman Creek (which are part of the Brisbane River catchment). The divide between the two catchments is defined by the line of ridge-top basalt that can be seen extending from south-west to north-east through the central-east area of the Meandu Mine.

Further information on the local geology is provided in Sections 4.1 and 4.2.

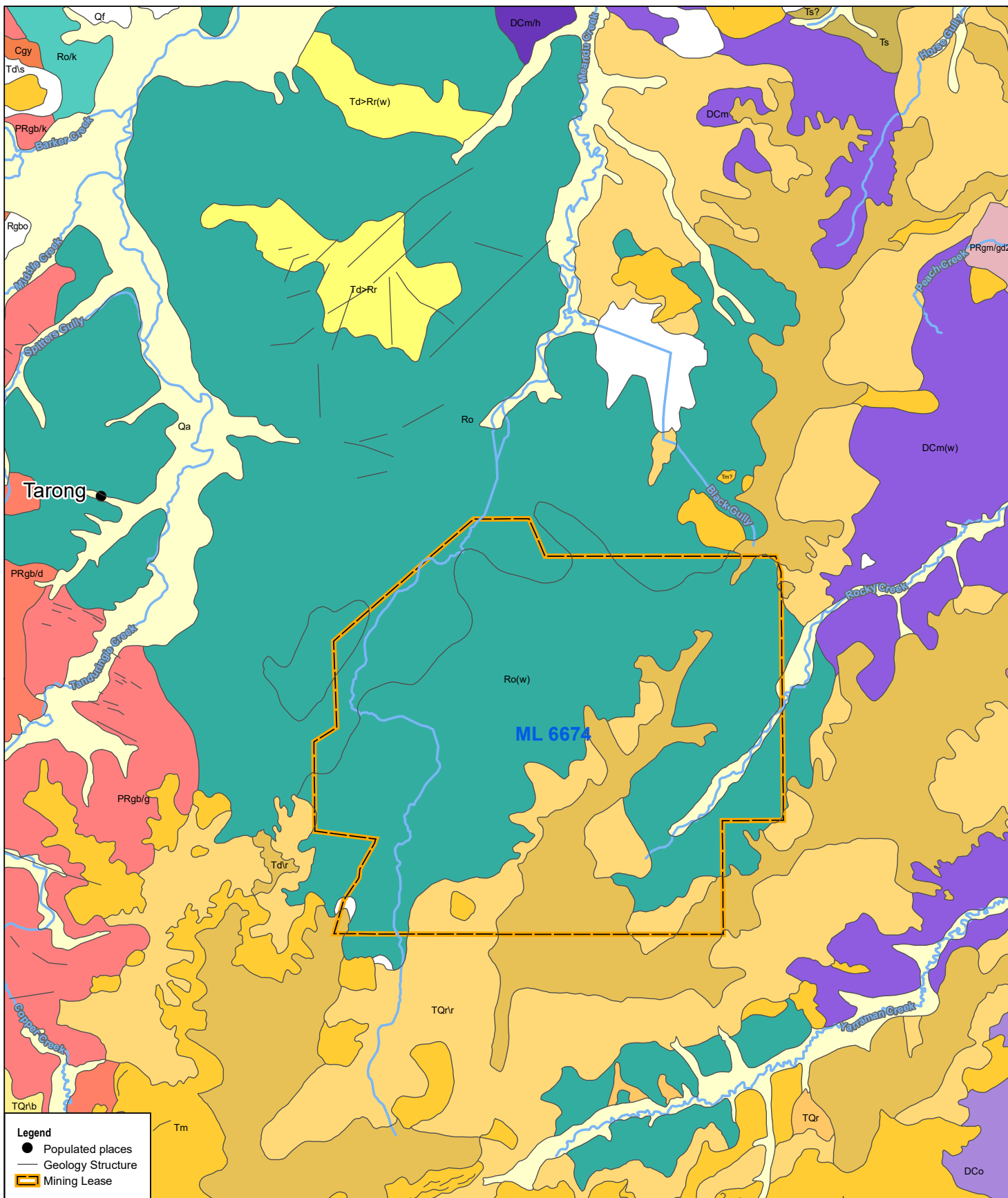
2.4 COAL RESOURCE

The seams at Meandu Mine generally dip gently to the south and south-east at less than five degrees from horizontal. The seam sequence (top down) in the Meandu deposit is:

- Ace Seam, which is typically oxidised and dry.
- King Seam, approximately 60 m below the Ace Seam. This seam generally contains groundwater though the unit may be dry depending on the reduced level of the strata.
- Queen Seam, a further 30 to 40 m below the King Seam, and generally containing groundwater.
- Coal seams below the Queen Seam, which are not mined at site (including Joker, Prince, Baron, Duke and Duchess (followed by a set of inconsistent low quality plies at great depth)).

Major faults, typically trending parallel to the basin axis, occur along the eastern margin of the basin disrupting the continuity of coal seams within ML6674. Vertical throws have been interpreted up to 80 m in height. The Tertiary sequence also includes poorly consolidated sediments.

In general, it can be said that the Tarong coal seams are sub-bituminous, high volatile, bright (less so in lower seams), have inherently high mineral matter content (‘high ash’), low sulphur, low to moderate phosphorus, low chlorine, and average arsenic.



Legend

Boondooma Igneous Complex (Permo-Triassic)-PRgb/d	Gilla Volcanics/a	Qa-QLD	Taromeo Igneous Complex/t	Td-SEQ>Tarong beds(w)
Boondooma Igneous Complex (Permo-Triassic)-PRgb/g	Main Range Volcanics	Sugarloaf Metamorphics	Tarong beds	Td'r-QLD
Boondooma Igneous Complex (Permo-Triassic)-PRgb/k	Main Range Volcanics?	TQr-QLD	Tarong beds(w)	Td'r-QLD>Main Range Volcanics
Chahpingah Meta-igneous Complex	Maronghi Creek beds	TQr\B-SEQ	Tarong beds/k	Ts-SEQ
	Maronghi Creek beds(w)	TQr\r-SEQ	Tarong beds?	Ts?-SEQ
	Maronghi Creek beds/h	Taromeo Igneous Complex/gd/2	Td-SEQ>Tarong beds	Water body (unspecified)

PS102396_Fig0_

Map: SurfaceGeology_r1v1

Author: NK/TW/HC

Date: 28/08/2018

Approved by: LR



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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3



Environmental Investigation Report

Figure 2.2 Surface Geology

2.5 COAL MINING (CURRENT OPERATIONS)

This section provides an overview of the current operations at the Meandu Mine. The location of key features of the mine are shown on Figure 1.1a and b.

2.5.1 COAL MINING

The Meandu Mine supplies the feed coal for the Tarong and Tarong North power stations, and is therefore linked to Stanwell's long-term business objectives for these stations. Coal production is directly linked to demand from the Tarong and Tarong North power stations and varies on a monthly basis depending on delivery requirements for the power stations. Meandu Mine operates using a single dragline and associated truck and shovel fleets (Photo 2.1 and Photo 2.2). The EA (EPML00709113) for Meandu Mine authorises the extraction of no more than 11.0 million tonnes per annum (Mtpa) of Run-of-Mine (ROM) (bituminous steaming) coal.



Photo 2.1 Dragline



Photo 2.2 Excavators

Mining operations currently advance the existing Central; Ramp 5; King 4 East (K4E); and King 4 South (K4S) pits. King 2 East (K2E) pit is not planned to be further mined until 2023. The location of these pits is shown on Figure 1.1a.

Mining occurs using a strip mining technique that utilises both dragline and truck/shovel to move the overburden. All material at the mine is blasted except the overlying Tertiary sediments. The area is pre-stripped of vegetation and topsoil, with the latter being used to cover areas of rehabilitation, which occurs progressively as the mining face moves forward.

2.5.2 WASTE MATERIAL STORAGE AND DISPOSAL

Waste rock material removed in advance of coal mining is comprised of:

- overburden, which is located above the upper coal seam
- interburden, which is located between adjacent coal seams
- coal roof, coal floor and coal partings, which is located adjacent to coal seams
- spoil material, which has previously been dumped and is rehandled to provide access to the targeted coal seams.

Waste rock material is moved by dragline and excavator/haul truck fleets to in-pit or ex-pit overburden dumps, appropriate to the mine plan and mining location.

2.5.2.1 COAL HANDLING AND PREPARATION PLANT

The CHPP was installed in 1986. Prior to this coal was fed directly to the Tarong Power Station. Due to this direct feed of coal to the Tarong Power Station, no rejects or tailings material were produced at the mine from 1983 to 1985.

Coal is transported to the RoM stockpiles or the RoM bin at the CHPP in rear dump trucks. The CHPP processes include screening, crushing and washing using gravity separation, to achieve product coal specifications. Product coal is then transported via a 1.5 km overland conveyor to the Tarong and Tarong North power stations.

ROM coal is sized in primary and secondary breakers, during which raw coal is separated from breaker rejects. During the CHPP process, raw coal is separated into coal and non-coal materials using a washing and flocculent method. The resultant product coal is sent to the Tarong and Tarong North power stations, while coarse rejects are co-mingled (commenced December 2017) with dewatered fine rejects and hauled to in-pit rejects dumps.

2.5.2.2 REJECTS DISPOSAL

Coarse rejects are stockpiled at the CHPP before being trucked to the current rejects dump location. All rejects materials are dumped at least 6 m beneath the final landform profile to ensure adequate capping can be constructed over the top of the rejects. The rejects placement methodology involves dumping in lifts and progressive watering and dozer-tracking or traffic compaction. When the rejects dump reaches its final landform capacity, it will be re-graded as required, capped with an average minimum 6 m soil cover system, and rehabilitated.

2.5.2.3 TAILINGS DISPOSAL

Coal tailings (fine rejects) are thickened in the CHPP thickener and treated with lime ($\text{Ca}(\text{OH})_2$) to attain a broadly neutral pH. They are then pumped in slurry form to solid bowl centrifuges, where they are dewatered to the required moisture content for transport. From December 2017, dewatered fine rejects are co-mingled with coarse rejects and the resulting Mixed Plant Rejects are stockpiled at the CHPP before being trucked to the reject dump locations.

Water that is recovered from the solid bowl centrifuges is recycled back through the CHPP system.

Coal tailings have historically been pumped as a slurry of circum-neutral pH directly to the K2W-TSF or North-West B TSF (previously the North-West B Pit). These TSFs may be used intermittently, when bypass of the solid bowl centrifuges is required for maintenance purposes. Decant water from the TSFs is reclaimed and pumped into the mine drainage system, where it passes through a series of retention dams to assist with the settling of sediment and coal fines. The supernatant water level in North-West B TSF is maintained at or below 443 m reduced level (RL). This water is reclaimed from RD2 and re-used through the CHPP, minimising raw water use.

2.5.2.1 ASH DISPOSAL

Fly-ash is produced during the coal combustion process at the power stations as a by-product of power generation. Dense-phase ash slurry has been pumped from the Tarong and Tarong North power stations to Meandu Mine for disposal in disused mine voids since 2009 under a Beneficial Use Approval (ENBU00736008).

Ash was initially deposited into the K2W void with approval for ash deposition in the combined King 2 West-North (K2W-N) voids obtained in January 2012. Mining in King 2 North (K2N) was completed in financial year 2015 after which the K2N void was prepared to receive ash. The ash slurry pipelines were diverted from K2W to K2N during financial year 2016, allowing ash deposition to occur directly into K2N.

Supernatant water is reclaimed from the K2W-N void and pumped in a closed-loop system back to Tarong Ash Dam for recovery and re-use.

Bunding and drainage systems have been installed along the pipeline route and catch dams constructed downgradient from each emergency dump valve along the ash pipeline, to contain any ash spill in the event of pipeline breach.

2.5.3 WATER MANAGEMENT

A comprehensive draining and retention system exists at Meandu Mine covering the operational and industrial areas, CHPP, workshops and the warehouse. This system, which is maintained and upgraded to preserve the separation of clean and dirty water and to maximise water recycling and minimise the need to discharge water from the mine area, is shown in Figure 2.3.

The Meandu Mine EA (EPML00709113) regulates the releases of mine-affected waters from Meandu Mine. Relevant details with respect to surface water releases are provided in the following sections.

2.5.3.1 COMPLIANCE POINTS

The Meandu Mine EA (EPML00709113) specifies compliance points for surface water quality monitoring. These compliance points are described in Table 2.2 and locations identified on Figure 2.3.

Table 2.2 *Meandu Mine water monitoring compliance points*

COMPLIANCE POINT	DESCRIPTION	MONITORING – PARAMETERS AND FREQUENCY
CP1	Interception of Meandu Creek and Meandu Creek Dam	Daily – pH and turbidity
CP2	Overflow from RD17B on Black Creek	Daily – pH, turbidity and electrical conductivity
CP3	Measuring weir on Meandu Creek	Daily – electrical conductivity
CP4	Measuring weir on tributary of Meandu Creek	Daily – electrical conductivity

Automated monitoring sensors and networks are used to monitor water quality at compliance points. Monitoring of water quality at compliance points occurs daily.

Surface water releases must comply with the contaminant limits defined in the EA (EPML00709113) (refer Table 2.3).

Table 2.3 *Water contaminant limits as outlined in EA (EPML00709113) (Condition C5 -Table C2)*

PARAMETER	MONITORING POINT	UNITS	MINIMUM	MAXIMUM
pH	CP1, CP2***	pH units	5.5	9.0
Turbidity	CP1, CP2***	NTU	-	1,000*
Electrical conductivity	CP3, CP4	µS/cm	-	2,500**
	CP2	µS/cm	-	1,600

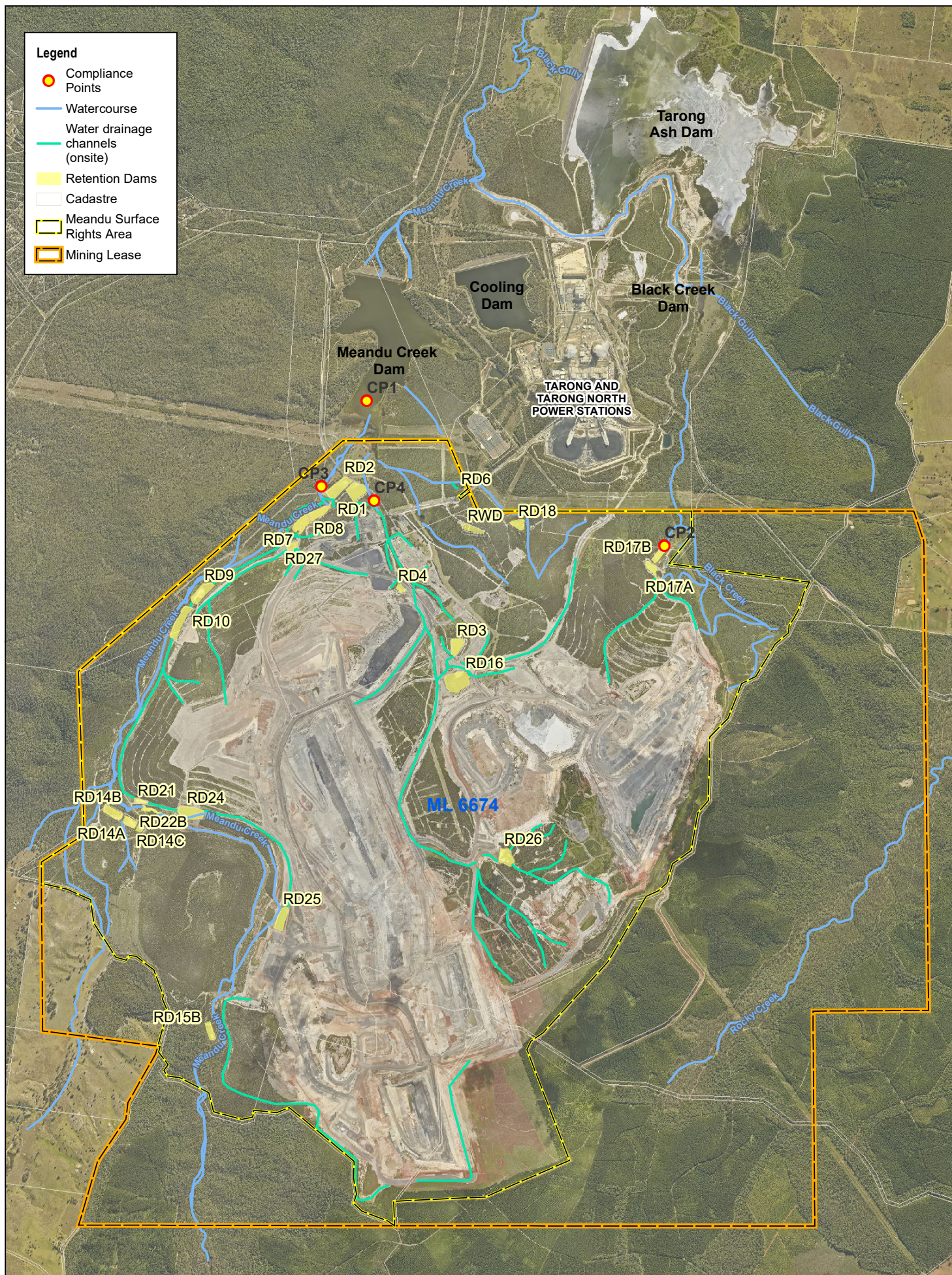
* In circumstances where rainfall events are extreme, the maximum limit for turbidity will be the background level, as determined by the turbidity in Meandu Creek at a point upstream of the mining lease, plus 10% or 1,000 NTU, whichever is the greater.

** Notwithstanding the limit for electrical conductivity, the limits for CP3 and CP4 may be exceeded, but cannot exceed a maximum limit of 2,800 µS/cm. For all discharges greater than 2,500 µS/cm, but less than 2,800 µS/cm a daily volume limit of 2.5 ML/day applied. The limits at CP3 and CP4 only apply when water is being discharged at these points.

*** Limits for CP2 only apply while Retention Dam 17B is discharging.

****A result in excess of 9.0 for pH at CP1 is not considered a breach of condition C5 of this environmental authority if concurrent monitoring at CP3 shows compliance for pH with the maximum stated in Table C2 – Water contaminant limits for CP1 and the holder of this environmental authority can demonstrate that the pH at CP1 is not a result of mine activities.

In addition, end of pipe releases from RD2 (overflow from RD2) must be monitored quarterly for oil and grease (Condition C6 – Table C4).



2.5.3.2 RETENTION DAMS

Table 2.4 and Figure 2.3 outline the retention dam network at the Meandu Mine. Retention dams upstream of CP3 can contribute water inputs to CP3, either via low flows or via high flow diversions.

Table 2.4 *Meandu Mine retention dams*

DAM NAME	CAPACITY (ML)	WATER CLASSIFICATION	WATER SOURCE	CONTROLLED DISCHARGE TO	OVERFLOWS TO	PUMPS TO
RD1	43.8	Mine-affected	Local catchment; RD3; RD4; RD17B; Industrial	N/A	RD2	N/A
RD2	29.5	Mine-affected	Local catchment; RD1; RD8	N/A	Meandu Creek Dam	CHPP; RoM Fill Point
RD3	29.3	Mine-affected	Local catchment; RD16	N/A	RD1	N/A
RD4	3.3	Mine-affected	Local catchment	N/A	RD1	N/A
RD6	0.9	Clean	Local catchment	N/A	Meandu Creek Dam	N/A
RD7	37.3	Mine-affected	Local catchment; RD9	N/A	RD8	N/A
RD8	20.1	Mine-affected	Local catchment; RD7	RD2	Meandu Creek Dam	N/A
RD9	25.8	Mine-affected	Local catchment; RD10	RD8	RD7	N/A
RD10	38.8	Mine-affected	Local catchment, RD14B; RD21	N/A	RD9	Ramp 7 Fill Point; Central Fill Point
RD14A	23.1	Mine-affected	Local catchment; RD14C	N/A	RD14B	N/A
RD14B	31.8	Mine-affected	Local catchment; RD14A	RD10	Meandu Creek Dam	N/A
RD14C	8.5	Mine-affected	Local catchment	N/A	RD14A	N/A
RD15B	22.6	Clean	Local catchment	N/A	RD22B	N/A
RD17A	18.2	Mined-affected	Local catchment; K2E Pit	N/A	RD17B	N/A
RD17B	26.6	Mine-affected	Local catchment; RD17A	N/A	Black Creek Stormwater Dam	RD1
RD18	14.3	Clean	Local catchment	N/A	Meandu Creek Dam	N/A

DAM NAME	CAPACITY (ML)	WATER CLASSIFICATION	WATER SOURCE	CONTROLLED DISCHARGE TO	OVERFLOWS TO	PUMPS TO
RD21	8	Mine-affected	Local catchment; RD24	N/A	RD10	N/A
RD22B	8.8	Clean	Local catchment; Meandu Creek headwaters; RD15B	N/A	Meandu Creek Dam	N/A
RD24	58	Mine-affected	Local catchment; RD25; Central Pit	N/A	RD21	N/A
RD25	44	Mine-affected	Local catchment; K2E and K4S pits	N/A	RD24	N/A
RD26A	46.2	Mine-affected	Pit	N/A	RD26B	Central Fill Point
RD26B	1.8	Mine-affected	Local catchment; RD26A	N/A	RD23	N/A
RD27	5	Mine-affected	Local catchment; North-West dump seepage water	N/A	RD7	RD26

RD26 was completed early financial year 2017 and receives runoff from the Boundary dump catchment and pumped flows from K2E Pit. It was constructed ahead of Central Pit progression removed RD23. The new Boundary water fill point sources its water from RD26. RD27 was constructed during financial year 2018 and collects water expressing from the toe of North-West Backfilled Pit, that is then lime-treated and pumped to other dams or directed to site facilities for re-use.

Retention dams are de-silted, as required, with the removed sediment placed within mine void or tailings void sub-catchments. Desilting is planned based on assessing effective capacity, location within the catchment and future activities to be undertaken within each catchment (including progressive rehabilitation).

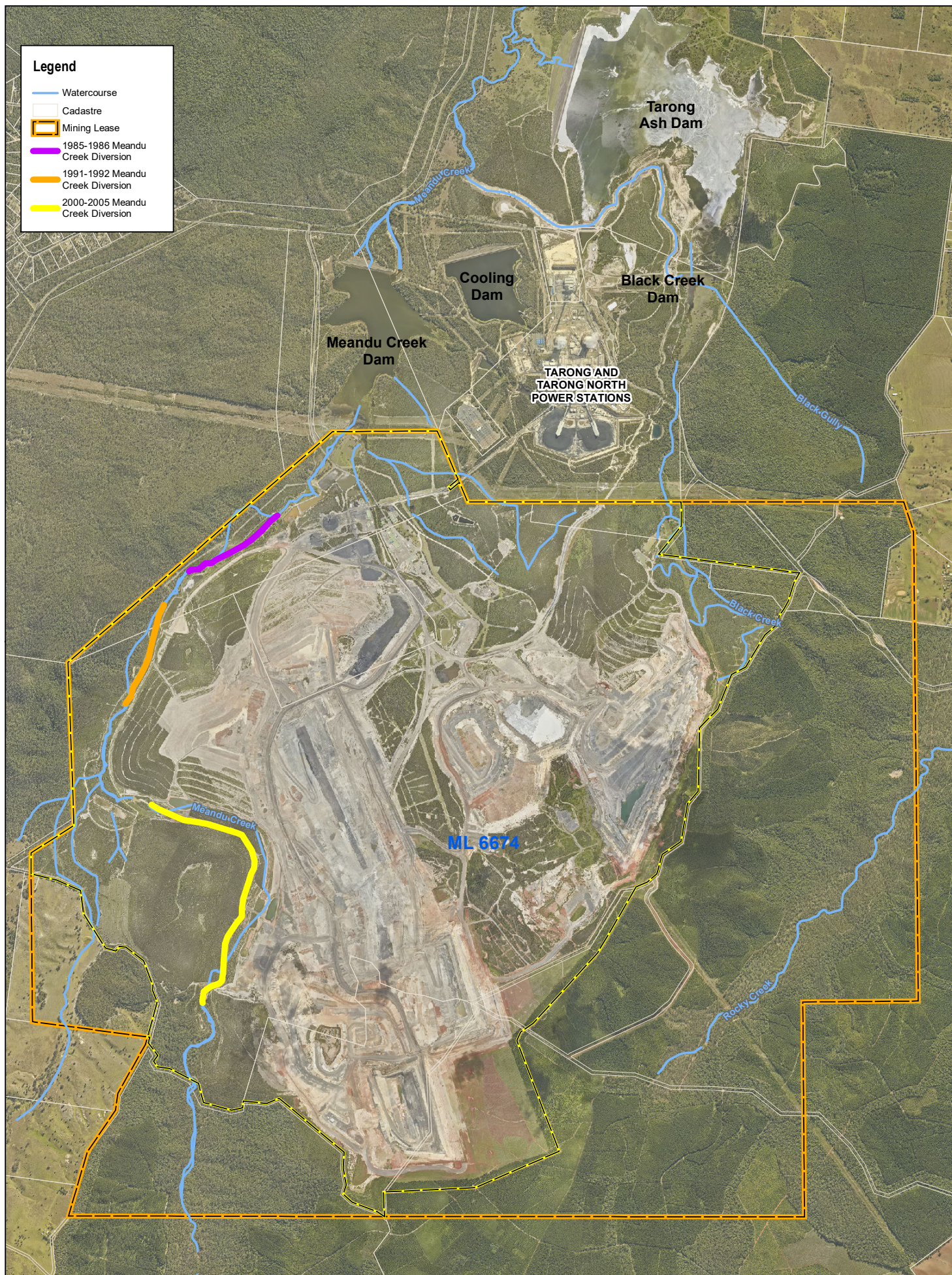
2.5.4 CREEK DIVERSIONS

Three creek diversions have been constructed within the surface rights area of Meandu Mine since mining operations commenced. These works were undertaken as follows:

- **1985 – 1986:** 1.0 km diversion of Meandu Creek through competent material with RD7 constructed within the original drainage channel.
- **1991-1992:** 0.8 km diversion of Meandu Creek through competent material, with RD10 constructed within the original drainage channel.
- **2000-2005:** 2.4 km diversion of Meandu Creek through backfilled spoil, which was approved and constructed under Water Licence 102005 to allow coal mining to occur through the south-west area.

The locations of these diversions are shown on Figure 2.4.

The 1985-1986 and 1991-1992 diversions are currently classified as “infrastructure” within the Financial Assurance calculations. Rehabilitation of the 2000-2005 Meandu Creek diversion has been undertaken according to detailed engineering design and has been revegetated according to success criteria specified in the EA (EPML00709113). These areas have been classified as being rehabilitated for the respective years in which they were seeded.



Map: PS102396_FigU_CreekDiversions_r1v1 Author: NK/HC

Date: 11/09/2018

Approved by: AOK



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Coordinate system: AGD 1984 AMG Zone 56
Scale ratio correct when printed at A3

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Figure 2.4 Meandu Creek - Creek diversions (approximate locations)

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2.5.5 GROUNDWATER MANAGEMENT

A comprehensive groundwater monitoring bore network currently exists around Meandu Mine. This includes bores located at strategic points downstream of mine operations and the ash disposal facility as well as background bores designed to detect any potential impacts further afield. Bores are monitored quarterly by an independent contractor and samples analysed by a National Association of Testing Authorities (NATA)-accredited laboratory. An annual review of groundwater monitoring data is undertaken to identify any changes and assess potential impacts to groundwater.

The groundwater monitoring bore network at Meandu Mine includes bores within Ace, King and Queen coal seams, alluvial aquifers on Meandu Creek and Black Creek, and within backfilled pits. The network has been developed on an ongoing basis since 1993.

The groundwater monitoring network is shown in Figure 2.5. Further information is provided in Section 4.3 of this Environmental Investigation Report.

Section D of EA (EPML00709113) regulates groundwater monitoring and quality at Meandu Mine. The following sections outline groundwater monitoring bore data and groundwater quality compliance requirements for the Meandu Mine.

2.5.5.1 GROUNDWATER COMPLIANCE MONITORING LOCATIONS

The following bores have been assessed to be hydraulically isolated (i.e. unimpacted by mining) for the purposes of meeting Condition D7 of EA (EPML00709113):

- Alluvial bore: GW39
- King Seam bores: GW45_s, GW46_s, GW58_d
- Queen Seam bores: GW43_d, GW44_d, GW44_s, GW45_d, GW46_d, GW63_d.

The location of these bores is shown on Figure 2.5. The locations for compliance monitoring from EA (EPML00709113) are presented in Table 2.5.

Table 2.5 Groundwater monitoring locations and frequency for Condition D5 - Table D1 of EA (EPML00709113)

GEOLOGY	MINIMUM NUMBER OF MONITORING LOCATIONS	MINIMUM MONITORING FREQUENCY
Meandu Creek Alluvium	1	Quarterly
Coal Measures – Ace Seam	0	Quarterly
Coal Measures – King Seam	2	Quarterly
Coal Measures – Queen Seam	3	Quarterly
Coal Measures below Queen Seam	2	Quarterly



Legend

- TPS GW Bores
- Meandu GW Bores
- GW DNRM Bore
- Watercourse
- Meandu Surface Rights Area
- Mining Lease
- Cadastre

Map: PS102396_Fig1_GWNetwork_r1v1

Author: NK

Date: 28/08/2018

Approved by: AOK



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Coordinate system: AGD 1984 AMG Zone 56

Scale ratio correct when printed at A3



Environmental Investigation Report

Figure 2.5 Groundwater monitoring network

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2.5.5.2 GROUNDWATER CONTAMINANT TRIGGER LEVELS

Groundwater contaminant trigger levels as per Condition D6 – Table D2 of the EA (EPML00709113) are presented in Table 2.6. The contaminant trigger levels are applied to the Meandu Creek alluvium (at bore GW39) as well as Triassic coal measures (King Seam, Queen Seam and units below Queen Seam in the area adjacent to Meandu Creek).

*Table 2.6 Groundwater contaminant trigger levels for Condition D6, Table D2 of EA (EPML00709113) **

GEOLOGY	PARAMETER	UNIT	TRIGGER LEVELS	LIMIT TYPE
Meandu Creek alluvium at GW39 and Triassic Coal Measures: — King seam GW46_s — Queen Seam GW45_d, GW46_d and GW63_d — Coal seams below Queen Seam GW01 and GW11	pH	pH Unit	5.5 – 9.0	Minimum and maximum range
	Electrical conductivity	µS/cm	3400**/6220***	
	Sulfate	mg/L	244****	Maximum
	Fluoride	mg/L	2	Maximum
	Aluminium	mg/L	0.08	Maximum
	Arsenic	mg/L	0.042	Maximum
	Boron	mg/L	0.68	Maximum
	Cobalt	mg/L	0.1	Maximum
	Lead	mg/L	0.154	Maximum
	Manganese	mg/L	2.5	Maximum
	Molybdenum	mg/L	0.05	Maximum
	Nickel	mg/L	0.12	Maximum
	Selenium	mg/L	0.018	Maximum
	Vanadium	mg/L	0.5	Maximum
	Zinc	mg/L	0.138	Maximum

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

**Proposed electrical conductivity trigger for Meandu Creek alluvium at GW39 is 3400 µS/cm.

***Proposed EC trigger level for coal measures is 6220 µS/cm

****Proposed sulfate trigger level is 244 mg/L for coal measures. No trigger level for Meandu Creek alluvium at GW39 due to influence of Meandu Creek Dam on sulfate concentration at this site.

2.5.5.3 GROUNDWATER LEVEL TRIGGERS

Groundwater level triggers presented in the EA (EPML00709113) have been established based on defined bore trigger thresholds from the *Water Act 2000*. The bore trigger threshold is defined in the *Water Act 2000* as 5 m for a consolidated aquifer and 2 m for an unconsolidated aquifer (refer Table 2.7).

With respect to Meandu Mine, a consolidated aquifer is taken to mean groundwater units within the Tarong Beds (Ace Seam, King Seam and Queen Seam). An unconsolidated aquifer is taken to mean the shallow, unconsolidated groundwater units at site (Tertiary/Quaternary sediments).

Table 2.7 *Groundwater level monitoring for Condition D10, Table D3 of EA (EPML00709113)*

MONITORING LOCATION	TRIGGER LEVEL THRESHOLD*
Shallow Tertiary / Quaternary Units	2m/year
Triassic coal seams (King Seam and Queen Seam, excluding Ace Seam)	5 m/year

*Trigger level threshold only applies if changes in water level are assessed to be related to mining activities, but not related to climatic variation and other non-mining factors.

2.5.6 MEANDU CREEK RECEIVING ENVIRONMENT MONITORING PROGRAM

Licensed discharges from Meandu Mine (via CP3) are received by Meandu Creek Dam, which also receives continual blow-down water from the Tarong and Tarong North power stations as well as stormwater runoff. Water from Meandu Creek Dam is subsequently released to the receiving environment of Meandu Creek via a release valve at the dam wall (monitoring site W3).

Stanwell has obligations under EA (EPPR00971913) for the Tarong and Tarong North power station to report, at 3-yearly intervals, the results of studies conducted to determine the impact of cooling water releases at the Tarong and Tarong North power stations on:

- surface water and sediment quality of Meandu Creek Dam and Meandu Creek (including the biota of Meandu Creek)
- groundwater quality.

The Meandu Creek Receiving Environment Monitoring Program (REMP) (previously known as the Meandu Creek Monitoring Protocol) has been prepared to satisfy conditions WT14, WT15, WT16 and WT24 of EA (EPPR00971913). The REMP addresses the study requirements of groundwater, surface water, sediment quality and aquatic biota in Meandu Creek (including Meandu Creek Dam) to monitor and report the impact of cooling tower blowdown releases and the Tarong Ash Dam on the surface water and groundwater receiving environments.

2.5.7 LANDFORM AND REHABILITATION

Spoil dumps are progressively rehabilitated during ongoing mining operations. The rehabilitation process involves regrading and contouring the spoil to the design slope of final landforms, followed by vegetation establishment. This is assisted by the strategic use of topsoil, which has been stripped ahead of the overburden removal.

Rehabilitation activities include:

- **Landform preparation:** Reshaping is performed by dozers and scrapers to achieve the final landform. Preparation includes shaping the slope to achieve specifications outlined in EA (EPML00709113), contour bank construction and drain shaping. Final landform slopes are generally designed up to 17%, with minor areas up to a maximum of 25% to achieve tie-in with surrounding areas. Minimum specifications for drainage structures are site-specific and determined through hydrologic and hydraulic assessment. Contour banks are aligned with the contours on either side of the area to ensure correct drainage and are generally 1 m high with a back slope of 17%.
- **Erosion control:** Contour banks slow the water sufficiently to allow for penetration to assist with vegetation growth. The distance between contour banks is outlined in EA (EPML00709113) for different slopes and is generally no more than 70 m. A fall of approximately 1% will allow for delivery of water from the rehabilitation areas to the drains. Drain specifications are dependent on drain alignment and catchment. If required, drains will be lined with basalt rock (generally +150-500 millimetres (mm)), rock sheeting or rock checks as appropriate for the conditions.
- **Topsoil placement:** Topsoil is sourced using direct-placed topsoil removed from cleared areas in advance of mining operations or recovery from existing topsoil stockpiles at Meandu Mine. Topsoil will be spread to a depth of approximately 200 mm after landform preparation but as close as possible to ripping/ seeding operations to minimise erosion risk.
- **Ripping and seeding:** Ripping of the area is performed post-topsoiling and pre-seeding (or in conjunction with seeding) to aid in erosion control and assist with root and moisture penetration. The furrows that are created help

slow runoff water flow and increase infiltration, in addition to encouraging short term seed germination and long-term strong root development. Ripping occurs to a depth range of approximately +300-500 mm.

2.6 SHORT-TERM MANAGEMENT ACTIONS AS A RESPONSE TO AMD

In response to the identification of AMD issues at the Meandu Mine, Stanwell has implemented interim controls and made a number of infrastructure and mine planning management changes since 2015/2016 to address AMD issues occurring on site. These have included:

- initial changes to water management infrastructure
- construction of seepage collection dam RD27, automated lime-dosing and pump and pipework
- installation of solid bowl centrifuges at the CHPP to dewater tailings
- changes to rejects placement
- rehabilitation design changes.

In addition to the above, investigation of engineering solutions has commenced as a result of the outcomes of this environmental investigation and are discussed in more detail in Section 10.

Table 2.8 provides an overview of the infrastructure, mining and materials management changes with further details provided in Sections 2.6.1 to 2.6.4.

Table 2.8 *Overview of infrastructure, mining and materials management changes*

CURRENT ACTIONS	PURPOSE	LOCATION	STATUS AS AT 3 AUGUST 2018
Initial changes to water management infrastructure 2015-2016	To minimise the amount of Ramp7 and Bullgang Corner seepage water reporting to CP3 and Meandu Creek Dam. To lime-dose Ramp7 and Bullgang Corner AMD water in RD7. To ensure overflow water from RD7 reports to RD8. To maximise the re-use of water from RD8 to CHPP.	RD7/RD8 CHPP	Temporary lime-dosing in RD7 was replaced in May 2018 after RD27 was constructed and the new automated lime-dosing was in place in RD27.
Construction of seepage collection dam RD27 and pump and pipework Partially operational in November 2017 Fully operational in May 2018	To reduce amount of seepage that drains directly to RD7 – pump back to blend with other water on site – primarily for use on watering of haul roads.	Interception of Bullgang Corner and Ramp 7 Drain	May 2018 fully operational - Ramp 7 and Bullgang Corner all low flows intercepted auto lime-dose and blended with other water for haul road dewatering.

CURRENT ACTIONS	PURPOSE	LOCATION	STATUS AS AT 3 AUGUST 2018
Changes to tailings deposition and installation of solid bowl centrifuges at the CHPP to dewater tailings	To convert site from wet tailing to dry. To dispose dry tailings with rejects in spoil dumps	CHPP	Refer to Table 2.9 for timeline of events leading up to operation of solid bowl centrifuges and decommissioning of the North-West B TSF.
Changes to rejects placement with Central Pit catchment Late 2015, early 2016	To change to Central Pit Spoil Dump so that drainage (if any) within Central Pit catchment.	Central Pit	Established as part of Life of Mine Plan. Continual monitoring of performance.
Rehabilitation design changes 2016	To introduce 6 m of non-acid forming (NAF) cover as design criteria in the final cover over rejects areas in Hitachi Hill and future areas rehabilitated from 2016 on. This was a conservative assumption without the benefit of detailed modelling and monitoring. Purpose was to reduce infiltration to rejects areas by having a deeper cover.	Hitachi Hill	Life of Mine predictive model includes nominal 6 m of NAF cover as design criteria. Established as part of Life of Mine Plan. Continual monitoring of performance.

2.6.1 INITIAL CHANGES TO WATER MANAGEMENT INFRASTRUCTURE AND WATER QUALITY MONITORING

A number of initial short- and medium-term changes to the water management system were completed during 2015 and 2016 to ensure water releases from CP3 complied with EA (EPML00709113) requirements. These included:

- Desilting of CP3 weir to 1.4 ML capacity (previous capacity was 0.3 ML).
- Commissioning of lime-dosing treatment at RD7 (refer Photo 2.3 and Photo 2.4).
- Installation of alarm notification (linked to existing water level sensor at CP3) to alert on-site and on-call personnel when water may flow over the CP3 weir to Meandu Creek Dam.
- Installation of automated water quality monitoring in key storages (RD1, RD2, RD7 and RD8 and other water bodies along Meandu Creek which have the potential to report to CP3) to detect elevated electrical conductivity or low pH in storages and used as triggers to initiate internal water transfers.
- Expanding parameters and surface water/groundwater sites that are sampled to establish trends and provide early indication of conditions with the potential to impact water quality.
- Construction of an under-drain in Hitachi Hill to contain and direct Bullgang Corner seepage water to RD7 after construction of Hitachi Hill landform.
- Installation of a containerised (portable) lime-dosing system to lime-dose Ramp 7 and Bullgang Corner seepage water at RD7, to target a pH in the range 7-8. RD7 overflows to RD8. RD8 was also set as the primary source of water for the CHPP to maximise the re-use of the AMD water from RD8 to the CHPP.



Photo 2.3 RD7 showing lime-dosing container in the distance and water monitoring station in the foreground



Photo 2.4 RD7 lime-dosing recirculation line

2.6.2 CONSTRUCTION OF SEEPAGE COLLECTION DAM RD27 AND PUMP AND PIPEWORK

RD27 was constructed during financial year 2018 and collects mine impacted water expressing from the toe of the North-West Backfilled Pit, that is then lime-treated in RD27 and pumped to other dams or directed to site facilities for re-use, predominantly for haul road watering (Photo 2.5 and Photo 2.6).



Photo 2.5 Construction of pipework



Photo 2.6 Pipeline in RD26

Any sludge resulting from the lime-dosing operation will mix with other sediments that enter RD27 and when RD27 is desilted, the material will be placed in the tailings facility or with Mixed Plants Rejects in the rejects dump or other suitable locations.

As at November 2017 temporary operation had commenced with pumping from RD8 for haul road watering.

From May 2018 the system was fully operational with all low flows from Ramp 7 and Bullgang Corner intercepted, lime-dosed and blended with other water for haul road dewatering.

Photo 2.7 and Photo 2.8 show RD27 during construction and at completion respectively.



Photo 2.7 RD27 during construction



Photo 2.8 RD27 at completion

2.6.3 INSTALLATION OF SOLID BOWL CENTRIFUGES AT THE CHPP TO DEWATER TAILINGS

Solid bowl centrifuges were installed at the CHPP to dewater tailings and allow deposition of dry tailings. The main benefit of the solid bowl centrifuges is in reducing the need for future wet tailings storage facilities. Specifically in the North-West B TSF, the solid bowl centrifuges allow wet tailings deposited in the TSF to be minimised, with the amount of tailings water reporting to the North-West Backfilled Pit reduced. Combined with other controls, the solid bowl centrifuges will subsequently reduce the amount of seepage from North-West Backfilled Pit. A timeline of events leading up to the installation and operation of the solid bowl centrifuges at the CHPP is outlined in Table 2.9.

Table 2.9 Timeline of events leading up to operation of the solid bowl centrifuges

DATE	ACTION
Early 2016	Tailings slurry discharge was moved to the southern end of North-West B TSF with supernatant water recovery from northern end, to reduce volume of water ponded against spoil low wall and enhance beaching, drying and consolidation. Prior to this, deposition in North-West B TSF was sub-aqueous.
September 2016	Filter wall and sump installed in North-West B TSF to provide constant drawdown of free water to the sump and improve return water recovery and tailings drying/ consolidation.
November 2016	Secondary (pipehead) flocculation commenced to assist with tailings dewatering.
August 2017	Tailings deposition to North-West B TSF stopped.
December 2017	Solid bowl centrifuges operational.
June 2017	Commenced investigations and early planning works for North-West B-TSF decommissioning.
June 2018	As part of decommissioning, tailings deposition in North-West B TSF re-commenced in June 2018 to fill depressions and assist with desiccation/ consolidation in both the North-West B and RD16 TSFs.

The North-West B TSF and K2W TSF (ex RD16) is at the time of this report being submitted retained for emergency tailings disposal should be centrifuges be by-passed during breakdowns or for maintenance or repairs.

2.6.4 CHANGES TO REJECTS PLACEMENT WITHIN CENTRAL PIT CATCHMENT

Since 2016 rejects material from the CHPP is being dumped approximately 6 m beneath the final landform profile to allow adequate capping to be constructed over the top of the rejects. When the reject dump reaches its final landform capacity, it will be regraded, capped with a minimum 6 m NAF cover material, and rehabilitated as per EA (EPML00709113) requirements. The purpose of this change was to reduce infiltration to the rejects (the main potentially acid forming (PAF) material at Meandu Mine) by having a deeper cover. This method is established as part of Mine Planning at Meandu Mine and the performance of this method will be monitored over the life of mine.

3 MINE MATERIALS PLACEMENT AND CHARACTERISATION

SECTION OVERVIEW

This section presents the results of the assessments undertaken by RGS to characterise mine materials and by Stanwell to identify the locations and extent of potential AMD source materials at the Meandu Mine. It specifically addresses requirements B1(iv), B3(i) and B3(iii) of the Notice.

B1(iv) a summary of geochemical data relevant to the investigation.

B3(i) geochemical assessments to characterise the chemical and physical properties of any material at Meandu Mine (soil, overburden, in-pit side cast coal, product coal, rejects, tailings, ash etc) with potential to generate AMD so these materials can be classified and then managed appropriately.

B3(iii) studies to identify the extent and locations of potential AMD source materials at Meandu Mine.

For this environmental investigation, Stanwell developed a 3D material placement concept model in Vulcan, which identified the historical placement of ash, rejects, tailings and waste material across the mine site since commencement of production in 1983 through to 2016. The 3D concept model of waste material placement has been used to inform the environmental investigation into AMD at Meandu Mine, particularly the material classification assessment undertaken by RGS and development of the Integrated Water Model by Golder (Section 9).

The results of the geochemical assessments (Appendix E) undertaken by RGS to characterise the geochemical properties of mined materials and processed mine waste at the Meandu Mine are also presented within this section. Mined materials assessed through this investigation include:

- coal
- soil, overburden and interburden from non-mined areas that will be mined until the end of operations and that could be used for rehabilitation as a component of the soil cover over mine waste or as general fill in backfilled pits
- spoil comprising previously mined overburden, interburden, rejects and tailings
- mine waste produced or managed including tailings, rejects, and ash from the Tarong and Taron North power stations.

The purpose of the work completed by RGS was to qualify, and where possible quantify, the potential extent of AMD source materials at Meandu Mine, in terms of both the spatial extent of mine material placement that may contribute to AMD and the potential extent in terms of the concentration of sulfide bearing minerals that could oxidise and release AMD. This was achieved through the implementation of a static and kinetic geochemical analytical program between November 2016 to August 2018. Based on the findings from this geochemical program, RGS consider the AMD issues at Meandu Mine to be relatively minor and able to be managed through implementing changes to mining and the placement of mined materials.

Results of the material characterisation assessment have been used to inform the preparation of the 2017 Life of Mine Plan developed by Xenith (Appendix D) for this environmental investigation. The 2017 Life of Mine Plan has been developed with the aim of ensuring that Meandu Mine continues to provide coal to the Tarong and Tarong North power stations until 2037, while specifically taking into consideration geochemical properties when modelling the placement of waste materials at the mine. The 2017 Life of Mine Plan with its final landforms and modelled placement of waste materials forms the base case of the Integrated Water Model (Section 9) to determine if the 2017 mine plan will result in environmental harm to surface or groundwater environmental values as a result of AMD.

In addition, information from this review, in conjunction with information from the hydrogeological assessment (Section 4) has been used to develop source terms to inform development of the Integrated Water Model (Section 9).

3.1 MATERIALS PLACEMENT

3.1.1 MINE PROGRESSION

Meandu Mine has been in operation since 1983. As mining, has progressed, different disposal locations for waste material, rejects and tailings have been used. Historical information has been interrogated to determine the location of tailing, rejects and ash placement within the waste dumps of the Meandu Mine. Historical locations for the disposal of waste material, rejects and tailing have been identified through reference to historic aerial imagery, mine documentation and conversations with site representatives and long-term employees of Meandu Mine. Historical locations are summarised in the following sections.

Operations at Meandu Mine commenced in the King 1 (K1) and King 2 (K2) open pits, progressing to the North-West A Pit. The North-West B Pit was opened after North-West A Pit had been mined. The North-West A Pit was used to store spoil, rejects and tailings until December 2005.

The Queen West and King 2 West (K2W) pits operated from mid-2002 through to late 2004 and were backfilled during 2005 and 2006. The K2W Pit continued to be mined to the east until 2012 and was then used to store ash from the Tarong and Tarong North power stations. Mining in the King 2 North (K2N) Pit commenced in 2010. Deposition of ash into the K2N Pit commenced in late 2016. Additional ash storage in the K2W and K2N pits was achieved by the construction of a dam wall between the backfilled spoil on either side of the ramp into K2W/K2N.

Mining operations currently advance the existing Central; Ramp 5; King 4 East (K4E); and King 4 South (K4S) pits. King 2 East (K2E) pit is not planned to be further mined until 2023.

3.1.2 MATERIAL DISPOSAL

Waste materials produced from operations at the Meandu Mine and disposed of on-site includes:

- Waste –overburden and interburden material hauled from mine pits
- Rejects – oversized/poor quality material hauled from the CHPP
- Tailings – waste material piped from the CHPP
- Ash – waste material piped from the Tarong and Tarong North power stations to the K2W/K2N pit voids.

Historic and current placement of these materials at the Meandu Mine site is summarised in the following sections.

3.1.2.1 WASTE MATERIAL DISPOSAL

Disposal locations for waste material at the Meandu Mine are outlined in Table 3.1 and shown on Figure 3.1.

Table 3.1 Disposal locations for waste material (to 2016)

LOCATION	MATERIAL DISPOSED	DURATION	COMMENTS
Central Dump	Waste material Rejects	2007 – present	Waste material originating from Central Pit.
K2 Dump	Waste material Tailings	1991 1995 – present	Waste material originating from the K2E and K2N pits.
K4 Dump	Waste material	1989 – 2001 2006 – present	Waste materials originating from the K4E, K4S, K4W and South-West pits.
R5 Dump	Waste material Rejects	1996 – present	Waste material originating from the Ramp 5, K4E and South-West pits.

LOCATION	MATERIAL DISPOSED	DURATION	COMMENTS
West Dump	Waste material Rejects Tailings	1987 – 1994 2001 – present	Waste material originating from the West, Central, Ramp 5, North-West B and the South-West pits.
Hitachi Hill	Waste material Rejects	2013 – 2016	Waste material originating from the Central Pit.
North-West TSF Dump (also referred to as Ramp 3 tailings)	Waste material Tailings	2006 - 2012	Waste material originating from the Central Pit.
North-West Dump	Waste material Rejects Tailings	1986 – 1996 2003 – 2011	Waste material originating from the Central West, North-West A and North-West B pits.
Boundary Dump	Waste material Rejects Tailings	2005 – 2007 2009 – 2010	Waste material originating from the K2E Pit.
Queen West Dump	Waste material	2002 – 2007	Waste material originating from the Queen West and the K2W pits.
South-West Dump	Waste material	1995 – 2003	Waste material coming from the South-West Pit
K1 Dump	Waste material Rejects Tailings	1983 – 1995 2001	Waste material coming from the K1 Pit.



3.1.2.2 REJECTS DISPOSAL

Coal rejects were initially placed into small cells and then into RSA1 to the west of the North-West Backfilled Pit (refer Figure 3.2). RSA1 was initially constructed on top of natural ground that allows surface runoff and seepage to report onto Ramp 7 haul road, into RD7 and into the upper ephemeral area of Meandu Creek via RD8 and RD2.

Disposal locations for rejects at the Meandu Mine are outlined in Table 3.2 and shown on Figure 3.2.

Table 3.2 *Disposal locations for rejects (to 2016)*

LOCATION	MATERIAL DISPOSED	DURATION	COMMENTS
Central Overburden Rejects	Rejects Waste material	2015 – present	Current rejects disposal area.
Western Haul Road Rejects	Rejects Waste material	2015 – present	Current rejects disposal off the Western Haul Road in the Central Dump.
West Overburden Rejects	Rejects Waste material Tailings	2014 – present	Current rejects disposal in the West Dump.
Ramp 5 Rejects	Rejects Waste material	2015	Rejects were disposed of into a small void in the Ramp 5 dump.
Hitachi Hill Rejects	Rejects Waste material	2013 – 2015	Large amount of rejects moved during Downer times has gone to Hitachi Hill.
K1E Rejects	Rejects Waste material	1991 – 1994	Identified and confirmed by long-term employees
North-West Rejects (6 m rehabilitation)	Rejects Waste material Tailings	1986 – 2012	Rejects on the North-West Dump which have been rehabilitated with 6 m of waste material.
North-West Rejects (3 m rehabilitation)	Rejects Waste material	1986 – 2012	Rejects on the North-West Dump which have been rehabilitated with 3 m of waste material.
North-West Rejects (1 m rehabilitation)	Rejects Waste material	1986 – 2012	Rejects on the North-West Dump which have been rehabilitated with 1 m of waste material.



3.1.2.3 TAILINGS DISPOSAL

Disposal locations for tailings at the Meandu Mine are outlined in Table 3.3 and shown on Figure 3.3. Tailings were initially placed into in-pit cells in the North-West A pit (North-West A tailings) and then into a valley fill tailings storage facility in the Black Creek catchment (K2 TSF) from 1986 to 1995 (refer Figure 3.3). Tailings were pumped to the TSF from the CHPP.

As tailings were placed into North-West A TSF, water within the tailings percolated into the adjacent spoil and rejects within the mined open pit. In about 2005 tailings placement in North-West A TSF stopped and rehabilitation commenced in 2008 by placing spoil and rejects on top of the tailings. Due to low geotechnical stability and overloading, the tailings were displaced vertically by some 50 m over about 3 years. From 2005 to December 2017 tailings were placed into North-West B TSF and water from the tailings continued percolating into adjacent spoil and into unsaturated spoil and rejects in North-West A TSF.

Table 3.3 Disposal locations for tailings (to 2016)

LOCATION	MATERIAL DISPOSED	DURATION	COMMENTS
North-West B TSF	Tailings	2006 – present	Current tailings storage facility
Cleavage Dump West Overburden West Overburden 2	Tailings Rejects Waste	2013	Tailings material from the old Ramp 2 TSF that has been dug out as Central Pit has progressed.
North-West A TSF	Tailings Rejects Waste	1997 – 2006	Tailings storage facility beneath Hitachi Hill. Was covered in waste material which created a pimple like effect with the centre of the North-West TSF rising up.
Ramp 2 TSF	Tailings Waste	1995 – 2003	Old Ramp 2 in K1 Pit was blocked off and used as a tailings storage facility. As Central Pit progressed the Ramp 2 TSF has been rehandled.
Ramp 3 TSF	Tailings Waste	1992 – 1996	Old Ramp 3 into North-West A Pit was blocked off and used as a tailings storage facility.
Tails Cells	Tailings Rejects	1992 – 1993	Tails Cells were constructed from rejects materials to dry out the tailings and sell off site. They were removed when North-West B Pit was dug.
K2 TSF	Tailings Waste	1986 – 1995	The original tailings storage facility when CHPP started.



Map: PS102396_FigR_Tailings_r1v4

Author: TW

Date: 11/09/2018

Approved by: AOK



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Coordinate system: AGD 1984 AMG Zone 56

Scale ratio correct when printed at A3

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Figure 3.3 Tailings disposal locations (to 2016)

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3.1.2.4 ASH

Until 2009 ash from the Tarong and Tarong North power stations was disposed of in the Tarong Ash Dam. From 2009 ash has been pumped from the Tarong and Tarong North power stations and deposited in Meandu Mine ash voids – K2W from 2009 and K2N from 2015.

Disposal locations for ash at the Meandu Mine are outlined in Table 3.4 and shown on Figure 3.4.

Table 3.4 Disposal locations for ash (to 2016)

LOCATION	MATERIAL DISPOSED	DURATION	COMMENTS
K2N ash void	Ash	2015 – present	Current ash disposal area
K2W ash void	Ash	2009-2016	Ash disposal area for the first 2-years of Downer contract. Recently has been covered with a 1.8 m layer of waste to control dust.

3.1.3 3D MATERIALS PLACEMENT CONCEPT MODEL

The information outlined in the previous sections was incorporated by Stanwell into a 3D materials placement concept model in Vulcan. This material placement concept model has informed this environmental investigation into AMD by providing an understanding of the historic mining and mine waste placement at Meandu Mine, and as such potential source locations of AMD.



Map: PS102396_FigS_AshDisposal_r1v4

Author: TW

Date: 11/09/2018

Approved by: AOK



0 430 860 m

1:30,000

Coordinate system: AGD 1984 AMG Zone 56

Scale ratio correct when printed at A3

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Figure 3.4 Ash disposal locations (to 2016)

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3.2 MATERIAL CHARACTERISATION AND CLASSIFICATION

3.2.1 OVERVIEW

The presence of AMD and non-compliance events associated with salinity in water released from the Meandu Mine triggered (amongst other technical studies) a drilling, sampling and static geochemical analytical program in 2015 (EGi 2016) and a static and kinetic leach testing program by RGS from November 2016 to August 2018.

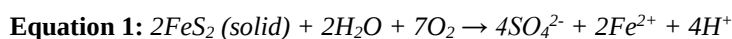
As part of the static and kinetic geochemical program, RGS reviewed geochemical reports from 1990 through to a comprehensive static assessment by EGi during 2015 that included over 1,000 samples from 9 drill holes. RGS added to the geochemical data by implementing additional static geochemical analysis of 1,418 samples and kinetic leach testing on 20 samples of ash, rejects and overburden samples. The kinetic leach testing has been ongoing for over 14 months. The results of these assessments are outlined in the following sections.

3.2.2 AMD CHEMISTRY AND CLASSIFICATION METHOD

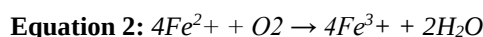
3.2.2.1 GENERAL AMD CHEMISTRY

AMD is generated from the oxidation of pyrite present in the coal and/or interburden material. The process generates a number of iron species and results in the precipitation of ferrous hydroxide minerals. A number of additional metals/metalloids are leached from the sediment into the seepage water during the process. The oxidation of pyrite to produce hydrogen ions (which lowers water pH) and ferrous hydroxides progresses as follows:

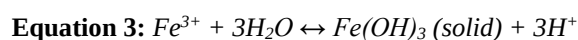
- Pyrite in the presence of water and oxygen is oxidised to form sulfate (SO_4^{2-}), ferrous iron (Fe^{2+}) and hydrogen ions (H^+), where the presence of free hydrogen (H^+) ions acts to lower the groundwater pH. This reaction is shown in Equation 1.



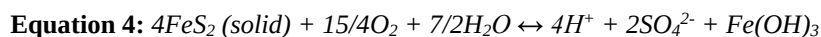
- Soluble ferrous iron (Fe^{2+}) is free to react further (in the presence of oxygen) to produce the ferric ion (Fe^{3+}) as shown in Equation 2.



- The reaction shown in Equation 2 may then proceed to the reaction shown in Equation 3, where ferric iron (Fe^{3+}) and water (H_2O) are converted to ferrous hydroxide ($\text{Fe}(\text{OH})_3$) and hydrogen (H^+) ions, which further lowers pH.



- The complete reaction described above is shown in Equation 4.

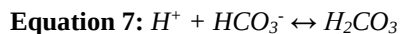
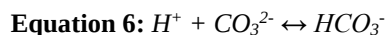


Ferrous hydroxide ($\text{Fe}(\text{OH})_3$) is often observable in AMD areas as a yellow or red stain on rocks or within streams that is known as “yellow boy”. Through the loss of water, the ferrous hydroxide can be converted to Fe_2O_3 (the rust-red mineral haematite) as shown in Equation 5.



It is this reaction process (i.e. rapid conversion of ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}), then ferrous hydroxide ($\text{Fe}(\text{OH})_3$) as groundwater discharges to the ground surface) that is interpreted to be occurring in areas where AMD is evident.

AMD depletes the buffering capacity of water through the addition of hydrogen (H^+) ions, which converts carbonate to bicarbonate (Equation 6) and then to carbonic acid (Equation 7), with the buffering capacity completely depleted at a pH of ~4.2 as all carbonate and bicarbonate within groundwater/ surface water is converted to carbonic acid:



The carbonic acid then readily breaks down into water and carbon dioxide, as shown below in Equation 8.



Based on the chemistry summarised above it could be expected that AMD-impacted groundwater would have low pH and relatively high iron. Iron concentration is interpreted to be a poor indicator of AMD impacts due to the relatively high concentration of iron in groundwater (especially in areas where basalt occurs, which is the case at Meandu Mine) and observation that the relatively high iron concentrations tend to occur at the initial site of seepage where groundwater seepage is oxidised as shown in the reactions above. As determined by JBT 2018 (Appendix F), better indicators of AMD-impacted groundwater are interpreted to include sulfate, cobalt, manganese, nickel and zinc. This is discussed further in Section 4.3.3.1.

3.2.2.2 COAL AND SULFUR

Sulfur in coal and mine waste materials can be present in a reactive sulfide form (such as pyrite or marcasite) and is typically the main contributor to the generation of acid and metalliferous drainage at mining operations. Generally, sulfur concentrations can be elevated in coal and coal reject materials due to the origin of these materials but can also be present in other stratigraphic units (RGS 2018).

Sulfur in coal is derived from two sources that include the original plant materials and ambient fluids in the coal forming environment. Abundance of sulfur in coal is controlled by depositional environments and the genesis of the coal seams and overlying strata. Typically, low-sulfur coal seams are formed by deposition in an alluvial environment not influenced by seawater. The sulfur in these low-sulfur coals is derived mostly from parent plant materials. High-sulfur coal seams are generally associated with marine strata where sulfate in the seawater diffuses into the initial peat and is reduced by microorganisms to form hydrogen sulfide, elemental sulfur and polysulfides. During early genesis in a reducing environment, ferric iron is reduced to ferrous iron, which reacts with hydrogen sulfide to form iron monosulfide. Iron monosulfide is later transformed by reaction with elemental sulfur into minerals such as pyrite (FeS_2) or marcasite (a polymorph of pyrite, also with chemical formula FeS_2), which upon exposure to oxidising conditions are typically reactive and generate acid and metalliferous drainage as outlined in Section 3.2.2.1.

Historical reports document that the depositional environment of the coal in the Tarong sequence at the Meandu Mine is understood to have been an alluvial environment with negligible marine influences at a regional level. Therefore, the magnitude of any acid generation is expected to be limited compared to coal formed in marine influenced strata. This was verified through sulfur data plots (RGS 2018). RGS worked with Stanwell to plot all total sulfur data within each coal seam and ply within the Joint Ore Reserves Committee (JORC) total sulfur database to allow the data to be presented as isopach (contour) maps. The purpose of the isopach maps was to define the distribution of the total sulfur laterally and vertically across the mine. The total sulfur isopach data verify that the distribution of total sulfur is consistent laterally and vertically within the seams and plies and is less than 0.5% total sulfur. A large majority of the coal samples have less than 0.2% total sulfur content. It can therefore be expected that the total sulfur content in rejects and tailings is also relatively low, but due to a lack of inherent acid-neutralising capacity (ANC), is still sufficient to generate acidity in some materials (e.g. coarse rejects).

3.2.2.3 AMD CLASSIFICATION METHODS

Standard Acid Base Accounting (ABA) methods used in the Australian mining industry (AMIRA 2002; COA 2016) and internationally (INAP 2009) were used by RGS to characterise and classify the mined materials from the drilling and sampling programs. The ABA estimates the balance between the potential for a material to generate and neutralise acid. They involve determining the maximum potential acidity (MPA) and the maximum inherent acid-neutralising capacity (ANC) of a sample, with the output expressed as kilograms of sulfuric acid per tonne (kg H₂SO₄/t).

Two parameters are calculated from the MPA and ANC: the net acid producing potential (NAPP) and the ANC/MPA ratio (also termed the neutralisation potential ratio (NPR)). The NAPP is a qualitative measure of the difference between the capacity of a sample to generate acid (MPA) and its capacity to neutralise acid (ANC), where $NAPP = MPA - ANC$. If the MPA is less than the ANC, then the NAPP is negative, indicating that the sample may have sufficient ANC to prevent acid generation. Conversely, if the MPA exceeds the ANC, then the NAPP is positive, indicating that the material may be acid-generating. The NPR provides an indication of the relative margin or factor of safety (or lack thereof) for a given material. Various NPR values are referenced in the literature for indicating safe values for the prevention of acid generation. Those values typically range from 1.5 to 3. As a rule, an NPR of 2 or more signifies that there is an increased probability that the material will remain near-neutral in pH and should not be problematic in terms of acidity generation and resultant acidic drainage.

Classification of mine waste materials using ABA analyses can be completed using a variety of standard methods, but the actual criteria are typically site dependent. For the purpose of this environmental investigation only, RGS has used the total sulfur content and the neutralisation potential ratio (NPR) to classify mined materials including soil, overburden, interburden, rejects, tailings and ash. A Leco analyser was used to measure the total sulfur (TS) concentration, which was then converted to a MPA value ($MPA = \text{weight\% sulfur} \times 30.625$). This conservative approach assumes all sulfur is present as sulfide minerals and that all sulfur will produce acidity. This assumption is known to overestimate the actual MPA because not all sulfur is present as reactive pyrite (i.e. sulfide sulfur measurements completed by RGS confirmed that approximately 20 to 40% of the total sulfur measured is likely to be present as either sulfate, sulfate minerals or organic sulfur). Chromium Reducible Sulfur (CRS) can be used to significantly improve estimates of sulfide sulfur.

The geochemical classification system used by RGS for this environmental investigation to classify the mine waste materials into different material types is summarised in Table 3.5.

Table 3.5 *Geochemical classification system used by RGS for mine waste materials*

MATERIAL TYPE	CLASSIFICATION CRITERIA
Acid Consuming (AC)	TS% < 0.05 and NPR > 10 and > 50 kg H ₂ SO ₄ /t
Non-Acid Forming (NAF)	TS% < 0.05 and NPR > 3
Non-Acid Forming Uncertain (NAF-UC)	TS% < 0.05 and NPR < 3
Potentially Acid Forming Uncertain (PAF-UC)	TS% > 0.05 and < 0.2% and NPR > 1 < 3
Potentially Acid Forming – Low Capacity (PAF-LC)	TS% > 0.05 and < 0.2% and NPR < 1
Potentially Acid Forming (PAF)	TS% > 0.2%

The NPR values adopted for the criteria are very conservative. For example, for PAF- UC, RGS assumes that the ANC levels will at least equal (i.e. balance the MPA), that is no acid would be returned in the NAPP test. It should be noted that additional testing such as Net Acid Generation (NAG) tests, can also be used in conjunction to ABA tests and could result in a reduction of PAF determinations and further that kinetic testing can result a more accurate determination as to whether a material has a significant potential to generate acid.

3.2.3 REVIEW OF PREVIOUS GEOCHEMICAL REPORTS AND SAMPLING PROGRAMS

In July 2015, IMEMS completed a review of historic geochemical reports that characterised and classified mine materials and process waste at the Meandu Mine. The main overall findings from these assessments were that:

- The materials at the Meandu Mine tend to have low sulfur content overall (below 0.5% sulfur).
- There was an overall lack of inherent buffering in these materials to offset any acid generation that occurred, with carbonaceous (organic carbon bearing) materials the main potential source of and AMD.
- There was no direct evidence of AMD from tailings, however this was based on limited samples.
- There was indication that higher sulfur (>0.2% sulfur) rejects may be PAF and some coal could also be PAF.
- Results from overburden were inclusive in that the samples did not represent the complexity of materials.

Based on these findings it was recommended that a dedicated geochemical assessment for Meandu Mine was undertaken to provide certainty in regards to the source and long-term impact of AMD. This resulted in the 2015 sampling program undertaken by EGi and described in the following section.

3.2.3.1 EGI 2015 SAMPLING PROGRAM

In June 2015, EGi was commissioned to undertake a static geochemical testing program, which included over 1,000 samples, obtained from 9 drill holes:

- 746 samples from reverse circulation drill holes in the area to the east of K4E and K4S and K2E
- 212 samples from reverse circulation drill holes in Hitachi Hill within the North-West Backfilled Pit
- 5 samples from a remined tailings void
- 22 samples from the reject stockpile
- 17 samples from the CHPP tailings stream.

The results of the 2015 EGi static work program were:

- Most of the overburden and interburden is expected to be NAF and not require special handling for AMD control.
- Most coal, rejects and tailings are likely to be PAF-LC requiring management to prevent repeat occurrences of the AMD observed in the North-West Backfilled Pit area. It was recommended that in new dumping areas, where possible, PAF-LC materials be placed in pit below the long-term recovery water table level to allow inundation at closure and prevent long-term exposure to atmospheric oxidation.
- Existing dump areas containing coal, rejects and tailings may require construction of a cover system to limit infiltration into PAF-LC materials, transport of pyrite oxidation products, and salt rise into the growth horizon. To design and model performance of cover options, an understanding of the physical/hydrological properties of mine materials was required. Defining the distribution of coal, rejects and tailings in the existing dump areas would help to prioritise efforts.
- In-situ coal may also influence pit water quality when exposed in pit walls and floor. AMD management requirements for pit voids will depend on the leaching characteristics of the coal and its interaction with other pit wall materials and fill, the amount of coal exposed in the pit wall, location of the coal relative to the long-term water table level, the nature and physical/hydrological properties of any backfill, and potential downstream impacts.
- There may be additional water quality implications if acid seepage interacts with ash from the power stations.

Following on from this investigation the following programmes were recommended to better understand the geochemical properties of mine materials and help determine appropriate materials management requirements for operations and closure:

- Implementation a kinetic leach column testing program to understand the leaching characteristics of key mine materials.

- Investigation of spoil dump and tailings cover design for operation control and long-term prevention.
- Development of an inventory of mine dumps and pits.
- A detailed assessment of surface water and groundwater flow and quality across site.
- A detailed assessment of surface water and groundwater quality across site to identify AMD influences and trends, and evaluate potential impacts.

These recommendations were considered in the RGS sampling and analysis program developed to inform this environmental investigation.

3.2.4 SAMPLING AND ANALYTICAL PROGRAM FOR ENVIRONMENTAL INVESTIGATION

In 2016 RGS commence a sampling and analytical program to specifically address the requirements of the Notice. The program used diamond drill core, reverse circulation drill chips and bulk samples from test pits and included:

- Monthly static CHPP rejects and tailing analysis to track the variability in the chemical parameters and elements in these process waste materials over a 12-month period.
- Sampling of Hitachi Hill rejects from a 4.5 ha area of rejects that was being reprofiled to fit into the landform design for Hitachi Hill.
- Rapid screening program (pH and electrical conductivity) of spoil from Central and Ramp 5 pits using existing drill chips which ranged in age from 10 to 20 years.
- Completion of additional indicative NAF and PAF tests on spoil material from Central and Ramp 5 pits using samples from 9 test pits.
- Hitachi Hill soil cover verification program using 9 test pits.
- Ramp 7 seepage test pits.

The results from the RGS sampling and analytic program are summarised in the following sections.

3.2.5 STATIC GEOCHEMICAL TEST PROGRAM

Static testing provides chemical or physical data of a sample that is essentially a “snap shot” in time. Static chemical analysis provides data such as:

- pH
- salinity
- total sulfur
- ANC
- cation exchange capacity
- nutrient content or the water soluble or total elemental content of the sample.

The purpose of the static geochemical test program was to characterise and classify the overburden and interburden in the K2E, K4E, K4S and Central pits into six geochemical classes ranging from acid consuming (AC) to potentially acid forming (PAF) waste classes (refer Table 3.5). The geochemical data was utilised with the geological understanding of the overburden and interburden to develop an inferred (first pass) geological model of these materials, so that a preliminary material balance for the overburden and interburden could be developed and then used in the 2017 Life of Mine Plan developed by Xenith to ensure that any PAF material was not placed into a 6 m vertical or 50 m horizontal area of the ‘as-designed’ final reshaped landform.

The static geochemical test and classification program was also extended to coal rejects, tailings and coal ash materials and development and implementation of additional management strategies for coal rejects and tailings as part of the 2017 Life of Mine Plan including placement of these materials into mined pits.

3.2.5.1 AMD DATABASE DEVELOPED BY RGS

For the purposes of this environmental investigation RGS developed an AMD database incorporating data from the RGS sampling and analytical program as well as from the EGi 2015 sampling and analytical program. The database included 2,436 data points covering:

- overburden, interburden and process wastes such as rejects, tailings and ash
- 10 mine domains
- 16 mined lithological units (alluvium, basalt, siltstone, clay, claystone, conglomerate, lignite, sand, sandstone, shale, siltstone, soil, spoil, coal, rejects and tailings).

Results of the geochemical classification assessment are presented in the following section.

3.2.5.2 MINE MATERIAL CLASSIFICATION SUMMARY

Results from the geochemical materials classification assessment undertaken by RGS are summarised in Figure 3.5 to Figure 3.7. The data presented in Figure 3.5 confirm that most coal, rejects and tailings were classified as PAF-LC and PAF, due to the low ANC concentration in the samples. The data in Figure 3.5 also provides the number of samples tested which fell within the waste classes by the logged major lithological units.

Of the 1,018 samples with total sulfur and ANC results (including coal, rejects and tailings):

- 51% of the samples were classified as NAF.
- 14% were classified as PAF-UC.
- 35% were classified as PAF.

When coal, rejects and tailings are removed from the data set:

- 67% of the samples were classified as NAF.
- 17% were classified as PAF-UC.
- 16% were classified as PAF.

The data showing the number of samples within each waste class in each of the major lithological units is presented for overburden in Figure 3.6 and interburden in Figure 3.7. The green bars within the cells are graphical representation of the values in table, while the pink bars are graphical presentation of the values in table corresponding to the number of samples within the lithological or waste types.

Lithology	AC	NAF	NAF-UC	PAF-UC	PAF-LC	PAF	# Check
Alluvium			3				3
Basalt	2	15	2	2	2		23
Carb.Siltstone	1	8	1	19	9	3	41
Clay		18	35	1	16		70
Claystone	1	15	30	11	12	2	71
Conglomerate	3	23	14	6			46
Lignite						2	2
Sand		3	6				9
Sandstone	3	124	159	25	55	1	367
Shale		48	1	41	3	1	94
Siltstone	1	75	37	37	32	3	185
Soil			1	25	1		27
Spoil		12	29	2	13		56
Coal		2		8	107	35	152
Rejects			2	12	71	34	119
Tailings					18	35	53
Total sample #	11	343	320	189	339	116	1318
% by waste class	0.8	26.0	24.3	14.3	25.7	8.8	
Major waste group		NAF		PAF-UC	PAF		
% by waste group		51		14	35		

Source RGS 2018

Figure 3.5 Number of samples in each waste class by major lithological unit and mine waste type (coal, rejects, tailings)

	AC	NAF	NAF-UC	PAF-UC	PAF-LC	PAF	Sample # by lithology
Alluvium			3				3
Basalt	2	15	2	2	2		23
Carb.Siltstone				10	4	1	15
Clay		18	35	1	16		70
Claystone		6	25	8	9	2	50
Conglomerate		14	9	4			27
Lignite						2	2
Sand		3	6				9
Sandstone		33	105	8	31		177
Shale		48	41	1	3	1	94
Siltstone		10	19	9	7		45
Soil			1	25	1		27
Spoil		2	46	1	48	4	101
Total sample #	2	149	292	69	121	10	643
% by waste class	0.3	23.2	45.4	10.7	18.8	1.6	
Major waste group	NAF			PAF-UC	PAF		
% by waste group	68.9			10.7	20.4		

Source: RGS 2018

Figure 3.6 Number of samples in each waste class by major lithological unit in the overburden above the Ace coal seam

	AC	NAF	NAF-UC	PAF-UC	PAF-LC	PAF	Sample # by lithology
Carb.Siltstone	1	7	1	9	5	2	25
Claystone	1	9	5	3	3		21
Sandstone	3	91	54	17	20	1	186
Siltstone	1	65	18	28	25	3	140
Conglomerate	3	9	5	2			19
Coal (Roof & Floor)		2		6	21	42	71
Total sample #	9	183	83	65	74	48	462
% by waste class	1.9	39.6	18.0	14.1	16.0	10.4	
Major waste group	NAF			PAF-UC	PAF		
% by waste group	59.5			14.1	26.4		

Source: RGS 2018

Figure 3.7 Number of samples in each waste class by major lithological unit in the interburden below the Ace coal seam

As explained previously (Section 3.2.2.3) the static geochemical data for total sulfur and total ANC are used to calculate the maximum or NAPP but do not consider the reaction rates that are measured using kinetic leach column testing. The static geochemical results using the total sulfur data and the NPR indicate that:

- Coal, rejects and tailings are generally classified as PAF.
- Coal roof, coal floor and coal partings are generally classified as PAF.
- Basalt and conglomerate are predominantly classified as NAF.
- There is no clear relationship between the lithological units and PAF mine waste, meaning that:
 - It is currently not possible to classify mine waste using lithological coding unless spatial relationships can be derived with ongoing work to determine if the PAF samples within lithological units are constrained to a particular location or zone in the deposit.
 - Ongoing sampling and analyses will be required to remove uncertainty around the location of PAF mine waste.
- From a materials management perspective, RGS finds that the bulk of the samples in the overburden and interburden are within the NAF mine waste class and this is typical of most coal mines.

3.2.6 KINETIC MINE WASTE MATERIAL CHARACTERISATION

Kinetic leach column (KLC) tests provide dynamic data such as the rate at which the minerals in the sample will oxidise, dissolve or precipitate over time. KLC data are used on their own to evaluate the risk associated with a material and are a key input (source term) for water quality modelling.

KLC testing can also be used to confirm the static classification of the samples using total sulfur, ANC and NPR or alternatively prove that some materials classified as PAF using static tests can be treated as NAF materials. For example, the tailings, fine-grade and coarse-grade rejects are all classified as PAF. However, after 14 months of leach testing the tailings and fine-grade rejects have retained neutral pH drainage. Long-term KLC tests will verify if the samples remain NAF or become PAF (i.e. quantify the lag-period required for the sample to turn from NAF to PAF).

The KLC program for this environmental investigation used samples obtained from the K4E Pit for coarse-grade reject samples, fine-grade rejects collected from the CHPP belt, tailings from the CHPP underflow thickener, ash from the K2N ash void and overburden samples from drill core samples collected from K2E. The samples were evaluated as individual samples (blue shaded samples in Table 3.6 and in a variety of mixtures to simulate potential management strategies such as:

- co-disposal of tailings and rejects
- co-disposal of tailings, rejects and ash
- co-mingling of rejects and overburden samples
- the addition of agricultural lime to increase the sample ANC.

Table 3.6 *Summary of the KLC samples evaluated*

SAMPLE ID	MATERIAL	SOURCE / TESTING
Waste material		
KLC2	Ash (100%)	Ash slurry deposited into K2N and K2W from Tarong and Tarong North power stations.
KLC3	Tailings (100%)	Tailings from the CHPP underflow thickener (< 0.075 mm) and used as provided after drying.
KLC5	Fine-Grade Rejects (100%) (Simulate end tip placement)	Fine-grade rejects from the CHPP (nominally < 10 mm PSD) collected from reject belts and used as provided.
KLC12	Coarse-Grade Rejects (100%) (Simulate end tip placement)	Coarse-grade rejects collected from K4E (> 75 mm PSD) and crushed to pass a 19 mm PSD in KLC.
KLC23	Rejects from Hitachi Hill (100%)	Medium-grade rejects from Hitachi Hill (nominally < 50 mm PSD)
Overburden/interburden		
KLC9	Weathered Basalt (100%)	Heavily weathered oxidised basalt / clay from 5 to 7.6 metres below ground level (mBGL) in K2E that was used as provided.
KLC10	Shale (100%)	From 87 to 92.4 mBGL in K2E crushed to pass a 19 mm PDS in KLC.
KLC20	Conglomerate (Weathered Coarse Sandstone) (100%)	Conglomerate from 40.1 to 44.3 mBGL in K2E crushed to pass a 10 mm PDS in KLC.
KLC21	Volcanic Transition (Base of Tertiary) (100%)	Weathered basalt (base of tertiary) (from 45.8 to 52.9 mBGL in K2E) – impermeable and did not leach
KLC22	Sandstone (100%)	From 75 to 82.7 mBGL in K2E crushed to pass a 10 mm PDS in KLC.

SAMPLE ID	MATERIAL	SOURCE / TESTING
Compaction		
KLC13	Coarse-Grade Rejects (100%) (Simulate traffic compaction)	Coarse grade rejects collected from K4E (> 75 mm PSD) and crushed to pass a 19 mm PSD in KLC and attempted compaction.
Co-disposal		
KLC1	Ash (90%) + Tailings (10%)	Testing co-disposal of tailings and ash
KLC6	Fine-Grade Rejects (75%) + Tailings (25%)	Testing co-disposal of reject and tailings
KLC15	Coarse-Grade Rejects (75%) + Tailings (25%)	Testing co-disposal of rejects and tailings
KLC8	Fine-Grade Rejects (60%) + Tailings (5%) + Ash (35%)	Testing co-disposal of rejects, tailings and ash
KLC11	Coarse-Grade Rejects (KLC#12) (60%) + Tailings (5%) + Ash (35%) (Simulate co-disposal)	Testing co-disposal of rejects, tailings and ash
KLC16	Coarse-Grade Rejects (75%) + Weathered Basalt (25%) (Simulate end tip placement)	Testing co-disposal of coarse-grade rejects with weather basalt
KLC17	Coarse-Grade Rejects (75%) + Weathered Basalt at the base of the Tertiary unit (25%) (Simulate end tip placement)	Testing co-disposal of coarse-grade rejects with weathered basalt
KLC4	Fine-Grade Rejects (75%) + Weathered Sedimentary (25%)	Testing co-disposal of fine-grade rejects with overburden / interburden
KLC7	Fine-Grade Rejects (75%) + Weathered Basalt (25%) (Simulate end tip placement)	Testing co-disposal of fine-grade rejects with overburden / interburden
KLC18	Fine-Grade Rejects (75%) + Sandstone (25%) (Simulate end of tip placement)	Testing co-disposal of fine-grade rejects with sandstone
Addition of lime		
KLC14	Coarse-Grade Rejects (100%) + Limestone (Simulate end tip placement)	Testing supplemental addition of calcium carbonate.
KLC19	Fine-Grade Rejects (100%) + Limestone (450g) (Simulate end tip placement)	Testing supplemental addition of calcium carbonate

The KLC program has been ongoing for over 14 months. Leach cycles were conducted each month. It is important to understand that the KLC results presented in this report as pH, electrical conductivity and mg/L concentrations are derived from the water / rock ratios used in the laboratory and do not reflect actual water quality that would occur in the field. Laboratory KLC tests provide a “worse case” outcome in terms of sulfide oxidation and solute leachability because the samples contact with oxygen or water is not limited. Under field conditions processes such as sulfide oxidation can be slower than under laboratory conditions. Results of the program are summarised in Table 3.7.

Table 3.7 *Kinetic leach column test results*

SAMPLE	CLASSIFICATION	
	STATIC	KINETIC
Coarse-grade rejects (KLC12)	PAF: Total sulfate: 0.13% Sulfide sulfate: 0.047% ANC: 2.1 kg H ₂ SO ₄ /tonne NPR: 0.5	— Sample dominated by coarse gravel size material with a high porosity and was free draining. — Initially leached neutral drainage but became acidic within six months. — After 14 months, leached drainage had a pH of 3 to 4. — After 14 months, the acidity in the leachate of this sample has increased slowly from 1 mg/L to 31 mg/L and sulfate was less than 100 mg/L. The sample has a lag period of less than six months to produce acidic drainage under unsaturated atmospheric conditions. — The coarse-grade rejects had relatively low concentrations of all metal(oids), however the concentration of copper and lead increased over 14 months up to 0.042 mg/L and 0.088 mg/L respectively. — The addition of 500 g of < 2mm agricultural lime to the sample (KLC15) (equivalent to 30 kg / tonne) had a substantial positive effect on maintaining the sample at neutral pH over 14 months. The initial pH was 8.2 and the final pH was 7.7. — The sulfate concentration was maintained at about 150 mg/L over the 14 months. The addition of agricultural lime ensures that the PAF-LC rejects do not become acidic (i.e. the PAF rejects become NAF through the addition of more ANC).
Fine-grade rejects (KLC5)	PAF-LC: Total sulfate: 0.15% Sulfide sulfate: 0.13% ANC: 1.9 kg H ₂ SO ₄ /tonne NPR: 0.4.	— Sample dominated by material less than 1 mm particle size and was not free draining. — Initially leached neutral drainage and retains a pH of 7.19 after 14 months of leaching. — Had low acidity over the program starting at 26 mg/L and ending with 11 mg/L. — Compared to the coarse-grade reject samples, the sulfate concentration was initially elevated (1,970 mg/L), but decreased rapidly to 154 mg/L after 14 months. The initially elevated sulfate concentration is attributed to entrained sulfate from the process water circuit in the CHPP and the high surface area of this sample. — Material represented by this sample therefore has a lag period of more than 14 months to produce acidic drainage under unsaturated atmospheric conditions. The fine-grade, low permeability of the material encourages moisture retention and limits sulfide oxidation. — The addition of 450 g of < 2mm agricultural lime to the sample (KLC19) (equivalent to 30 kg / tonne) had a substantial positive effect on maintaining this fine reject sample at neutral pH over 14 months. The initial pH was 8.1 and the final pH was 8.2. The sulfate concentration was initially elevated at 3,030 mg/L, but decreased rapidly over 14 months to 289 mg/L. — The addition of agricultural lime ensures that the PAF-LC rejects do not become acidic (i.e. the PAF rejects are rendered NAF through the addition of more ANC).

SAMPLE	CLASSIFICATION	
	STATIC	KINETIC
Tailings (KLC3)	PAF-LC: Total sulfur: 0.14% Sulfide sulfur: 0.048% ANC: 3.3 kg H ₂ SO ₄ /tonne NPR: 0.7.	— Dominated by material less than 0.075 mm and was not free draining. — Initially leached neutral drainage and retains a pH of 6.2 after 14 months of leaching. — Had low and consistent acidity and sulfate concentration over the test program of approximately 4 mg/L and 350 mg/L, respectively. — Material represented by this sample therefore has a lag period of more than 14 months if it were capable of producing acidic drainage under unsaturated atmospheric conditions. — The fine-grained and low permeability nature of the material encourages moisture retention and limits sulfide oxidation. — It is noted that lime [Ca(OH)₂] is added to the tailings stream to maintain the pH of the tailings at about pH 7, because there are times when the tailings has the potential to generate acidity at the CHPP.
Ash (KLC2)	NAF: Total sulfur: 0.02% Sulfide sulfur: <0.005% ANC: 1.1 kg H ₂ SO ₄ /tonne NPR: 0.6	— Dominated by material less than 0.075 mm particle size, but was free draining. — Initially leached pH 6.7 drainage and retained a pH of 7.4 after 14 months leaching. Lime (Ca(OH)₂) is added to the ash stream to increase the pH of the ash slurry to about pH 7 because there are times when the ash (like the coal and tailings) may produce some acidity. This process neutralises any actual acid in the ash. — Had low and decreasing acidity that reduced from 24 mg/L to 2 mg/L. — The concentration of dissolved sulfate also decreased rapidly from 1,910 mg/L to 10 mg/L over 14 months. The initially elevated sulfate concentration is most likely due to entrained water in the process circuit more so than sulfate released from sulfate dissolution. — Elevated but declining levels of trace elements were measured in the KLC leachate although vanadium levels remained consistent. Due to the very low sulfur content and non-detectable sulfide content it has no potential to produce acidic drainage.
OVERBURDEN / INTERBURDEN		
Clay-highly weathered basalt (KLC9)	PAF-LC: Total sulfur: 0.18% Sulfide sulfur: <0.008% ANC: 0.3 kg H ₂ SO ₄ /tonne NPR: 0.1.	— Dominated by material less than 2 mm particle size and had low permeability. — Initially leached pH 4.5 drainage and retained a pH of 5.5 after 14 months. This is normal for weathered volcanic soils and the acidity in this instance is attributed to soluble aluminium (Al³⁺) and manganese (Mn²⁺). — Had low and decreasing acidity that reduced from 33 mg/L to 6 mg/L over the 14 month test period. — The dissolved sulfate concentration also reduced from 212 mg/L to 115 mg/L over 14 months. — The electrical conductivity was initially elevated at 3,660 µS/cm, but this is due to the presence of dissolved sodium chloride (NaCl) and not sulfate. This is important as it shows that weathered overburden contains sodium chloride, which contributes to salinity in drainage at the site.

SAMPLE	CLASSIFICATION	
	STATIC	KINETIC
		— The very low sulfide sulfur concentration, coupled with its position in the upper fully oxidised and weathered regolith in the stratigraphic profile at the site, infers that this material is highly unlikely to produce acidic drainage due to sulfide oxidation.
Conglomerate / coarse sandstone (KLC20)	PAF-UC: Total sulfur: 0.05% ANC: 0.25 kg H ₂ SO ₄ /tonne NPR: 1.6 Noting that the sample lies at the intersection of NAF-UC / PAF-UC as total sulfur is neither below or above 0.05%.	— Dominated by material in the gravel fraction and was free draining. — Initially leached pH 7.7 drainage and retained a pH of 8.3 after 14 months of leaching. — The electrical conductivity was initially elevated at 2,400 µS/cm and decreased to 184 µS/cm at the end of the test period. The electrical conductivity was again dominated by sodium chloride rather than sulfate, indicating that the overburden is a source of salinity. — Elevated, but declining levels of the metal selenium were measured in the KLC leachate.
Sandstone (KLC22)	PAF-LC: Total sulfur: 0.08% CRS: <0.06% ANC: 0.25 kg H ₂ SO ₄ /tonne NPR: 0.1.	— Dominated by material in the gravel fraction and was free draining. — Initially leached pH 4.16 drainage and returned a pH of 2.65 after 14 months of testing. — Over the KLC test period, the acidity concentration increased from 48 mg/L to 232 mg/L and the sulfate concentration decreased progressively from 1,860 to 762 mg/L. — Elevated levels of metalloids were measured in the KLC leachate.
Shale (KLC10)	PAF-UC: Total sulfur: 0.05% CRS: <0.25% ANC: 0.03kg H ₂ SO ₄ /tonne NPR: 0.1	— The static classification and KLC tests results are consistent. — Sample initially leached pH 7.1 drainage and returned a pH of 5.4 after 14 months. — Over the KLC test period, there was no substantial change in the acidity (approximately 4 mg/L) and sulfate (approximately 600 mg/L) concentrations. — The shale had relatively low concentrations of metal(oids).

3.2.6.1 HITACHI HILL REJECTS

In addition to the test results noted in Table 3.7, reject samples collected from Hitachi Hill (location shown in Figure 3.2) in March 2016 were also analysed. At the time of collection (March 2016) these samples had a neutral in-field pH. However, after exposure to atmospheric conditions in sample containers at the site for six months, the samples were found to have a pH of < 3. This suggests that if rejects are co-mingled and progressively encapsulated they are unlikely to oxidise and produce acidity. In contrast, if rejects are left exposed to atmospheric conditions (in the range 3 to 6 months) they will oxidise and produce acidity.

KLC testing on the oxidised acidic reject sample was undertaken and while the pH has been consistent at 3.14 to 2.92 over 14 months the magnitude of the acidity decreased from 258 mg/L to 72 mg/L and the sulfate concentrations decreased from 1,190 to 105 mg/L. These data suggest that this particular reject sample was pH neutral during its placement and encapsulation, but following surface exposure, there was a period of oxidation and accumulation of AMD weathering products, that were subsequently rapidly leached from the sample during the KLC program. This data suggest that if the PAF rejects are emplaced and co-mingled with NAF spoil within four to eight weeks of being placed onto the reject stockpile they have a low potential to produce acid drainage.

3.3 OVERVIEW OF FINDINGS

3.3.1 ACID DRAINAGE POTENTIAL

The production of acidic drainage from mine waste materials is a function of the sulfide content and sulfide mineral morphology, the particle size distribution (and associated porosity) of the material, and the way the materials are mined, stored and managed.

The static analytical program undertaken by RGS for this environmental investigation has verified that in general terms the coal, overburden and interburden has very little acid neutralising capacity and therefore some samples with even minor sulfide content have the potential to oxidise and produce acidic drainage. The sulfide content of coal from Meandu Mine was plotted using isopachs and was confirmed to be low with most coal samples having less than 0.3% total sulfur. The static geochemical analysis results also verified that some potentially acid forming samples are present within the major lithological units (e.g. sandstone).

It was originally thought that AMD seepage from Ramp 7 and Bullgang Corner may have been due to porewater being squeezed directly from the tailings. RGS has shown however that this is not the case with over 14 months of KLC testing of tailings verifying that tailings continue to generate neutral pH drainage.

RGS has determined that the most probable cause of historic and ongoing AMD events from the North-West Backfilled Pit was oxidation of sulfide minerals and subsequent leaching of AMD weathering products from the reject storage. Reject materials collected from the re-exposed area in Hitachi Hill were initially pH neutral but become acidic within six months of exposure to oxidising conditions. KLC testing of this material confirmed that after oxidation, solute concentrations decrease rapidly. Hence, under free draining conditions it is expected that the weathering products from this material would be removed from the system quite rapidly.

Fresh coarse reject material had a six-month lag period until the onset of acid production. The fine-grade rejects, tailings and ash maintained neutral pH over the test period of 14 months. The weathered clay samples had acid leachate from the first leach cycle but this acidity is due to soluble aluminium and manganese not sulfide oxidation processes. The PAF sandstone material used in the KLC testing program produced acid leachate within one month. This sample selected for the KLC program is not representative of sandstone in general (sandstone is predominantly NAF or AC) but does provide an example of how some PAF material could behave.

The current Meandu Mine management practice of limiting storage/exposure time of coarse reject materials at the reject stockpile to less than two weeks appears to be an effective way of controlling the risk of acidic drainage generation. The potential for oxidation will be further reduced through the incorporation of fine-grade rejects and tailings as part of implementation of the dewatering process on-site, whereby pore voids within the coarse rejects will be filled with highly plastic low permeability tailings limiting oxidation and permeability. The combined reject and tailings streams will be placed into the spoil dumps and progressively co-mingled or encapsulated with overburden and interburden. The PAF overburden units identified in the highwall during mining will be segregated and placed at least 6 m under the final landform and covered by NAF material. If acidic drainage is perceived as an ongoing issue, then supplemental liming could be considered, but it is unlikely to be required. Ongoing drilling, sampling and analysis will be continued to improve the reliability of the overburden model so that PAF units can be identified ahead of mining and managed appropriately. Sampling of reject, tailings and ash streams should be continued into the future for basic geochemical test parameters to ensure the geochemical nature of the mine waste is tracked over time.

3.3.2 SALINE DRAINAGE POTENTIAL

Saline drainage can be attributed to sulfate released from the oxidation of sulfur bearing mine waste and overburden units but can also be from the mobilisation of sodium chloride from Tertiary and Triassic overburden and interburden. Saline drainage will continue in the absence of acidic drainage and acid bearing minerals. Whilst acidic drainage can be neutralised, saline drainage can only be managed through dilution or concentration. High salinity recorded in some

groundwater in the Black Creek catchment may be resulting from Tertiary Basalt in this area. This is discussed in Section 5.2.

3.3.3 *METALLIFEROUS DRAINAGE POTENTIAL*

Metalliferous drainage is mostly associated with acidic sulfide bearing minerals. However, the ash data verifies that some materials with neutral pH can leach anionic elements such as lithium, molybdenum and vanadium. The primary metals and ions in the AMD at Ramp 7 and Bullgang Corner include:

- aluminium (n=33 and avg. 0.56 mg/L)
- cobalt (n=31 and avg. 0.699 mg/L)
- iron (n=33 and avg. 98.79 mg/L)
- manganese (n=33 and avg. 31.19 mg/L)
- nickel (n=31 and avg. 0.512 mg/L)
- zinc (n=31 and avg. 4.26 mg/L)
- sulfate (n=37 and avg. 1,156 mg/L)
- sodium (n=37 and avg. 360 mg/L)
- chloride (n=37 and avg. 303 mg/L).

This seepage reports to RD7 where it mixes with other mine-affected water. Water from RD7 flows to RD8 where it is either reused for site purposes or reports to Meandu Creek Dam via CP3. Results of the surface water and aquatic ecology assessments undertaken for this environmental investigation have found that concentration of metals within Meandu Creek receiving environment are unlikely to be toxic to aquatic flora and fauna. This is discussed in detail in Sections 7 and 8 of this Environmental Investigation Report.

As discussed in Section 2.6, since 2015/2016 Stanwell has implemented a number of short-term and medium-term changes to ensure water releases from CP3 complied with EA (EPML00709113) requirements. These include desilting of CP3 weir to increase capacity and construction of RD27 to capture AMD seepage. Following treatment with lime, water from RD27 is either directed to other on-site dams for site facilities for reuse.

4 CONTAMINANT HYDROGEOLOGY INVESTIGATIONS

SECTION OVERVIEW

This section describes the results of the hydrogeological investigation undertaken by JBT (Appendix F) to inform the environmental investigation. Specifically, it addresses requirements B3(ii) (iv) (v) and B5(iii) of the Notice:

B3(ii) contaminant hydrogeological investigations inclusive of drilling and installation of monitoring bores (if required)

B3(iv) investigations to identify physical and/or environmental influences relating to storage areas (coal rejects, overburden, waste rock and topsoil) that may determine the occurrence, rate of progression or volume of AMD generated at Meandu Mine for examplewater infiltration and drainage characteristics

B3(v) a dedicated site plan showing the location and extent of AMD at Meandu Mine, including existing seepage flow paths

B5 The predictive model must include:

B5(iii) potential contaminant pathways.

The requirements of Section B4 of the Notice relating to determining existing or future AMD-related impacts on groundwater environmental values are addressed in Section 6 of this EIR.

The hydrogeological investigations undertaken for this environmental investigation included:

- installation of an additional 12 groundwater monitoring bores
- airborne geophysics investigation to improve the understanding of geology and potential seepage zones at Meandu Mine
- development of a conceptual groundwater model for the Meandu Mine site based around understanding of groundwater units, groundwater recharge, groundwater inflow to mine voids, groundwater flow direction and groundwater seepage pathways.

Based on the investigations undertaken, the main mechanisms for seepage at Meandu Mine have been identified as:

- The major preferential pathway for groundwater seepage from voids is either the natural ground surface or the deepest mined surface, depending on the surface that exists at a given location.
- Seepage from spoil-filled voids tend to occur when the water level within the spoil rises to a level where seepage from the void is possible via topographic low-points such as pre-mining drainage channels or haul roads into the pit
- In areas where out-of-pit dumping of spoil has occurred, the groundwater flow within the spoil, as well as the pathways for seepage from the spoil will tend to honour the underlying topography.

The focus of the hydrogeological investigation has been on the North-West Backfilled Pit as the only area where AMD-impacted seepage expresses at the surface at Bullgang Corner and Ramp 7. Based on review of water quality data, two additional areas for further monitoring have been identified:

- a saline plume that has been identified with an origin close to the Queen West void
- an area within the Black Creek catchment in the northern area of the mining lease (where elevated levels of electrical conductivity, aluminium and zinc as well as low pH have been recorded).

It is noted that neither of these additional areas are assessed at this stage to involve seepage that is related to AMD, but have been included within the assessment for completeness. The hydrogeological investigations undertaken to identifying these areas are discussed in this section. Hydrogeological mechanisms for each domain of interest are presented in Section 5.

4.1 SURFACE GEOLOGY

As introduced in Section 2.3, the Meandu Mine is located within an area where the Late Triassic Tarong Beds that overlie part of the Triassic-aged Tarong Basin, a north-northwest – south-southeast trending elongated pull-apart basin, the maximum dimensions of which are approximately 80 km long and 30 km wide (Pegrem 1986). In the area of the Meandu Mine the maximum width of the Tarong Basin is approximately 10 km. the approximate western and eastern limits of the Tarong Basin are shown on Figure 2.2. These limits are based on interpretation of the boundary between the Boondooma Igneous Complex (Permo-Triassic intrusives) to the west, the Maronghi Creek beds to the east, and sediments of the Tarong Beds in the Meandu Mine area.

4.1.1 FORMATION OF THE TARONG BASIN

Three stages in development of the Tarong Basin have been described in Flood and Garces (1986) and are shown on Figure 4.1. The stages comprise:

- Stage 1 – A strike-slip fault developed with a northwest-southeast orientation. The fault has a regional kink shown in the area where the Tarong Basin has later developed. To the west are located granitic rocks of the Boondooma Igneous Complex, while to the east are developed meta-sediments of the Maronghi Creek beds. The direction of paleo-drainage is from west to east.
- Stage 2 – The Tarong Basin started to open up due to movement along the strike-slip fault. On the western side of the fault, rocks of the Boondooma Igneous Complex moved in a relative northwest direction, while to the east of the fault, metasediments of the Maronghi Creek beds moved in a relative southeast direction. As the basin started to open up, the central area of the Basin began to subside and the deposition of sediments, which were derived from the basin margins, commenced. The dominant direction of sedimentation was from the west.
- Stage 3 – Increasing sedimentation from the west resulted in deposition of an alluvial fan complex that is known as the Tanduringie Fan (Flood and Garces 1986). Peat swamp depressions formed to the north and the south of the Tanduringie Fan, with coal deposits forming within the swamp environments as the basin widened and subsided further and sedimentation continued. The coal deposits to the south of the Tanduringie Fan are currently mined at Meandu Mine (i.e. the Tarong beds, which are up to 450 m thick at Meandu Mine (Pegrem 1986)), while the coal deposits to the north of the Tanduringie Fan are located within the area of the Kunioon deposit. There are no known coal deposits within the Tanduringie Fan between Meandu Mine and the Kunioon deposit and fan deposits can be seen at surface in road cuttings along the Tarong-Nanango Road (Pegrem 1986).

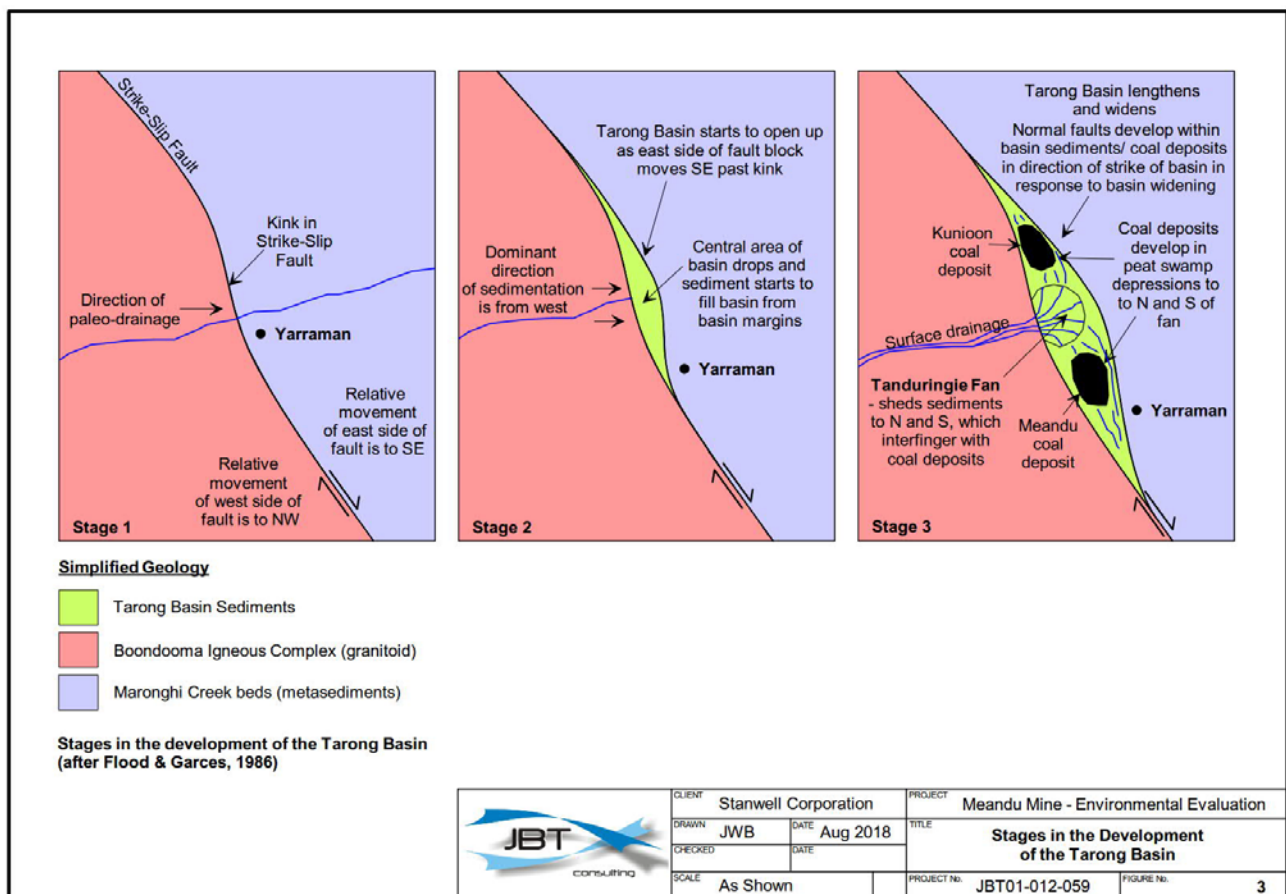


Figure 4.1 Stages in development of the Tarong Basin

4.2 CONCEPTUAL GROUNDWATER MODEL

A conceptual groundwater model was developed for the Meandu Mine site. This conceptual model is based on an understanding of groundwater units, groundwater recharge, groundwater inflow to mine voids, groundwater flow direction and groundwater seepage pathways within the Meandu Mine site. Each of these elements are outlined in the following sections.

4.2.1 GROUNDWATER UNITS

Mine-scale geology at Meandu Mine comprises, from the surface downwards: Quaternary alluvium, Tertiary basalt, spoil, regolith and upper Triassic coal measures (Tarong beds) with sandstone/siltstone between the coal seams. A summary of the known groundwater occurrence within each unit is provided in Table 4.1. It also includes reference to mine spoil, which is an anthropogenic unit specific to the Meandu Mine site that influences groundwater flow patterns and water quality.

Table 4.1 *Hydrogeological units – Meandu Mine*

GEOLOGICAL PERIOD	GEOLOGICAL UNIT	COMMENT
Quaternary	Alluvium	— Within the Meandu Mine area, alluvial sediments of the Meandu Creek and Rocky Creek systems comprise clay, silt, sand and gravel. — The aquifers are variable in extent (width and thickness). Permeable zones are often discontinuous and the degree of hydraulic connection throughout the alluvium is variable. — Within Meandu Creek the aquifers are generally less than 5 m thick, but thickness of up to 35 m have been observed from drilling along Barkers Creek (Pegrem 1986). The alluvial plain is more extensive near the confluence between Barkers and Meandu creeks and the alluvium in this area is up to 30 m thick. — Within the Meandu Mine area, the alluvium within Rocky Creek is relatively thin and unsaturated, with a regional water table below the base of the creek. — The coarser materials (sands and gravels) within the alluvial sediments form aquifers which are exploited for irrigation supply and town water supply, particularly within the Barkers Creek alluvium and downstream of the confluence of Barkers Creek and Meandu Creek. — DNRME bore logs indicate that the alluvium upstream of the confluence between Meandu and Barkers creeks is more extensive than is shown by geological mapping, which was based largely on aerial photographic interpretation.
Tertiary	Basalt (Main Range Volcanics)	— The Main Range Volcanics comprise olivine basaltic flows and lesser pyroclastics. Basaltic flows are interbedded with minor siltstones, shales, sandstone, silcrete. The basalts tend to occur as ridge-cap deposits which tend to be deeply weathered. — Groundwater occurs within the secondary porosity of fractures, or between and beneath flows where minor strikes of water may occur within interflow sediments. It is noted that all groundwater monitoring bores within the adjacent Meandu Mine which monitor the basalt have historically been dry.
Tertiary	Laterite, residual soils and slope wash deposits	— This unit is used to broadly categorise Tertiary-age colluvial deposits, alluvial fans, pediment slope wash, clay, silt, scree, pebbles and cobbles, and regolith. — At Meandu Mine the Tertiary unit comprises a unit that is known locally as the regolith; the regolith comprises the upper 20-30 m of Tarong beds that have been weathered during the Tertiary and consists of weathered sandstone, shale and conglomerate. The regolith is generally dry, though the unit may become variably saturated following recharge.

GEOLOGICAL PERIOD	GEOLOGICAL UNIT	COMMENT
Triassic	Tarong beds	Regionally the Tarong beds comprise: — A main lithology of labile (arkosic to sub-arkosic), fine to very coarse grained, poorly sorted sandstones and matrix supported conglomerates. The conglomerates tend to be dominant towards the basin margins and the lower parts of the sequence (Pegrem 1986). — Minor lithologies that include shale, siltstone, mudstone and coal. At Meandu Mine the coal deposits are developed to an extent that is economic for mining, with mining undertaken of the: — Ace Seam, which is typically oxidised and dry — King Seam, approximately 60 m below the Ace Seam. This seam generally contains groundwater though the unit may be dry depending on the reduced level (RL) of the strata — Queen Seam, a further 30 to 40 m below the King Seam, and generally containing groundwater. Located between the coal seams is the interburden, which comprises sandstone, siltstone and shale. The interburden is generally hydraulically “tight” and is of lower permeability than the coal seams; therefore, the coal seams are generally the water-bearing units at site.
Permian-Triassic	Boondooma Igneous Complex	— The Boondooma Igneous Complex comprises pink medium to coarse-grained biotite-hornblende granite, minor quartz diorite. — The granite may provide useable volumes of water to private bores where the unit is weathered or fractured, though the unit is regarded as a basement unit of the Tarong Basin (Flood and Garces 1986).
Devonian-Carboniferous	Maronghi Creek beds	— The Maronghi Creek beds comprise mudstone, shale, arenite, chert, jasper, acid to basic metavolcanics. — Groundwater within the Maronghi Creek beds occurs within fractures that are interpreted to be discontinuous and hydraulically isolated. — Regionally, a number of private groundwater bores are developed within this unit, which has the potential to provide low yielding supplies of groundwater suitable for stock watering (based on salinity).
Devonian-Carboniferous	Sugarloaf Metamorphics	— The Sugarloaf Metamorphics comprise slate, spotted hornfelsed slate, phyllite, quartzite, schist, amphibolite. — A number of private groundwater bores are developed within this unit, which has the potential to provide low yielding supplies of groundwater suitable for stock watering (based on salinity). This unit is regarded as a basement unit of the Tarong Basin (Flood and Garces 1986).
	Spoil	— Spoil, which comprises reworked material from coal mining. The spoil is variably saturated, containing perched water tables resulting from variable rates of recharge through the spoil material, as well as saturated zones at the interface between the base of spoil and underlying lower-permeability material.

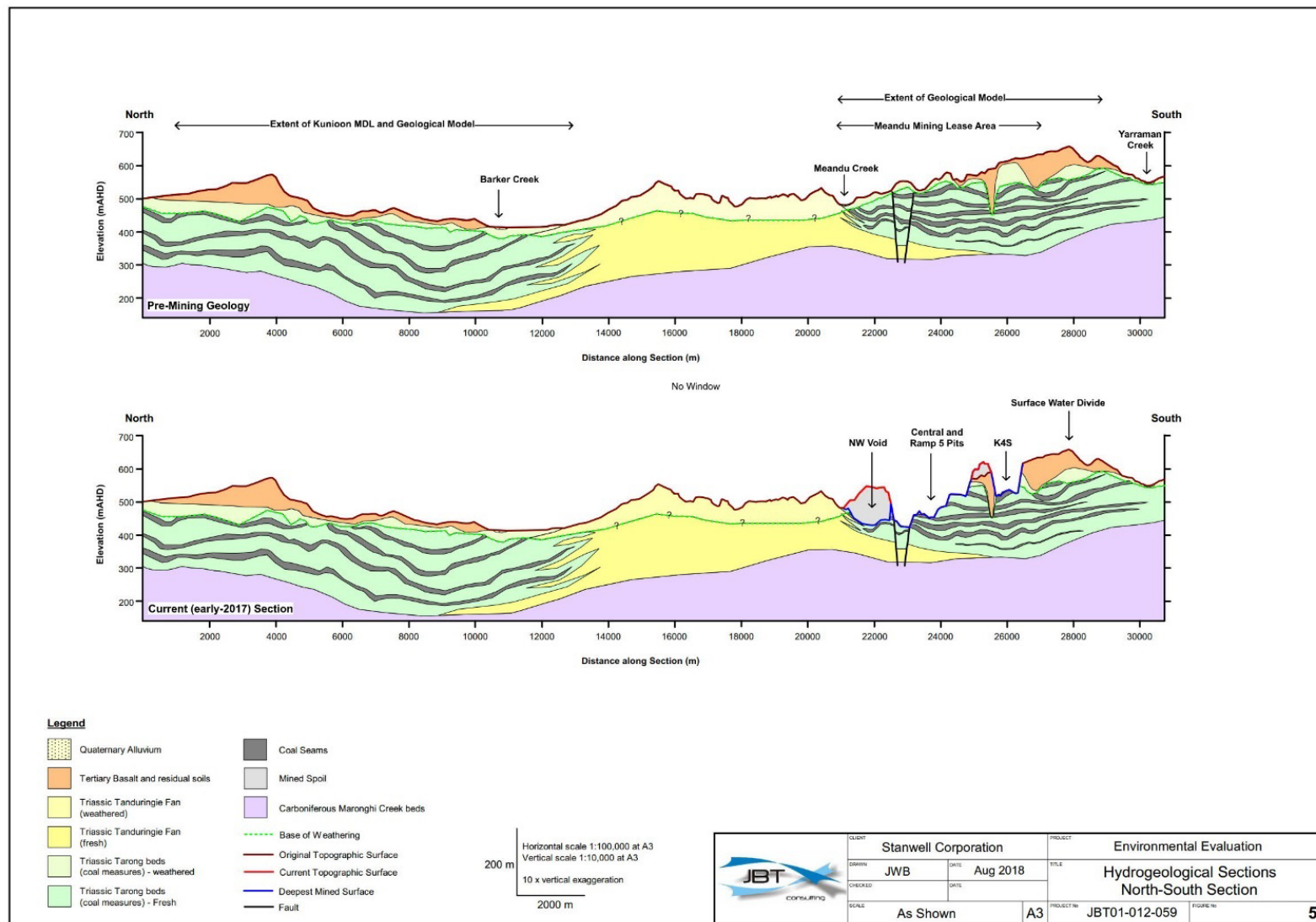
4.2.2 HYDROGEOLOGICAL CROSS-SECTIONS

As part of the hydrogeological investigation a number of cross sections were prepared showing the relationship between features of the Tarong Basin and the Meandu Mine. Hydrogeological sections north and south and east and west are presented in Figure 4.2 and Figure 4.3 respectively. In Figure 4.2 the upper cross-section shows the pre-mining geology and the lower-section the current (early 2017) extent of mining. This figure shows that:

- In the Meandu Mine area, the Tarong beds extend to the south beneath Yarraman Creek. It is interpreted that recharge to the deeper coal seams such as the Queen Seam is likely to occur in this area.
- The topography reduces in elevation from south to north and the bedrock elevation also decreases from south to north (based on the base of coal measures modelled at both the Meandu Mine and Kunioon deposit). It is stated in publications such as Pegrem (1986) that the coal seams dip at shallow angles towards the south and south-east, away from the central area of the alluvial fan (Tanduringie Fan); however, due to local and regional-scale faulting and folding, the overall dip of the coal measures is to the north in the sections shown on Figure 4.2.

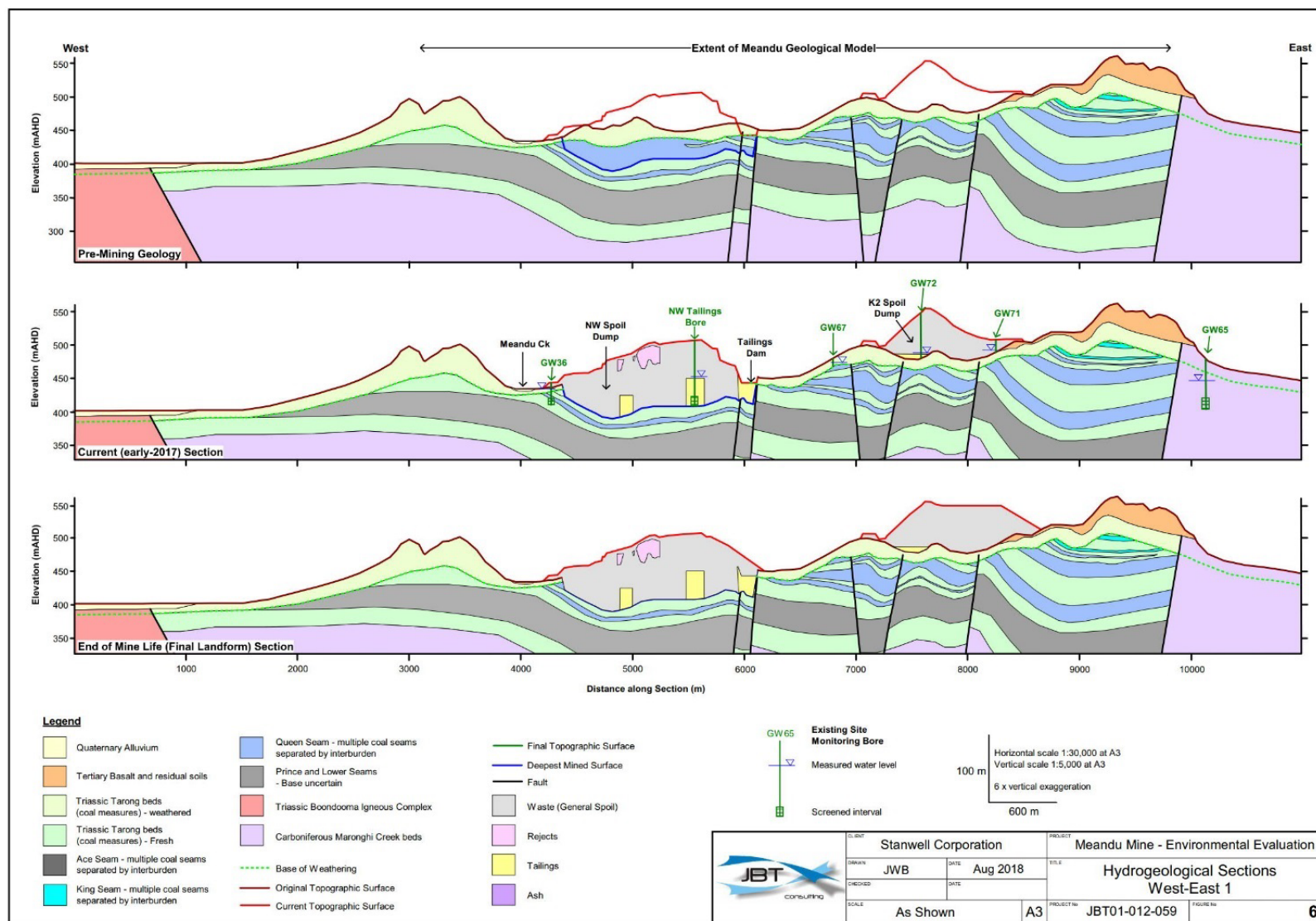
In Figure 4.3, the upper cross section shows the pre-mining geology, the middle cross section the current (early-2017) natural and mined geology and the lower cross section the final landform, that is, the full extent of mining. These sections shows that:

- A series of north-west/south-east trending faults significantly disrupt the lateral continuity of the coal measures. These faults have the potential to disrupt groundwater flow in cases where the throw of the fault is greater than the thickness of the coal seam resulting in, for example, the abrupt termination of a transmissive coal seam against lower permeability interburden.
- The overall dip of the coal seams is towards the east (away from the central area of the Tanduringie Fan, as noted in Pegrem 1986). However, the faulting has, in many cases, resulted in the western side of the fault dropping relative to the eastern side of the fault. Therefore, while the coal seams may dip locally to the east, the throw on the faults tends to result in a situation where the RL of the coal seams are higher in the east relative to the west. This results in a potential for groundwater flow from east to west (i.e. towards Meandu Creek), which is against the general dip of the coal seams.



Source: JBT Consulting 2018 (Appendix F)

Figure 4.2 Hydrogeological sections north-south section



Source: JBT Consulting 2018 (Appendix F)

Figure 4.3 Hydrogeological sections east-west section through North-West Backfilled Pit

4.2.3 GROUNDWATER OCCURRENCE AND FLOW DIRECTION

Based on a review of available geological data undertaken by JBT, the following conclusions are made with respect to groundwater movement and flow direction.

At Meandu Mine the dip of the coal seams is to the south and south-east (Pegrem 1986). However, as noted above the overall groundwater flow direction in the coal measures is interpreted to be towards the north-west (i.e. towards Meandu Creek). This is interpreted to be related to:

- The overall reduction in topography from south to north within the Meandu Creek catchment, with topography exerting a control on groundwater flow.
- The overall reduction in bedrock elevation from south to north within the section of the Tarong Basin where Meandu Mine, the Tanduringie Fan and the Kunioon deposit are located. The RL of the bedrock and topographic surface therefore also control the RL of the coal measures, with an overall reduction in the elevation of the base of coal measures from south to north.
- The north-west/south-east trending faults that are present at Meandu Mine create a situation where, in some areas of the mine, the western side of the fault is downthrown relative to the eastern side, creating a potential for groundwater to flow in the opposite direction to dip.

As such, groundwater flow direction within the coal measures is extremely complex and will be impacted by a number of factors including:

- Regional recharge patterns and localised (preferential) zones of recharge
- The dip of the coal seams
- Faulting, which acts to:
 - Locally alter the groundwater flow direction, with groundwater flow potentially occurring contrary to the direction of the dip of the coal seams
 - Compartmentalise groundwater occurrence and perturb groundwater flow, due to the truncation of coal seams (the conduits for groundwater flow) against low-permeability interburden.

Therefore, it is interpreted that the overall groundwater flow direction is as follows:

- For the shallow Tertiary units (Tertiary basalt and regolith) the groundwater flow direction is assessed to be in the direction of topography (i.e. from topographically elevated areas towards topographically lower areas and surface water drainage lines). It is also interpreted that the groundwater and surface water divides will be the same for the Tertiary units (i.e. the surface water and groundwater flow direction will tend to be to either side of the catchment divide).
- For the Meandu Creek alluvium, it is noted that Meandu Creek is a naturally ephemeral system and remains ephemeral upstream of the Meandu Creek Dam (below the Meandu Creek Dam the creek is perennial due to regular dam discharges). Upstream of Meandu Creek Dam, groundwater within the alluvium, which may be present due to seasonal recharge or mine seepage, will flow in a downstream direction within the alluvial channel but may also seep downwards in areas where the regional water table is below the base of the creek.
- For the Triassic coal measures, the overall groundwater flow direction is towards Meandu Creek. It should be noted that, for the coal measures, the groundwater divide is not the same as the surface water divide.

4.2.4 GROUNDWATER RECHARGE

Recharge to the groundwater system is conceptualised to occur as follows:

- Recharge to coal seams occurs where the units subcrop beneath shallow Tertiary sediments and Quaternary alluvium. The main area where recharge of the coal seams is conceptualised is to the south of the Meandu Mine lease, where the coal seams subcrop beneath Yarraman Creek (refer to the north-south section that is shown on Figure 4.2).
- The Tertiary basalt is recharged via direct rainfall, with recharge preferentially occurring in fractured zones (i.e. groundwater occurs only in fractures and is not pervasive). As noted above, the basalt tends to be dry in the Meandu Mine area, so the units that underlay the basalt (generally the Tarong beds) will receive a component of recharge via downward leakage from the basalt (which may therefore have an impact on the groundwater chemistry of the underlying units).
- Recharge to the Tertiary regolith will be via direct rainfall recharge, or via seepage from adjacent areas of spoil.
- The spoil is recharged via direct rainfall recharge. The spoil is porous and of relatively high permeability (based on observations of seepage following rainfall). Within previously mined voids, groundwater within the spoil tends to occur in the lower portion of the spoil pile and there is no evidence to date (from water level monitoring within the North-West Backfilled Pit void and Queen West void) of either significant groundwater mounds or perched water tables within the spoil.

4.2.5 GROUNDWATER INFLOW TO MINE VOIDS

The pits at Meandu Mine generally receive only minor volumes of groundwater inflow. Table 4.2 summarises observations of groundwater occurrence within the current operational areas of Meandu Mine provided by mine geological personnel.

Table 4.2 *Observed groundwater occurrence within current operational area of Meandu Mine*

PIT	OBSERVED GROUNDWATER OCCURRENCE
K2E Pit	Groundwater inflow occurs from the Queen Seam coal and from Tertiary basalt on the eastern/southern side of the pit
Central Pit	Groundwater inflow occurs through: — faults and joint surfaces — the Queen Seam, especially the plies above the D and E plies — from spoil on the Meandu Creek diversion side of the pit (inferring that, in the area where the Meandu Creek diversion occurs over mined spoil, downward seepage from the creek channel to the spoil occurs)
K4E Pit	Minor groundwater inflow is observed from the Queen Seam
K4S Pit	Minor groundwater inflow is observed from the low wall ramp area and from faults
K2W ash void	Groundwater seepage is observed from the base of Tertiary basalt along the eastern/southern wall of the pit void.

While it is observed that groundwater inflow occurs from faults in the mining area, it is not conceptualised that faults act as major conduits for groundwater flow in a regional sense (i.e. in areas beyond Meandu Mine). This is because:

- Faults tend to be closed and “tight”, however in mining areas the faults can open up (dilate) as overlying and adjacent material is removed by mining, allowing the faults to act as groundwater conduits.
- The volume of groundwater that is capable of being stored within individual faults is generally low and dissipates quickly once the fault is exposed by mining; therefore, ongoing seepage tends to be due to surface water that has recharged the faults (i.e. the faults are acting as conduits for surface water drainage).

4.2.6 GROUNDWATER FLOW DIRECTION

The factors that influence groundwater flow direction at Meandu Mine are complex and for this reason there has been no attempt to construct maps of groundwater elevation contours; rather, general observations of groundwater flow are provided as follows:

- For the shallow groundwater units (e.g. Tertiary basalt, Tertiary regolith, Quaternary alluvium) the groundwater flow direction honours topography (i.e. flows from highest elevation to lowest elevation).
- It is conceptualised that the Tertiary regolith was dry prior to mining and likely contained groundwater only in areas adjacent to surface water features such as Meandu Creek. Within the central area of Meandu Mine, the Tertiary regolith tends to contain groundwater as a result of seepage from mining areas or recharge through spoil, but the flow of groundwater within the regolith in these areas will still honour topography as discussed previously.
- Within the Triassic Tarong beds, the interburden tends to be dry and groundwater flow occurs in the more permeable coal seams. Due to the truncation of the coal seams by faulting, the conduit for groundwater flow (the coal seam) may be terminated abruptly and this will result in complex flow patterns. In general, however, the groundwater flow direction in the coal seams is conceptualised as follows:
 - Pre-mining – groundwater flow would be generally to the west/ north-west (i.e. towards Meandu Creek).
 - Post-mining/current – groundwater flow is towards the pits and groundwater inflow is removed via pumping and enters the surface water control system. Therefore, it is concluded that groundwater flow within the coal seams towards Meandu Creek only occurs in the western area of the mine (i.e. the area below and west of the North-West Backfilled Pit).

4.3 GROUNDWATER MONITORING DATA

Details of the groundwater monitoring bore network at the Meandu Mine are outlined in Section 2.5.5. An overview of the water quality and water level data obtained from these bores is provided in the following sections.

4.3.1 DATA AVAILABILITY

As discussed in Section 2.5.5, development of the current groundwater monitoring network has occurred on an ongoing basis since 1993. Development of the bores comprising the groundwater monitoring network is summarised in Table 4.3.

Table 4.3 *Development of bores within the groundwater monitoring network*

BORES	BORE SERIES	COMMENTS
Historic bores	GW1 to GW22 (not all bores were drilled)	Drilled in 1993 for development of groundwater monitoring network. Sampled water level and water quality on an irregular basis between 1993 and 2011. Monitoring was discontinued in 2011. In 2016 a number of bores were re-added to the monitoring program (GW01, GW02, GW05, GW09, GW11, GW21, GW22, GW25 and GW30 (Note GW25 and GW30 were drilled later in the program but their construction dates are unknown). GW05 was included as part of the K2W monitoring network and has been regularly monitored for groundwater level and quality data from August 1993 to present.

BORES	BORE SERIES	COMMENTS
K2W bores	GW50 to GW62	Drilled in September / October 2008 to monitor seepage from the K2W ash disposal facility. Bores GW52A, GW54B and GW59A were destroyed by the progression of mining and were re-drilled at nearby locations.
Hydrocarbon monitoring bores	GW33 to GW40 GW41 and GW42	Drilled in April 2011 in areas down-gradient of historic hydrocarbon storage and treatment areas and within Meandu Creek down-gradient of mining. Bores GW41 and GW42 were drilled in June 2013 to monitor groundwater conditions down-gradient of the North-West B TSF.
SRE bores	GW43 to GW46 GW62 to GW65	Drilled in February 2014 to monitor groundwater conditions in the area east of the current surface rights area. Bores in the series GW62 to GW65 were added to the network in July 2015.
EEE bores	GW66 to GW78	Drilled in August 2016 to provide additional data in areas that are down-gradient of prior voids and spoil dumps and to provide further information to support this environmental investigation into AMD.

The availability of groundwater level data from the groundwater monitoring network is summarised in Table 4.4.

Table 4.4 Summary of groundwater level availability for site monitoring bores

GROUNDWATER BORES	BORES	MONITORING PERIOD AND FREQUENCY
Historic bores	GW01, GW02, GW09, GW11, GW21, GW22, GW25 and GW30	August 1993 and January 2007 Quarterly since November 2016 (except GW25 where water level monitoring recommenced in February 2015)
K2W bores	GW05, GW50 – GW62	Quarterly intervals since 2008
Hydrocarbon bores	GW34-GW42	From May 2011
SRE bores	GW43 – GW46	Quarterly from February 2014
	GW62- GW65	Quarterly from September 2015
EEE bores	GW66-GW78	Quarterly from November 2016

An overview of the available groundwater quality data from the monitoring network is provided in Table 4.5.

Table 4.5 *Summary of groundwater chemistry availability for site monitoring bores*

GROUNDWATER BORES	BORES	MONITORING PERIOD	FREQUENCY	PARAMETERS
K2W monitoring bores	GW05, GW50 – GW62	2008 to December 2015	quarterly	pH; electrical conductivity; total dissolved solids; major ions; fluoride; metals (total/dissolved) – arsenic, boron, molybdenum, selenium, vanadium
		March 2016 to present	quarterly	pH; electrical conductivity; total dissolved solids; major ions; fluoride; metals (total/dissolved) – aluminium, arsenic, boron, cadmium, cobalt, copper, iron, manganese, molybdenum, nickel, selenium, vanadium, zinc
Historic monitoring bores	GW01, GW02, GW09, GW11, GW21, GW22, GW25	1993 to 2010	Generally six-monthly or annual	pH; electrical conductivity; total dissolved solids; major ions; metals (total) – arsenic, cadmium, cobalt, copper, iron, manganese, nickel, selenium, zinc
		2010 to August 2017	No data	No data
		August 2017 to present	Quarterly	pH; electrical conductivity, total dissolved solids; major ions; fluoride; metals (total/dissolved) – aluminium, arsenic, boron, cadmium, cobalt, copper, iron, manganese, molybdenum, nickel, selenium, vanadium, zinc
Hydrocarbon monitoring bores	GW34- GW42	August 2011 to November 2014	Quarterly	pH; electrical conductivity; total dissolved solids; major ions; fluoride; TPH; BTEX
		May 2015 to present	Quarterly	pH; electrical conductivity; total dissolved solids; major ions; fluoride; metals (total/dissolved) – aluminium, arsenic, boron, cadmium, cobalt, copper, iron, manganese, molybdenum, nickel, selenium, vanadium, zinc
			Annual	TPH
SRE Bores	GW43- GW46	February 2014 to present	Quarterly	pH; electrical conductivity; total dissolved solids; major ions; fluoride; metals (total/dissolved) – aluminium, arsenic, boron, cadmium, cobalt, copper, iron, manganese, molybdenum, nickel, selenium, vanadium, zinc
	GW63- GW65	August 2016 to present	Quarterly	
EEE bores	GW66- GW78	November 2016 to present	Quarterly	

4.3.2 FACTORS INFLUENCING GROUNDWATER CHEMISTRY

Natural processes that impact on groundwater occurrence and movement also influence groundwater chemistry at Meandu Mine. These natural processes include:

- Proximity to groundwater recharge areas.
- The residence time of groundwater in the system, with electrical conductivity and total dissolved solids tending to increase with increasing residence time.

- The impact of faults on groundwater flow and residence time. For example, the coal seams tend to be the main conduits for groundwater flow within the Triassic coal measures (rather than the interburden, which tends to be dry and hydraulically “tight”). Therefore, the occurrence of faults that have a large enough throw to completely displace the coal seams, resulting in the abrupt termination of a permeable coal seam on one side of the fault against relatively impermeable interburden on the other side of the fault, may result in increased groundwater residence time due to the disruption in groundwater flow. An example of this phenomenon is interpreted at bores GW44 (s and d), which are screened within the Queen Seam on the south-east side of a regional fault and GW45 (s and d), which are located on the north-west side of the fault with GW45_d screened within the Queen Seam and GW45_s screened within the overlying King Seam. The groundwater quality within the Queen Seam is significantly different on either side of the fault, with GW44 (s and d) generally recording electrical conductivity in excess of 10,000 $\mu\text{S}/\text{cm}$ and GW45_d generally recording electrical conductivity of $\sim 1,200$ $\mu\text{S}/\text{cm}$. The difference in water quality is interpreted to be related to an increased residence for groundwater on the south-east side of the fault, with groundwater flow towards the north-west (i.e. towards the pits) disrupted by the fault.

Flow of groundwater between different groundwater units (e.g. recharge water entering the basalt and seeping down to the underlying coal measures) could be expected to have a different groundwater chemistry to groundwater that is recharged directly to the coal measures.

4.3.3 MINE IMPACTED GROUNDWATER QUALITY

JBT assessed mine-impacted groundwater quality by first assessing the bores that could be regarded as being hydraulically isolated background bores (and therefore containing background water quality), with the remaining bores assessed to be mine-affected to some degree. Locating hydraulically isolated background bores for each groundwater unit is challenging at Meandu Mine for the following reasons:

- The coal seam bores (Ace Seam, generally dry, as well as King Seam and Queen Seam) are difficult to locate in background areas as the units do not exist to the east and west of the mining area (due to basin-scale faulting, as well as the dip of the coal seam bringing the deeper seams close to surface beneath Meandu Creek, i.e. the unit pinches out). For this assessment, it is interpreted that mine-affected bores are located either adjacent to the pits or between/down-gradient of the pits, while background bores tend to be more distant from the mining area and up-gradient with respect to regional groundwater flow (i.e. to the east of the mining operation). Another assumption for background bores is that a cone of depression exists towards the pits, so groundwater in the background bores is sourced from areas that are distant from mining.
- The Tertiary basalt occurs as ridge-cap deposits in the mining area and tends to be unsaturated. There is only one basalt bore within the mining area that contains water (GW43_s – others are dry), and GW43_s was specifically constructed at a location where water was encountered in basalt during geological drilling (it has been observed from geological drilling that the basalt is generally dry). In areas that could be regarded as being hydraulically isolated from mining (i.e. up-gradient, topographically elevated areas to the east of the pits) the basalt tends to be unsaturated. The regolith groundwater unit is often saturated within the mining area or areas that are down-gradient, i.e. towards Meandu Creek. This means that the regolith tends to contain water in mine-affected or potentially mine-affected areas and to be dry in upgradient (background) areas. As such, locating bores that could be considered as background or reference bores within this unit is difficult and there are no bores within the current monitoring network that are assessed to be background bores.
- The Meandu Creek alluvium, which is the main groundwater unit that could be impacted by AMD and down-gradient seepage of ash or other mine impacted water, was ephemeral prior to mining. The main indicator bore for mining impacts on the alluvium prior to off-site groundwater flow (towards Meandu Creek Dam) is GW39. The water quality in this bore is likely to be reflective to some degree of Meandu Creek Dam water quality as water from the dam backs up into the upstream alluvium.

Bores that are assessed to be background bores (i.e. unimpacted by mining) include the following (refer Figure 2.5 for bore locations):

- Alluvial bore GW39
- King Seam bores – GW45_s, GW46_s, GW58_d
- Queen Seam bores GW43_d, GW44_d, GW44_s, GW45_d, GW46_d, GW63_d.

4.3.3.1 AMD GROUNDWATER CHEMISTRY

From assessment of available data, the parameters that are indicative of potential impacts from mining on groundwater are shown below in Table 4.6.

Table 4.6 *Parameters assessed to be indicative of mining impacts on groundwater*

PARAMETER	AMD INDICATOR	ASH SEEPAGE INDICATOR	GENERAL MINING INDICATOR
PHYSICAL PARAMETERS / IONS			
pH	X		X
Electrical conductivity			X
Sulfate	X	X	X
Fluoride		X	
METALS / METALLOIDS			
Aluminium			X
Arsenic		X	
Boron		X	
Cobalt	X		
Iron	X		X
Manganese	X		X
Molybdenum		X	
Nickel	X		
Selenium		X	
Vanadium		X	
Zinc	X		

AMD-impacted groundwater is expected to comprise low pH and relatively high iron. However, iron concentration is interpreted to be a poor indicator of AMD impacts due to the relatively high concentration of iron in groundwater (especially in areas where basalt occurs, which is the case at Meandu Mine) and observation that the relatively high iron concentrations tend to occur at the initial site of seepage where groundwater seepage is oxidised. Better indicators of AMD-impacted groundwater are interpreted to include sulfate, cobalt, manganese, nickel and zinc.

4.3.4 SUMMARY OF GROUNDWATER CHEMISTRY TRENDS

Summary statistics for groundwater quality were calculated for pH, electrical conductivity, total dissolved solids, major ions, fluoride and dissolved metals/metalloids. Statistics were presented for the data sets based on hydrogeological units as outlined in Table 4.7. Mean water quality data for each groundwater unit, as well as a number of surface water sites, are shown below in Table 4.7.

Table 4.7 Milliequivalent data and water type for site groundwater/surface water samples

GROUNDWATER UNIT/ SITE	RELEVANT BORES	PERCENTAGE MILLIEQUIVALENT/L (meq/L) OF TOTAL CATION / ANION						WATER TYPE
		Ca	Mg	Na + K	Cl	CO ₃ + HCO ₃	SO ₄	
Alluvium	GW39; GW40	5.6	20.0	74.4	81.6	5.4	13.1	Na-Cl
Regolith	GW02; GW25; GW30; GW37; GW50_s; GW51_s; GW52; GW52A; GW52B; GW53; GW61_s; GW67; GW68; GW69; GW73; GW74; GW78	4.6	23.6	71.8	86.4	2.4	11.2	Na-Cl
Basalt	GW43_s	12.9	44.6	42.6	44.4	50.4	5.2	Mg-Na-CO ₃
Spoil	GW35; GW41; GW42; GW54A; GW54B; GW66; GW70; GW71; GW72; GW75; GW76	7.1	25.9	67.0	72.4	7.0	20.6	Na-Cl
Coal Measures - Background	GW45_s; GW46_s; GW58_d (King seam) GW43_d; GW44_d; GW44_s; GW45_d; GW46_d; GW63_d (Queen seam)	18.9	26.1	55.0	79.9	11.8	8.3	Na-Cl
Coal Measures – Mine-Affected	GW56_d (Ace seam) GW59B; GW59_d (King seam) GW05, GW50_d, GW51_d, GW55_d, GW60 (Queen seam)	11.4	25.9	62.7	74.9	11.0	14.2	Na-Cl
Bullgang Drain		10.3	42.4	47.4	31.7	0.2	68.1	Na-Mg-SO ₄
K2N Ash Void		22.8	27.2	49.9	53.1	0.0	46.9	Na-Cl-SO ₄
K2W Ash Void		31.2	18.6	50.2	51.0	0.2	48.8	Na-Cl-SO ₄
Tailings Void		16.6	28.5	54.9	52.7	5.1	42.3	Na-Cl-SO ₄
Ramp 7-1		10.7	41.4	47.9	38.1	2.1	59.8	Na-Mg-SO ₄

General groundwater chemistry observations for each of these hydrogeological units based on this analysis are:

- The alluvium and regolith groundwater units are both strongly sodium-chloride type water.
- The basalt aquifer is of a mixed water type (magnesium-sodium carbonate) rather than the sodium-chloride water type observed for other groundwater units.
- The spoil groundwater unit is assessed to be entirely mine-affected and has a higher proportion of sulfate relative to other groundwater units. The water in the spoil aquifer is of sodium-chloride water type.
- The coal measures have a distinct chemistry relative to other groundwater units (although the groundwater is still sodium-chloride type) and are summarised as follows:
 - For coal measures bores that are assessed to be background, the unit is relatively low in sodium, relatively high in carbonate/bicarbonate, relatively high in calcium, and relatively low in sulfate

- For groundwater samples from mine-affected coal measures bores, the sulfate is elevated compared to background bores, the calcium is slightly lower and the sodium is slightly higher
- Samples from the K2W/K2N ash disposal void and North-West B TSF are of sodium-chloride water type; however, the sulfate is significantly higher than for the natural groundwater units, therefore the water type is assessed to be sodium-chloride-sulfate.
- Samples from areas where AMD-impacted seepage is evident (Bullgang Drain, Ramp 7-1) have a distinctly different water chemistry and are of sodium-magnesium-sulfate type (the samples have a lower chloride content and higher magnesium content than other sites and the sulfate meq% is >50%).

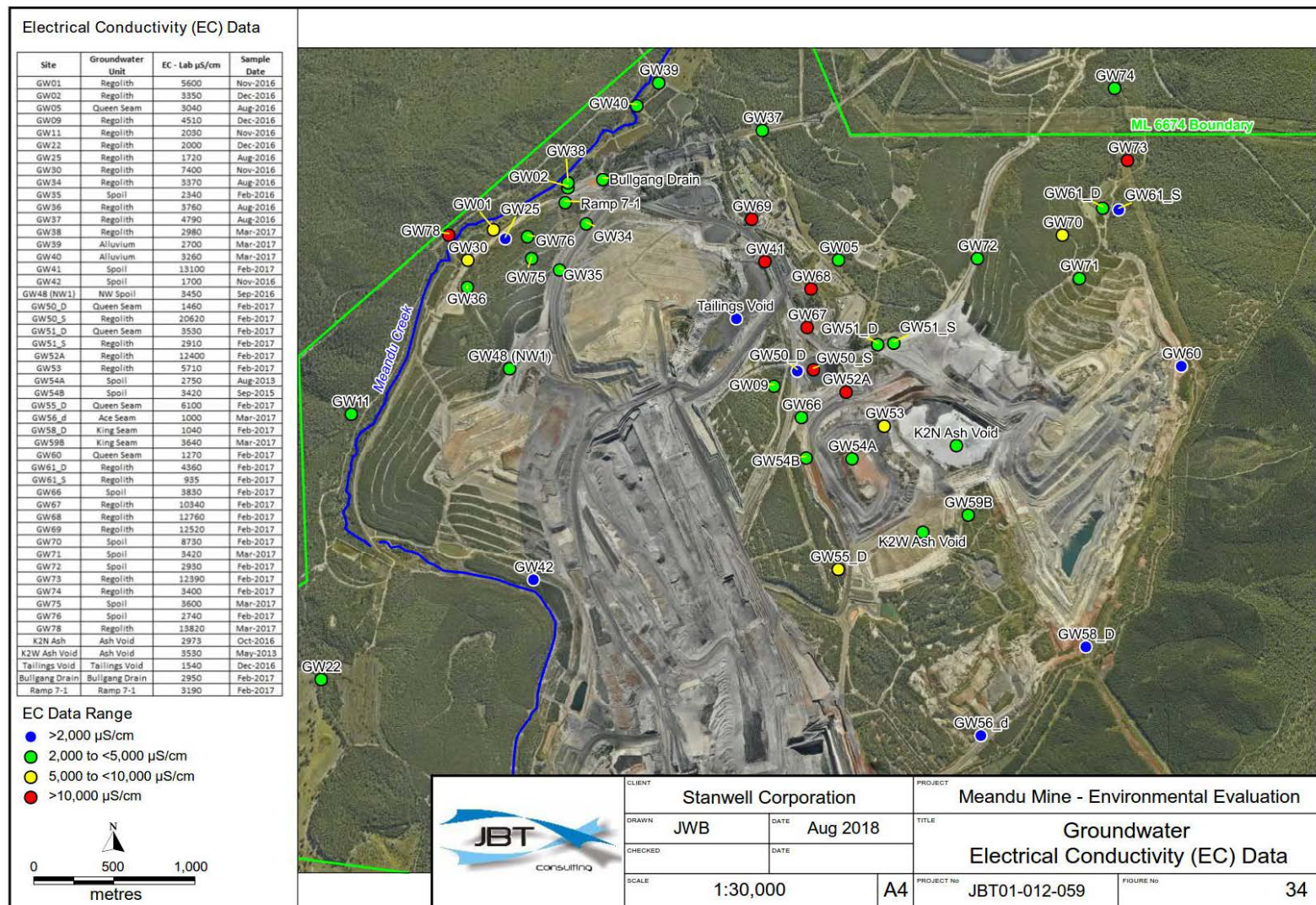
Trends for specific water quality parameters are discussed in the following sections.

4.3.4.1 ELECTRICAL CONDUCTIVITY

Figure 4.4 shows data for electrical conductivity for site groundwater bores, the K2W and K2N ash disposal voids, the tailings void, Bullgang Drain and Ramp 7-1. The data has been colour-coded according to electrical conductivity data range, to provide a visual indication of zones of low and high salinity. Electrical conductivity varies over a wide range for groundwater units at the Meandu Mine site.

Based on the information presented in Figure 4.4, the following observations are made:

- A high salinity plume (> 10,000 $\mu\text{S}/\text{cm}$) is evident which extends from the area around GW52A to GW69, with this plume also evident from the aerial geophysics data (refer Section 4.4). The bores that are recording high electrical conductivity within the plume are screened within regolith or the interval between spoil and regolith. The plume occurs in the location of a natural surface water drainage channel, which extends through the mine infrastructure area and ultimately discharges towards RD1/ RD2.
- Areas of confirmed AMD seepage (e.g. Bullgang Drain and Ramp 7-1) are relatively low in electrical conductivity (median value of ~3,000 $\mu\text{S}/\text{cm}$), as are the tailings void, K2W/K2N ash voids (median EC of ~2,500 $\mu\text{S}/\text{cm}$), and spoil monitoring bores (median electrical conductivity ~2,800 $\mu\text{S}/\text{cm}$).
- High electrical conductivity groundwater (> 13,000 $\mu\text{S}/\text{cm}$) is observed in bore GW78, which is located on the western side of Meandu Creek and screened within the regolith to a depth of 12 m. The electrical conductivity recorded at bore GW78 is significantly higher than the electrical conductivity of mine-impacted water from any site sources. Review of geophysics data (Section 4.4) does not indicate a source of high electrical conductivity groundwater to the west of Meandu Creek, therefore the high electrical conductivity at this site may be a result of the residence time for groundwater at this location. The installation of additional groundwater monitoring bore(s) to the west of Meandu Creek is recommended as a means of determining whether the high electrical conductivity recorded at GW78 is indicative of water quality to the west of Meandu Creek and to validate data from geophysics investigations.
- High electrical conductivity (>12,000 $\mu\text{S}/\text{cm}$) groundwater is also observed at bore GW73, which is located within the Black Creek catchment in the north-east area of the mining lease. The Black Creek catchment ultimately discharges to Meandu Creek downstream of the Meandu Creek Dam.



Source: JBT Consulting 2018 (Appendix F)

Figure 4.4 Groundwater electrical conductivity data results

4.3.4.2 SULFATE

Figure 4.5 shows data for sulfate concentration for the same sites discussed above for Figure 4.4.

Based on the information presented in Figure 4.5, the following observations can be made:

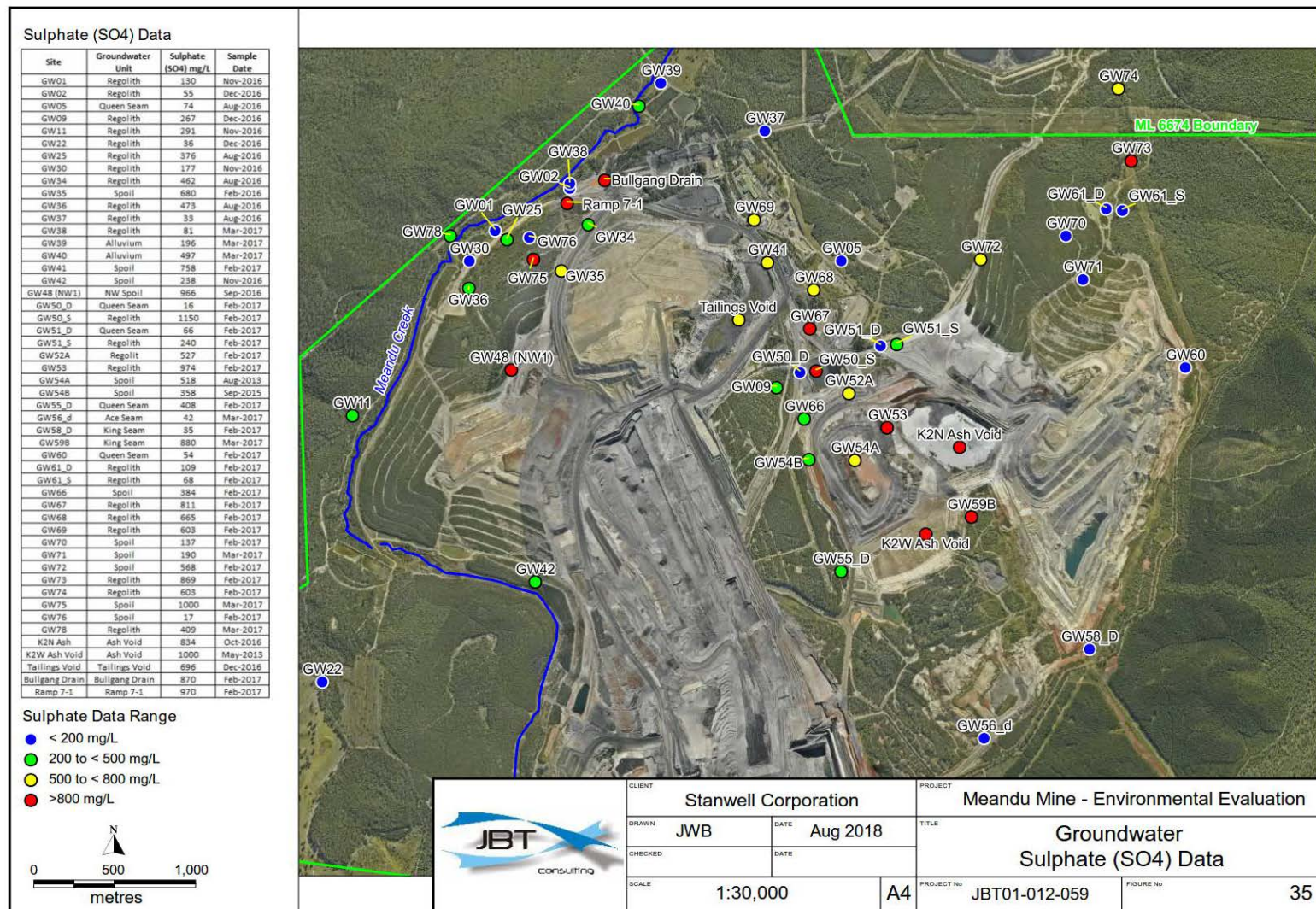
- High sulfate concentrations are recorded at:
 - sites that are known to be impacted by AMD (Bullgang Drain, Ramp 7-1)
 - the K2W/K2N ash disposal voids and sites that are impacted by ash seepage (e.g. GW53 and GW59B)
 - bores that are screened within spoil (e.g. GW75, GW48)
 - groundwater bores that record high electrical conductivity, therefore the sulfate concentration is elevated as a percentage of the total ions; examples include GW73 (Black Creek catchment) as well as GW50_s, GW67 and other bores within the saline plume between GW52A and GW69.

As noted previously sulfate is interpreted to be the most reliable indicator parameters of mining impacts to groundwater.

4.3.4.3 DISSOLVED METALS/METALLOIDS

The following were noted for dissolved metals/metalloids assessed to be indicators for AMD:

- **Cobalt:** Relatively high cobalt concentrations are recorded at sites that are known to be AMD impacted (Bullgang Drain, Ramp 7-1) and in bores GW75, GW66 and GW52A (spoil bores or bores that monitor the interface between spoil and the underlying regolith).
- **Iron:** Relatively high iron concentrations are recorded at sites in areas where AMD seepage has been identified (Bullgang Drain, Ramp 7-1) and in bores GW54B, GW70, GW71, GW72 (spoil monitoring bores).
- **Manganese:** Relatively high manganese concentrations are recorded at sites where AMD seepage has been assessed to be occurring (sites between the North-West void and Meandu Creek as well as bore GW78 (west of Meandu Creek where electrical conductivity >13,000 $\mu\text{S}/\text{cm}$ is recorded), sites close to the inferred origin of the saline groundwater plume that extends to the north-west of the Queen West void area (GW50_s, GW67) and sites within buried tailings (GW72) spoil (GW70) in the Black Creek catchment.
- **Nickel:** Relatively high nickel concentrations are recorded at sites that are known to be AMD impacted (Bullgang Drain, Ramp 7-1) and in bores GW75, GW66, GW67, GW52A (spoil bores or bores that monitor the interface between spoil and the underlying regolith).
- **Zinc:** Relatively high nickel concentrations are recorded at sites that are known to be AMD impacted (Bullgang Drain, Ramp 7-1) and in bores GW75, GW35, GW66, GW67, GW52A (spoil bores or bores that monitor the interface between spoil and the underlying regolith).



Source: JBT Consulting 2018 (Appendix F)

Figure 4.5 Groundwater sulfate data results

4.4 GEOPHYSICS DATA

4.4.1 TRANSIENT ELECTROMAGNETICS (TEM) SURVEYS

Land-based and airborne geophysical surveys measuring the electrical resistivity of the surveyed ground have been undertaken at Meandu Mine using the transient electromagnetic (TEM) method. In groundwater investigations, it is common to present the data as electrical conductivity, which is the inverse of electrical resistivity (i.e. low resistivity ground has high electrical conductivity and high resistivity ground has low electrical conductivity). As such TEM data has been presented as electrical conductivity. It should be noted however that the electrical conductivity data that is presented from the TEM surveys are not directly comparable to the electrical conductivity data that are recorded from groundwater samples, as the electrical conductivity that is recorded by the TEM method is impacted by a number of factors in addition to the electrical conductivity of groundwater. Factors that influence the electrical conductivity of TEM data include:

- The relative proportion of clay minerals in the geological materials. Clays tend to have relatively higher electrical conductivity, therefore clay-rich sediments will provide a different electrical conductivity signature than, for example, clean quartz sand.
- The presence of conductive minerals. For example, AMD results in the precipitation of ferrous hydroxide and haematite, which may have a high electrical conductivity relative to surrounding sediments.
- The rock type, for example basalt tends to have a high electrical conductivity relative to the sandstone/siltstone units that are encountered at Meandu Mine (e.g. Tarong beds, Maronghi Creek beds).
- Saturated rock/sediment will tend to have a higher electrical conductivity than the same unit in an unsaturated state.
- Saline groundwater will have a higher electrical conductivity than fresh water.
- Weathered bedrock will tend to have a higher electrical conductivity than the same bedrock unit in an unweathered state.
- The data is also influenced by infrastructure that affects the electromagnetic signature, such as steel buildings and power lines. The impact of this type of infrastructure was apparent in the airborne TEM survey.

Determining what the electrical conductivity data (as recorded by the TEM method) are indicating at different depths in the subsurface therefore becomes a matter of interpretation, with this interpretation aided by use of geological data (e.g. drilling logs, geological mapping), water quality data and field observations. Interpretation of the data obtained from the land-based (June 2015) and airborne (March 2017) TEM surveys was undertaken by JBT. Details of the surveys are provided in Appendix F.

4.4.2 AIRBORNE TEM SURVEY RESULTS

Figure 4.6 shows the contoured electrical conductivity data produced from the airborne geophysical survey for an interval between 2 and 4.2 m depth from the surface. The following features are evident from this figure:

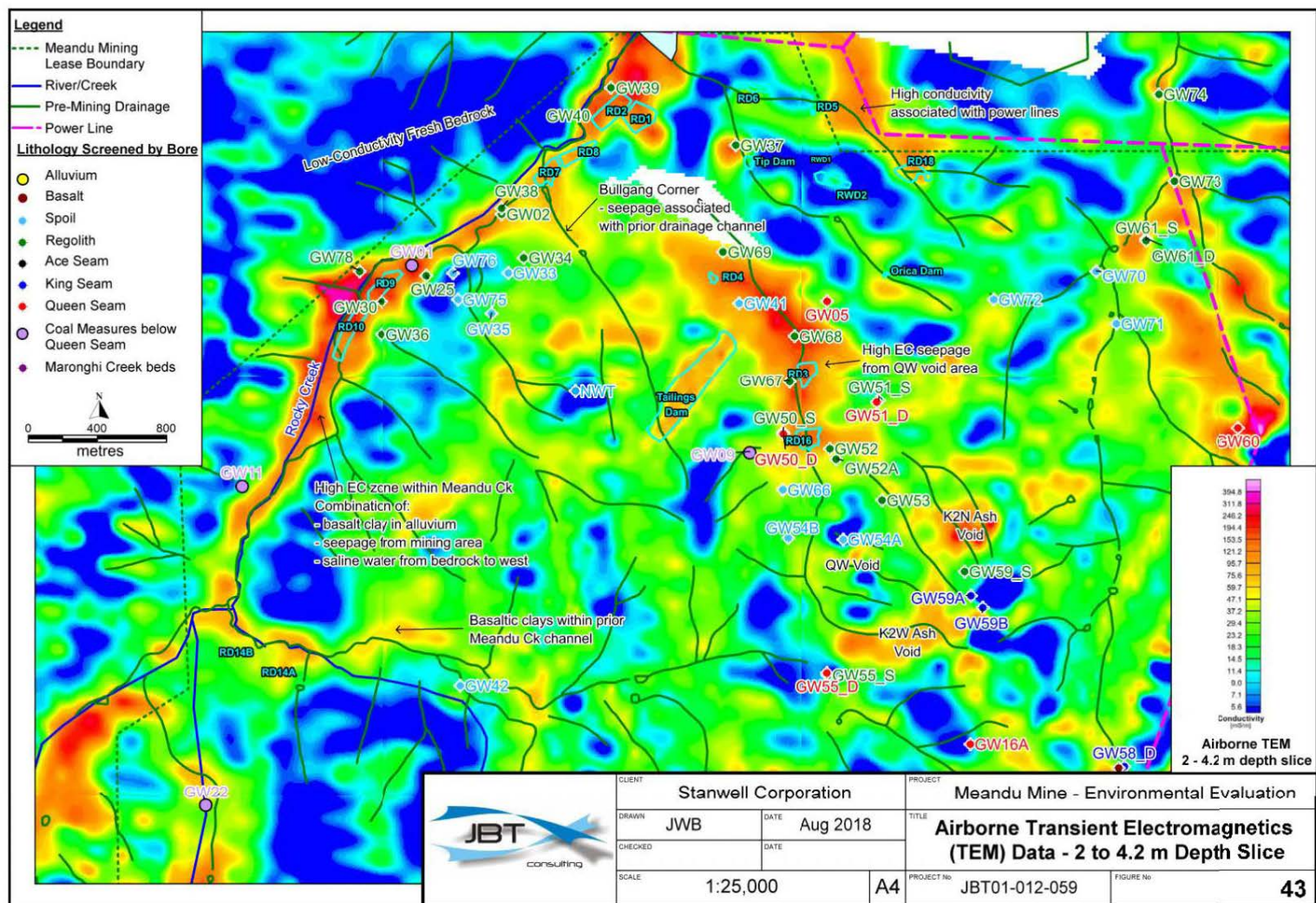
- A high electrical conductivity zone is evident in Meandu Creek to the west of the mining area. This is interpreted to be related to a combination of factors, including:
 - the presence of basaltic clays (from the southern area of the lease) within the Meandu Creek alluvium
 - saline seepage from the mining area
 - saline seepage from high salinity areas to the west of Meandu Creek (e.g. the drainage channel adjacent to GW78, with electrical conductivity at GW78 >13,000 $\mu\text{S}/\text{cm}$).
- The high electrical conductivity zone within Meandu Creek appears to be mostly confined to the areas of alluvium and there are no channels evident from the geophysics data that suggest that drainage could occur to the west of Meandu Creek; in fact, Meandu Creek appears to be the focus of drainage from the west and the east, with high electrical conductivity areas to the west of Meandu Creek correlating strongly with current surface water drainage lines that flow from west to east towards Meandu Creek.

- From review of geophysics data from surface to the full depth of investigation (~300 m depth) it is concluded that there is no evidence of flow paths to the west of Meandu Creek, with Meandu Creek acting as a capture zone for groundwater flow from the east (mining area) and west (with groundwater flow direction honouring topography in this area).
- A saline plume is evident to the north-west of the former Queen West void. This coincides with the high electrical conductivity groundwater plume identified from bores GW52A, GW50_s, GW67, GW68, GW41 and GW69.
- Relatively high electrical conductivity conditions are also identified within storages such as the K2W and K2N ash voids and the North-West B TSF. The groundwater electrical conductivity of these storages is relatively low; therefore, the high electrical conductivity signature from the geophysics is interpreted to be related to the mineralogy of the ash and tailings (for example pyrite, which has an elevated electromagnetic signature).
- A further zone of relatively high electrical conductivity is evident in the spoil areas to the north of K2E pit and bores within the Black Creek drainage channel (e.g. around bores GW61_s, GW61_d, GW73 and GW74). The interpretation in this area is complicated by the presence of high voltage transmission lines. However, the results from the geophysics survey correlate with bore electrical conductivity data and appear to correlate with the presence of prior and current drainage channels that could act as conduits for seepage.

A high electrical conductivity zone to the north of the mining lease (near RD18 and RD5) correlates with the location of high voltage transmission lines, therefore the presence of saline seepage is not inferred at this location.

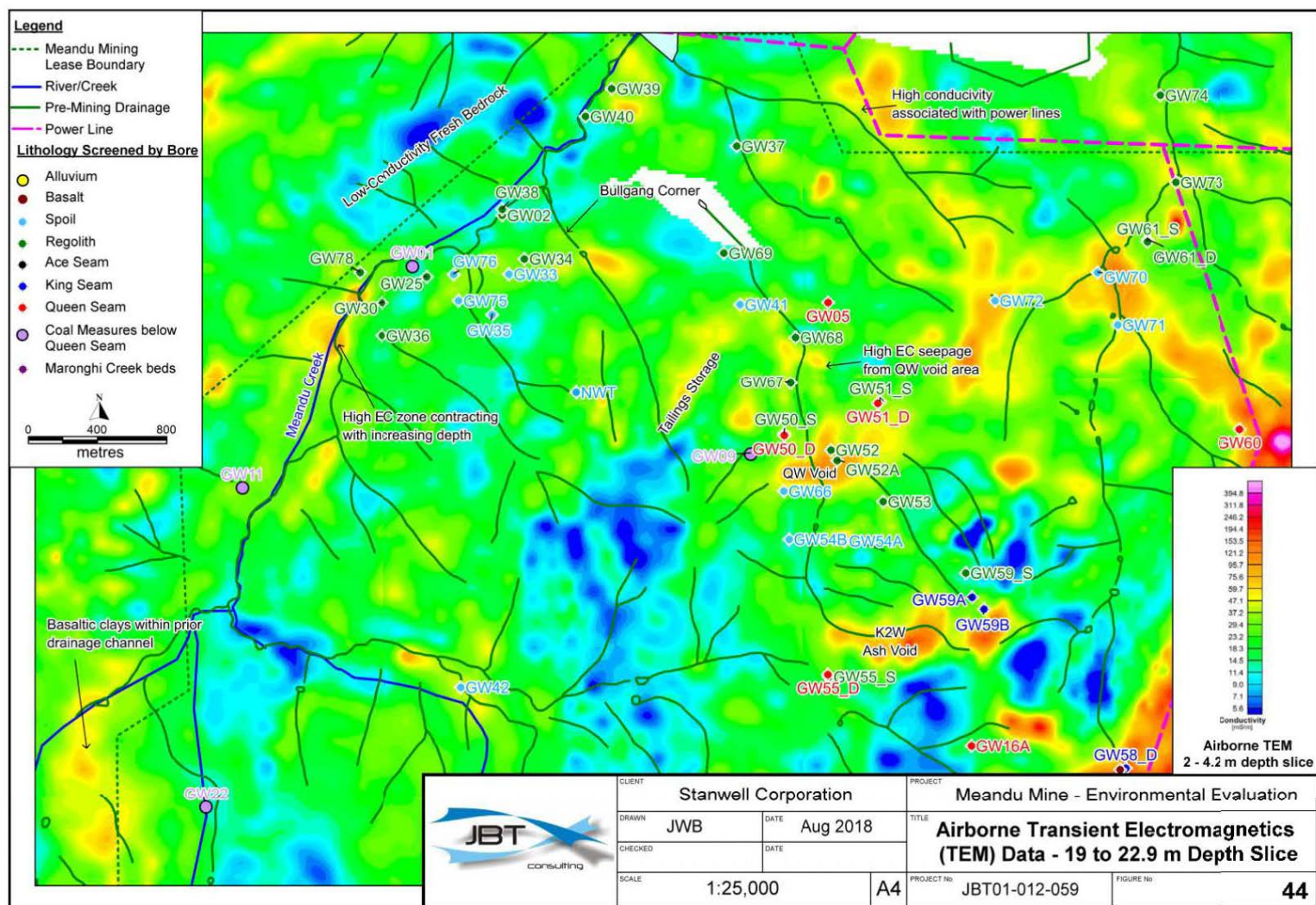
Figure 4.7 shows the contoured electrical conductivity data produced from the airborne geophysical survey for an interval between 19 and 22.9 m depth from the surface. The following features are evident from this figure:

- The high electrical conductivity zones that are evident in the shallow data for Meandu Creek (Figure 4.6) are largely absent from the image shown on Figure 4.7, which is interpreted to indicate that seepage is confined to a relatively shallow interval adjacent to Meandu Creek.
- Relatively high electrical conductivity zones are associated with the K2W ash void and Queen West void at the 19 to 22.9 m depth interval; however, the high electrical conductivity plume that extends to the north-west of the Queen West void is absent from Figure 4.7, indicating that the saline seepage is confined to the upper intervals in this area.



Source: JBT Consulting 2018 (Appendix F)

Figure 4.6 Airborne Transient Electromagnetic data – 2 to 4.2 m depth slice



Source: JBT Consulting 2018 (Appendix F)

Figure 4.7 Airborne Transient Electromagnetic data – 19 to 22.9 m depth slice

4.4.3 GROUNDWATER SEEPAGE PATHWAYS

The following general mechanisms for seepage at Meandu Mine have been identified:

- The major preferential pathway for groundwater seepage from voids is either the natural ground surface or the deepest mined surface, dependant on what surface exists at a given location. In other words, groundwater seepage occurs predominantly via shallow seepage within the regolith unit or the underlying coal measures (where the regolith has been mined out) and the seepage pathways can therefore be defined by the topography of the deepest mined surface (which includes the natural surface in areas that have not been mined)
- Seepage from spoil-filled voids tends to occur when the water level within the spoil rises to a level where seepage from the void is possible via topographic low-points such as pre-mining drainage channels or haul roads into the pit.
- In areas where out-of-pit dumping of spoil has occurred, the flow of groundwater within the spoil, as well as pathways for seepage from the spoil, will tend to honour the underlying topography.

The identified mechanisms for seepage from the North-West Backfilled Pit (as the only area where AMD-impacted water is currently being expressed to the surface) is discussed in detail in Section 5.

Two separate areas with high electrical conductivity groundwater have been identified during this environmental investigation, based on review of water quality and flow data and information available from aerial geophysics. These are:

- a saline plume that has been identified with an origin close to the Queen West void; groundwater within the plume moves through shallow regolith along a natural drainage line towards RD1 and RD2
- an area within the Black Creek catchment in the northern area of the lease.

It is noted that neither of these areas are assessed at this stage to involve seepage that is related to AMD, however are discussed for completeness.

The evidence for seepage and/ or groundwater impacts in these areas, as well as the mechanisms for seepage, are discussed in Section 5 and in detail in Appendix F (JBT 2018). In relation to Queen West, it is interpreted based on water quality data that the high electrical conductivity plume is not related to AMD and is unrelated to the groundwater quality impacts within the Black Creek catchment. As stated in Appendix F, it is concluded, based on a preliminary assessment, that, even if the saline plume has extended to RD1/RD2, the potential rate of inflow to the dams is calculated to be low and, based on available water quality data, it is evident that the plume has not made a discernible impact to date on the electrical conductivity of dams RD1 and RD2. It may be further concluded that, due to the relatively low seepage rates and the presence of retention dams to intercept groundwater flow, the risk to the environmental values of Meandu Creek is also low.

5 ON-SITE DOMAINS OF INTEREST

SECTION OVERVIEW

Based on the findings and results of the technical assessments completed as part of the environmental investigation, this section provides an overview of the known source and extent of AMD at the Meandu Mine. It specifically addresses requirements B3(iv) and B3(v) of the Notice:

B3(iv) investigation to identify physical and/or environmental influences relating to storage areas (coal rejects, overburden, waste rock and topsoil) that may determine the occurrence, rate of progression, or volume of AMD generated at Meandu Mine, for example: stockpile locations, size, surface area, profile/geometry, water infiltration and drainage characteristics.

B3(v) a dedicated site plan showing the location and extent of AMD at Meandu Mine, including existing seepage flow paths.

The discussion in the section focuses on the North-West Backfilled Pit as the only known mine domain currently seeping AMD. This is a complex layered domain containing over 30 years of rejects, tailing and waste material.

There is little evidence from the 30 years of water quality data from K2 TSF, North-West A TSF and North-West B TSF that there was or is an acidity production issue associated with tailings. In addition, RGS has shown that over 14 months of static and kinetic leach cell testing, tailings continue to generate neutral pH drainage. Data from the KLC tests indicates however that oxidised rejects have the potential to leach salts, metals and metalloids at elevated concentrations depending on the geochemical and physical characteristics of the material. Based on the assessment undertaken RGS expects that the acidic drainage at Ramp 7 and Bullgang Drain is from the oxidation of sulfide minerals placed (predominantly) into reject storage area 1 (RSA1) from circa 1986 to 1995 and may also be attributed to the oxidation of sulfide minerals in rejects that have been emplaced (and left open to atmospheric conditions for more than six months) into the North-West Backfilled Pit.

Seepage from the North-West Backfilled Pit along the pre-development drainage line initially occurs through spoil, with visible seepage occurring at the point where the spoil attains a zero thickness and the seepage therefore expresses at surface (i.e. at the location of Bullgang Corner).

Groundwater flow direction within the North-West Backfilled Pit is towards the west and north-west, exiting via either:

- Seepage along prior drainage channels (e.g. at Bullgang Corner)
- Diffuse seepage in the western void area where the remnant natural material forms a relatively thin barrier to seepage.

The floor of the North-West Backfilled Pit is low permeability interburden material and it is conceptualised that this will restrict downward seepage due to the low vertical permeability of the interburden. However, groundwater movement to the west (towards Meandu Creek) is interpreted to be possible. Groundwater flow to the west of Meandu Creek is assessed to be unlikely.

This section of the environmental investigation report describes the source and extent of AMD within mine domain comprising the North-West Backfilled Pit. It also provides information on the mechanisms for seepage from the Queen West Backfilled Pit, K2N and K2W; and Black Creek catchment domains which have been identified as areas with high groundwater electrical conductivity unrelated to AMD.

5.1 SOURCE AND EXTENT OF AMD

5.1.1 NORTH-WEST BACKFILLED PIT

5.1.1.1 PIT DEVELOPMENT

The North-West Backfilled Pit is a complex layered domain that contains over 30 years of placement of rejects, tailings and waste material. Construction of the North-West Backfilled Pit has been ongoing since mining commenced in the North-West A Pit in 1984 and later the North-West Pit B in 1996. These pits were eventually linked when the land bridge between them was mined out. Backfilling of North-West Pit commenced immediately with dragline operations dumping mining waste directly into the previous strip void. The dump over the North-West Backfilled Pit currently covers an area of approximately 400 ha.

In addition to mining waste the North-West Backfilled Pit includes:

- Ramp 3, North-West A and North-West B TSFs
- Ramp 2 TSF from Central Pit that have been relocated and intermingled with waste rock from Central Pit
- Rejects storage (North-West rejects) constructed in six stages
- North-West waste dump
- Hitachi Hill rejects/waste solids.

A 3D concept model (in Vulcan) of waste material placement in the North-West Backfilled Pit was prepared to inform this environmental investigation and development of the Integrated Water Model (refer to Section 9). Given that the historical data was limited in detail, the exact ratio of rejects to tailings to waste in the North-West Backfilled Pit is unknown without further monitoring (such as drilling and sampling). Assumptions around material placement have been made based on historical flyover images and confirmation by long-term Meandu Mine employees. The locations of material placement within the North-West Backfilled Pit are shown in Figure 5.1.

The North-West Backfilled Pit began seeping AMD at Ramp 7 and Bullgang Drain at about 2 ML per day from mid-2013 (and on average 1.3 ML/day during 2016), which is when the water level in the pit reached pre-mine topographic low points around the rim of the pit (refer to Section 5.1.1.3). A source of the water in the North-West Backfilled Pit is due to the addition of entrained water in the tailings that was emplaced into the North-West A and North-West B pits from about 1995 to December 2017.

5.1.1.2 SOURCE OF AMD

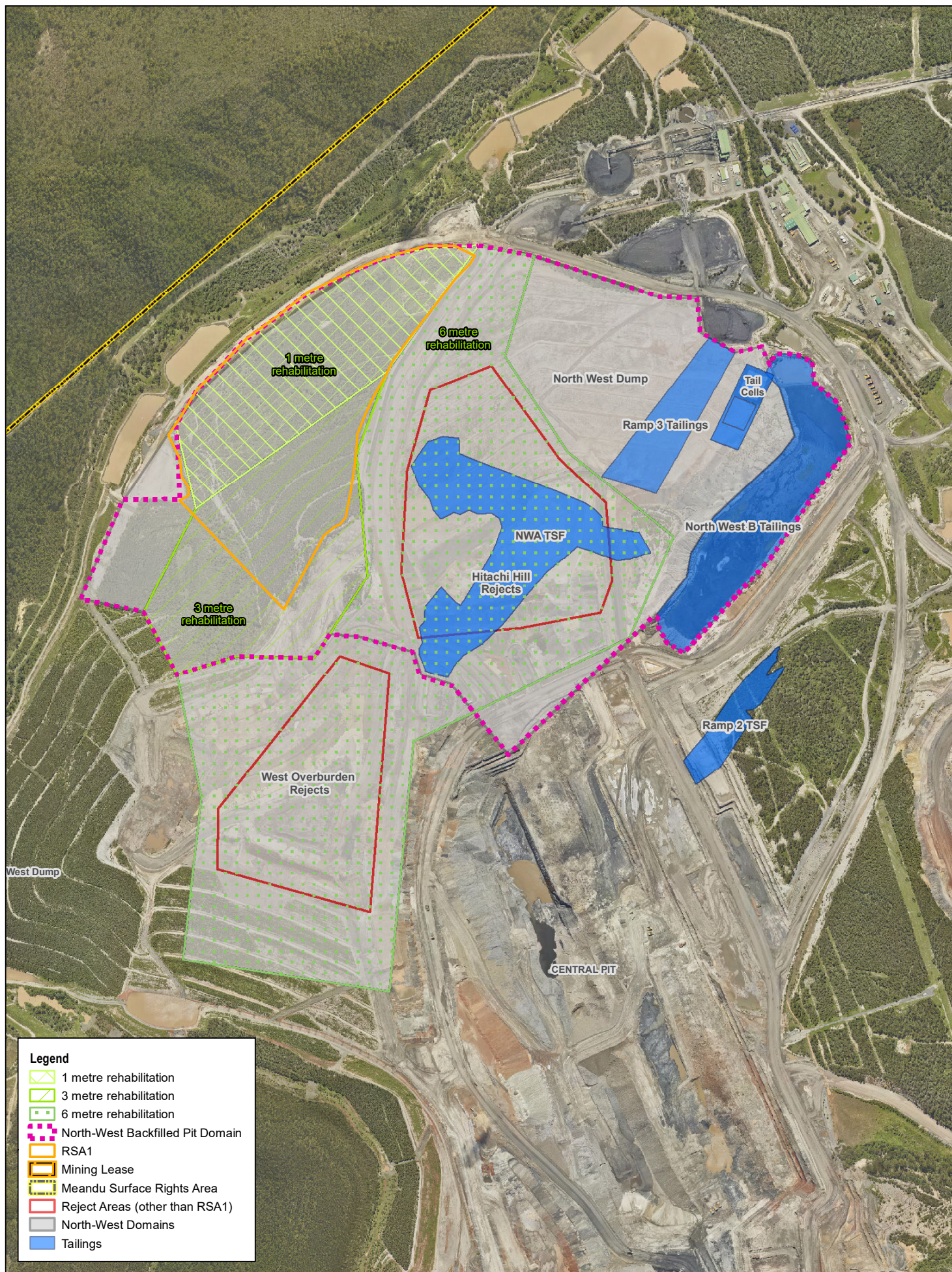
Early in the investigation it was thought that water being squeezed out of tailings that had been deformed vertically during backfilling of North-West A Pit was the primary source of AMD from the North-West Backfilled Pit. This has been discounted by RGS for the following reasons:

- There is no evidence of acidic drainage in tailings from the K2 TSF that operated early in the mine life
- KLC testing over a 12-month period of exposed tailings (at least 2-years) from the North-West A TSF (collected in 2007 by EGi), showed that the tailings retained neutral pH over 12 months
- There is no evidence from KLC testing (undertaken over a 14 month period by RGS for this investigation) that acidic drainage is likely from tailings within this time-period under laboratory-controlled conditions
- The low sulfide content and fine-grained physical nature of the tailings encouraged moisture retention and limits oxidation.

RGS expects that the acidic drainage at Ramp 7 and Bullgang Drain is from the oxidation of sulfide minerals placed (predominantly) into RSA1 from circa 1986 to 1995 and may also be attributed to the oxidation of sulfide minerals in rejects that have been emplaced (and left open to atmospheric conditions for more than six months) into the North-West Backfilled Pit.

Reject materials collected from the re-exposed area in Hitachi Hill were initially pH neutral but become acidic within six months of exposure to oxidising conditions. Kinetic leach column testing of this material confirmed that after oxidation, solute concentrations decrease rapidly. Hence, under free draining conditions it is expected that the weathering products from this material will be removed from the system quite rapidly.

Results from the kinetic leach column tests undertaken by RGS for this environmental investigation showed that fresh coarse reject material had a six-month lag period until the onset of acid production. The fine-grade rejects, tailings and ash maintained neutral pH over the test period of 14 months. The weathered clay samples had acid leachate from the first leach cycle but this acidity is due to soluble aluminium and manganese not sulfide oxidation processes.



Environmental Investigation Report
 Figure 5.1 North-West Backfilled Pit Domain

5.1.1.3 SEEPAGE FROM THE NORTH-WEST BACKFILLED PIT

The North-West Backfilled Pit is the only known mine domain currently seeping AMD. Seepage from the North-West Backfilled Pit has been observed as seepage to Bullgang Drain, as well as relatively diffuse seepage that occurs towards Ramp 7 haul road. The locations of these seepage pathways from the North-West Backfilled Pit are shown on Figure 5.2.

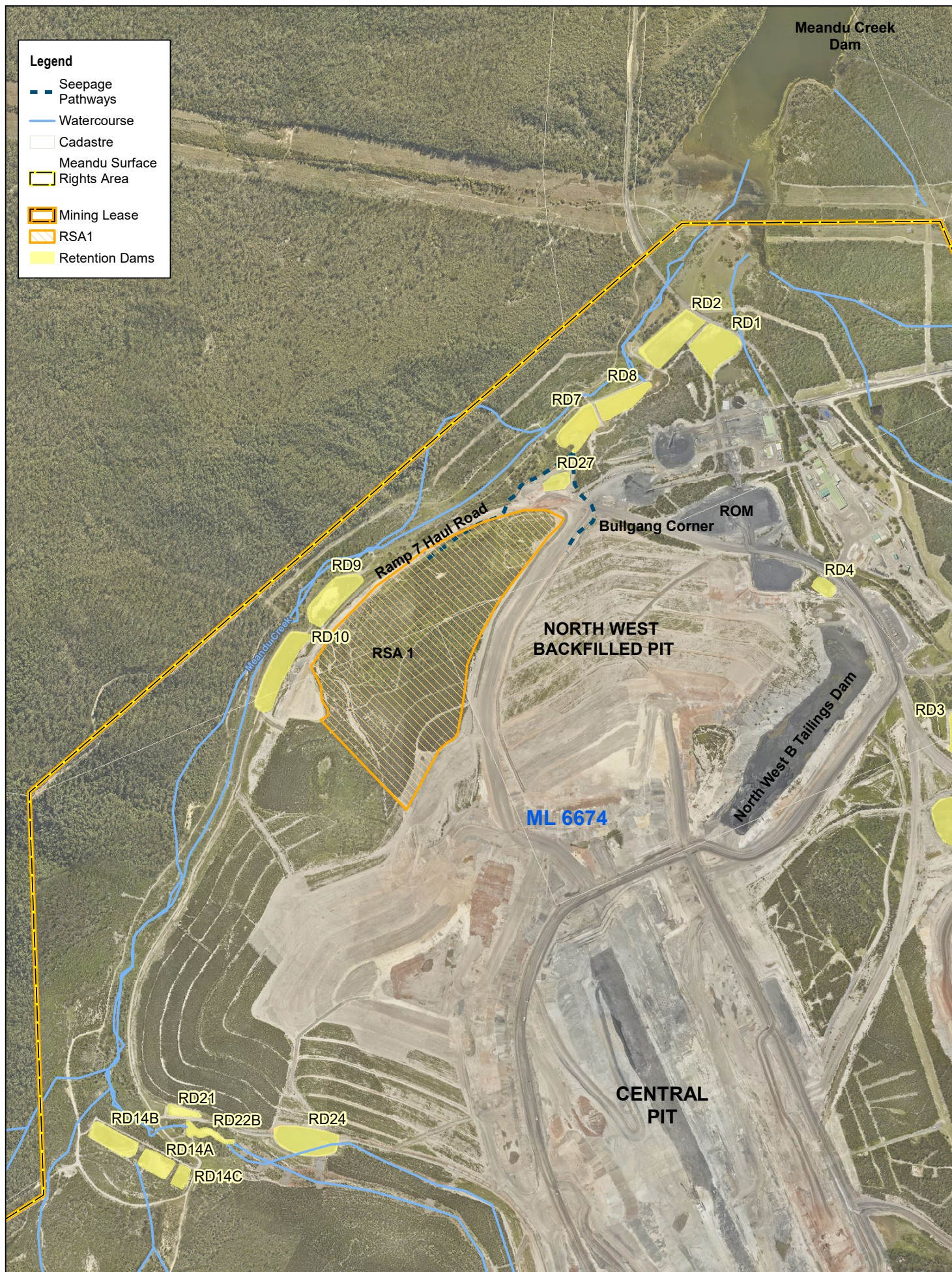
Active mining and associated pit dewatering in North-West Backfilled Pit, whilst operational would have created a localised effect of water drawdown, resulting in the open pits functioning as a sink to water held within backfilled material. Following cessation of mining in these pits, the water level in the North-West Backfilled Pit would have increased over time as the pit was filled with tailings, rejects, mining waste, rainwater infiltration and tailing water entering the backfilled waste, eventually reaching the spill point elevation around mid-2013. This has resulted in the continual seepage of water from the North-West Backfilled Pit.

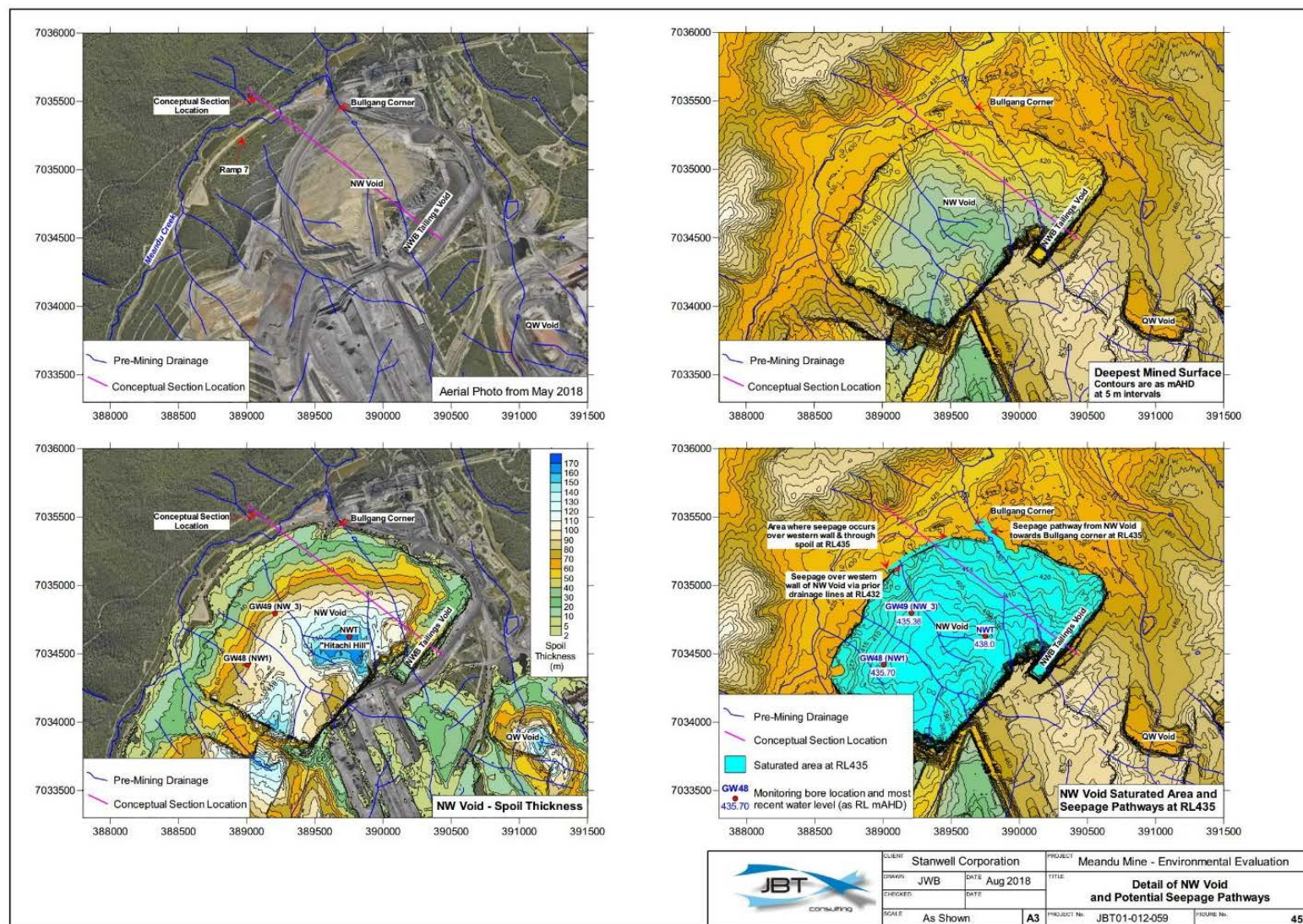
Figure 5.3 provides four plots developed by JBT to understand the location and mechanisms for seepage from the North-West Backfilled Pit.

The upper left plot is based on aerial imagery from May 2018 and shows the location of the North-West void, which has been filled and rehabilitated creating the North-West Backfilled Pit. The locations of the North-West B TSF, Bullgang Corner, pre-mining drainage lines, and the location of a conceptual section through the North-West Backfilled Pit and Meandu Creek (Figure 5.4) are also shown on this plot.

The upper right plot shows contours of the deepest mined surface with the mine area, focussing on the North-West Backfilled Pit. The surface for the deepest mined void was prepared by contouring data points for the deepest ever surface at a given location. For areas that have not been mined, the deepest mined surface is the same as the original topographic surface. The plot shows the mined extent of the North-West void and North-West B TSF and when compared to the aerial photo (upper left plot) the extent of the rehabilitated area to the west of the North-West void (and adjacent to Meandu Creek) is evident. It is also noted that there is a direct connection (via tailings/spoil) between the North-West B TSF and the North-West void.

The lower left plot shows the extent and thickness of spoil in the area of the North-West Backfilled Pit. The spoil thickness was generated as the difference between the current topographic surface and the deepest mined void at any location. For areas that have never been mined, or for areas that are currently being mined, the spoil thickness is zero. The spoil reaches a maximum thickness of approximately 150 m beneath the area known locally as “Hitachi Hill”. It is also noted that the spoil thickness reduces to zero near Bullgang Corner; this is discussed further in the next dot point.





Source: JBT Consulting 2018 (Appendix F)

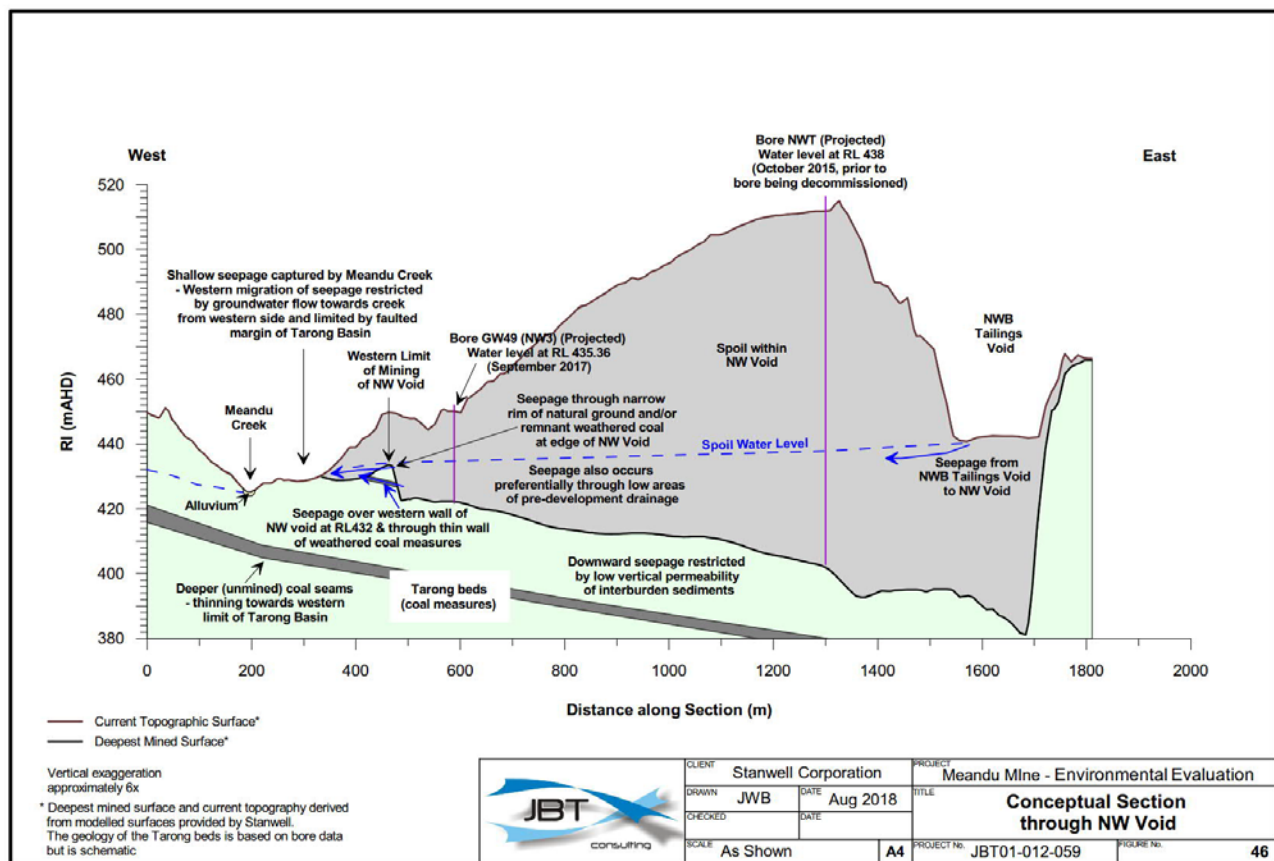
Figure 5.3 Detail of the North-West Backfilled Pit and potential seepage pathways

The lower right plot shows the deepest mined surface with the region at or below RL435 mAHD shaded in blue. RL435 mAHD is the elevation at which seepage begins to occur from the North-West Backfilled Pit towards Bullgang Drain, with seepage occurring preferentially along a pre-development drainage line. The following observations are made based on the information presented in this plot:

- Seepage via prior drainage channels in the western area of the North-West Backfilled Pit begins to occur at RL432 mAHD. Therefore, at a groundwater elevation of RL435 mAHD (when seepage begins to occur along a prior drainage line towards Bullgang Drain) there will be approximately 3 m thickness of saturated spoil above the western wall of the North-West Backfilled Pit along a wide area. In addition, the western wall of the North-West Backfilled Pit is relatively thin at this location and it is conceptualised that this will allow diffuse seepage to occur at an elevation slightly below RL432 mAHD when direct seepage via prior drainage lines can occur. This seepage mechanism allows a relatively large area of spoil west of the North-West void to become saturated, with this seepage expressing at an area where the spoil approaches a zero thickness and the seepage therefore expresses at surface (i.e. along the eastern side of the Ramp 7 haul road).
- At RL435 mAHD seepage commences from the North-West Backfilled Pit along a pre-development drainage line and towards Bullgang Corner. This seepage initially occurs through spoil, with visible seepage occurring at the location where the spoil attains a zero thickness and the seepage therefore expresses at surface (i.e. at the location of Bullgang Corner).
- The most recent water level for spoil monitoring bores within the North-West Backfilled Pit shows that a slight groundwater mound occurs within the void, with the water level at RL438 mAHD in bore NWT (drilled at the top of Hitachi Hill), reducing to RL435.36 mAHD in bore GW49 to the west. Significantly, the water level in all monitoring bores is above RL435 mAHD, which is the elevation at which seepage from the North-West Backfilled Pit towards Bullgang Corner occurs along the pre-development drainage line and seepage over the western wall of the North-West void (at RL432 mAHD) is already occurring through approximately 3 m of saturated spoil.

Figure 5.4 shows the conceptual section through the North-West Backfilled Pit and Meandu Creek. Observations for the North-West Backfilled Pit include:

- At the western limit of the North-West void, a relatively thin wall of remnant coal measures remains. It is conceptualised that this thin wall of remnant material allows relatively diffuse seepage to occur across a relatively wide area (as highlighted on the lower right plot of Figure 5.3). Seepage occurs initially to the rehabilitated spoil on the western side of the wall of remnant coal measures before reporting as seepage to the Ramp 7 haul road at a location where the spoil approaches zero thickness.
- The predicted water level within the spoil is shown as a blue dashed line in Figure 5.4, with water level data available from bores NWT and GW49 and an assumption has been made that the water level within the North-West B TSF is at or close to surface. Available water level data indicates that the groundwater flow direction is from east to west (i.e. towards Meandu Creek) and that water within the North-West B TSF seeps to the North-West void due to a direct connection between the two features.



Source: JBT 2018 (Appendix F)

Figure 5.4 Conceptual section through North-West Backfilled Pit and Meandu Creek

In summary, it is concluded that groundwater flow direction within the North-West Backfilled Pit is towards the west and north-west and exits the North-West Backfilled Pit by either:

- Seepage along prior drainage channel at RL435 mAHd towards Bullgang Corner where seepage is expressed at surface at a location where the spoil thickness approaches zero (i.e. Bullgang Corner)
- Seepage through and over the western wall of the North-West Backfilled Pit, commencing along prior drainage lines at RL432 mAHd and through saturated spoil at higher elevations. Seepage via the western wall also occurs as diffuse seepage through remnant natural material at locations where this material forms a relatively thin barrier to seepage.

The floor of the North-West Backfilled Pit is low permeability interburden material and it is conceptualised that this will restrict downward seepage due to the low vertical permeability of the interburden. However, groundwater movement to the west of the North-West Backfilled Pit (towards Meandu Creek) is interpreted to be possible, via the mechanisms discussed above.

Groundwater flow to the west of Meandu Creek is assessed to be unlikely for the following reasons:

- In the area adjacent to the North-West Backfilled Pit, the deepest seam mined (Queen Seam) does not occur beneath Meandu Creek due to the dip of the coal measures from west to east in this area.
- The lower coal seams also dip from west to east (i.e. the occurrence of the coal seams gets shallower to the west), with the coal measures discontinued to the west against the faulted margin of the Tarong Basin. Therefore, the dip of the strata and the shallow depth of coal measures beneath Meandu Creek combine to result in Meandu Creek acting as a capture zone for groundwater flow within the coal measures.
- It is conceptualised that there will be a natural flow of groundwater towards Meandu Creek on the western side of the creek (because generally, the water table is a subdued reflection of topography and the topography is elevated to

the west of Meandu Creek). In other words, it is conceptualised that Meandu Creek is a capture zone for groundwater flow from the west and east.

5.1.1.4 GROUNDWATER QUALITY

From review of groundwater chemistry data, it is concluded that the primary indicators of AMD seepage include pH, sulfate and metals/metalloids including cobalt, iron, manganese, nickel and zinc.

AMD-impacted groundwater is assessed to be present at a number of groundwater monitoring sites that are adjacent to the North-West Backfilled Pit and Meandu Creek. These sites are shown on Figure 5.2 and include GW25, GW34, GW35, GW36 and GW75. Groundwater quality data from these sites are summarised in Table 5.1. Sections 7 and 8 specifically addresses the impact of elevated concentrations of these parameters on the receiving environment.

To date, AMD impacts are not evident in groundwater monitoring bores that monitor the Meandu Creek alluvium, which include GW40 and EA compliance monitoring bore GW39.

Table 5.1 Groundwater quality data from bores potentially impacted by AMD seepage

GROUNDWATER BORE	WATER QUALITY
GW25 Regolith	This site is interpreted to be impacted by seepage from the North-West Backfilled Pit, based on the following: — Electrical conductivity has risen from <1,000 $\mu\text{S}/\text{cm}$ in 1999 to > 2,000 $\mu\text{S}/\text{cm}$ in August 2016 — Sulfate has risen from <100 mg/L in 1999 to > 450 mg/L in August 2016 — Manganese is elevated at this site relative to other bores in the area (~6 to 16 mg/L) — This site contains concentrations of dissolved aluminium, nickel and zinc that are higher than other bores in the area — The concentration of dissolved iron is increasing, from below the LoR over 5 sample events (March 2015 to February 2016) to over 3 mg/L in September 2017.
GW34 Queen Seam beneath spoil	This site is potentially impacted by seepage from the North-West Backfilled Pit based on groundwater quality data, though data is inconclusive. It is noted that: — Sulfate concentration has been reducing over time at this site, from > 700 mg/L in 2011 to < 400 mg/L in 2016 — The dissolved iron concentration is sporadic at this site, though the concentration is generally >10 mg/L.
GW35 Spoil (North-west dump)	— The sulfate concentration at this site has been relatively consistent between August 2011 and February 2016, generally in the range of 550 to 650 mg/L — The concentrations of dissolved iron, manganese, nickel and zinc are elevated relative to other spoil monitoring bores. Note this bore has been removed due to re-contouring of the North-West Backfilled Pit with the final reading in February 2016.
GW36 Regolith beneath spoil	This site is potentially impacted by seepage from North-West Backfilled Pit based on water quality indicators. It is noted that: — The sulfate concentration has increased from < 50 mg/L in 2011 to > 450 mg/L in May 2017 — The dissolved iron concentration is generally in the range of 80 – 90 mg/L — The dissolved manganese concentration is within the range of 2.4 to 2.8 mg/L. The manganese trigger value for ANZECC 2000 90% species protection is 2.5 mg/L.

GROUNDWATER BORE	WATER QUALITY
GW75 Spoil	— The electrical conductivity at this site is relatively low (~3,500 µS/cm). However, the sulfate concentration is relatively high (~1,000 mg/L) as is the concentration of AMD indicator parameters including cobalt, iron, manganese, nickel and zinc. — It is interpreted that groundwater at this site is impacted by AMD seepage.

High electrical conductivity groundwater (> 13,000 µS/cm) is observed in bore GW78, which is located on the western side of Meandu Creek and screened within the regolith to a depth of 12 m. The electrical conductivity recorded at bore GW78 is significantly higher than the electrical conductivity of mine-impacted water from any site sources. Review of geophysics data (Figure 4.6 and Figure 4.7) does not indicate a source of high electrical conductivity groundwater to the west of Meandu Creek, therefore the high electrical conductivity at this site may be a result of the residence time for groundwater at this location. The installation of additional groundwater monitoring bore(s) to the west of Meandu Creek is recommended as a means of determining whether the high electrical conductivity recorded at GW78 is indicative of water quality to the west of Meandu Creek and to validate data from geophysics investigations.

5.1.1.5 SEEPAGE WATER QUALITY

Rate of seepage has been measured using v-notch weirs as approximately 1.3 ML/day during 2016. Characteristics of the seepage data from Ramp 7 and Bullgang Drain is summarised in Table 5.2. A series of above average rainfall events in 1995 lead to AMD seepage from RSA1. The characteristics of this seepage are also included in Table 5.2.

Table 5.2 Seepage data characteristics – Ramp 7 and Bullgang Drain (July 2013 to February 2017) compared to 1995

PARAMETER	MINIMUM	AVERAGE	MAXIMUM	AMD QUALITY (1995)*
pH	3.4		6.3	3 – 3.5
Electrical conductivity	1,690 µS/cm	3,199 µS/cm	4,500 µS/cm	4,350 µS/cm
Acidity	12 mg/L	277 mg/L	490 mg/L	1,530 mg/L
Sulfate (SO ₄ ²⁻)	223 mg/L	1,113 mg/L	1,580 mg/L	3,540 mg/L
Aluminium (Al)	0.005 mg/L	0.84 mg/L	4.52 mg/L	-
Cobalt (Co)	0.01 mg/L	0.7 mg/L	1.21 mg/L	-
Iron (Fe)	0.33 mg/L	91.6 mg/L	181 mg/L	358 mg/L
Manganese (Mn)	0.88 mg/L	32.9 mg/L	50.3 mg/L	-
Nickel (Ni)	0.03 mg/L	0.51 mg/L	0.92 mg/L	5.6 mg/L
Zinc (Zn)	0.01 mg/L	4.11 mg/L	12.3 mg/L	95.6 mg/L

* metal/metalloid concentrations are assumed to be non-filtered and could include metals sorbed within suspended sediments.

The AMD seeping from Ramp 7 and Bullgang Drain was typically in the order of pH 3 with 300 mg/L average acidity and elevated dissolved concentrations of aluminium, cobalt, iron, manganese, nickel and zinc. The quality of the water has been relatively consistent over time, although the data trend suggests that the magnitude of the acidity and dissolved metals concentrations is decreasing, although longer data measurement of the water as close as possible to the actual seepage sources is needed to confirm this trend. RGS expects that the acidity and metal concentrations in seepage will continue to decrease over time.

5.1.1.6 RECOMMENDATIONS AND CONTROL MEASURES

Based on the identification of AMD issues at the North-West Backfilled Pit, Stanwell has implemented controls and made a number of infrastructure and mine planning management changes to address AMD issues occurring on site. These have included:

- initial changes to water management infrastructure
- construction of seepage collection dam RD27, automated lime-dosing and pump and pipework
- installation of solid bowl centrifuges at the CHPP to dewater tailings
- changes to rejects placement with Central pit catchment
- rehabilitation design changes.

Solid bowl centrifuges have been installed at the CHPP to dewater tailings and allow deposition of dry tailings. The solid bowl centrifuges allow wet tailings deposited in the North-West B TSF to be minimised, with the amount of tailings water reporting to the North-West Backfilled Pit reduced. Combined with other controls, the solid bowl centrifuges will subsequently reduce the amount of seepage from North-West Backfilled Pit.

The current Meandu Mine management practice of limiting storage/exposure time of coarse reject materials at the reject stockpile to less than two weeks appears to be an effective way of controlling the risk of acidic drainage generation. The potential for oxidation will be further reduced through the incorporation of fine-grade rejects and tailings as part of the implementation of the dewatering process through the installation of the solid bowl centrifuges. Through this process, pore voids within the coarse rejects will be filled with highly plastic low permeability tailings limiting oxidation and permeability. The combined reject and tailings streams will be placed into the spoil dumps and progressively co-mingled or encapsulated with NAF overburden and interburden. The PAF overburden units identified in the highwall during mining will be segregated and placed at least 6 metres under the final landform and covered by PAF material by truck and shovel mining methods.

If acidic drainage is perceived as an ongoing issue, then supplemental liming could be considered, but is unlikely to be required. Ongoing drilling, sampling and analysis will be continued to improve the reliability of the overburden model so that PAF units can be identified ahead of mining and managed appropriately. Sampling of reject, tailings and ash streams should be continued into the future for basic geochemical test parameters to ensure the geochemical nature of the mine waste is tracked over time.

Potential long-term control measures for the groundwater seepage from the North-West Backfilled Pit are assessed as part of the Integrated Water Model (Section 9) and summarised in Section 10.

5.2 OTHER DOMAINS OF INTEREST

Two separate areas with high electrical conductivity groundwater have been identified based on review of water quality data and aerial geophysics:

- a saline plume that has been identified with an origin close to the Queen West void; groundwater within the plume moves through shallow regolith along a natural drainage line towards retention dams RD1 and RD2
- an area within the Black Creek catchment in the northern area of the lease.

Both areas will be monitored by Stanwell as part of the ongoing groundwater monitoring program. While neither of these additional areas are determined at this stage to be related to AMD, they have been discussed in the following sections for completeness.

5.2.1 *QUEEN WEST BACKFILLED PIT, K2N AND K2W*

5.2.1.1 PIT DEVELOPMENT

The Queen West and K2W pits operated from mid-2002 through to late 2004 and were backfilled during 2005 and 2006.

K2W continued to be mined to the east until 2012 and was then utilised to store ash from the Tarong and Tarong North power stations. Mining of K2N Pit commenced in 2010. Deposition of ash into the K2N Pit commenced in late 2016. Additional storage in these pits was achieved by the construction of a dam wall between the backfilled spoil on either side of the ramp into K2W and K2N.

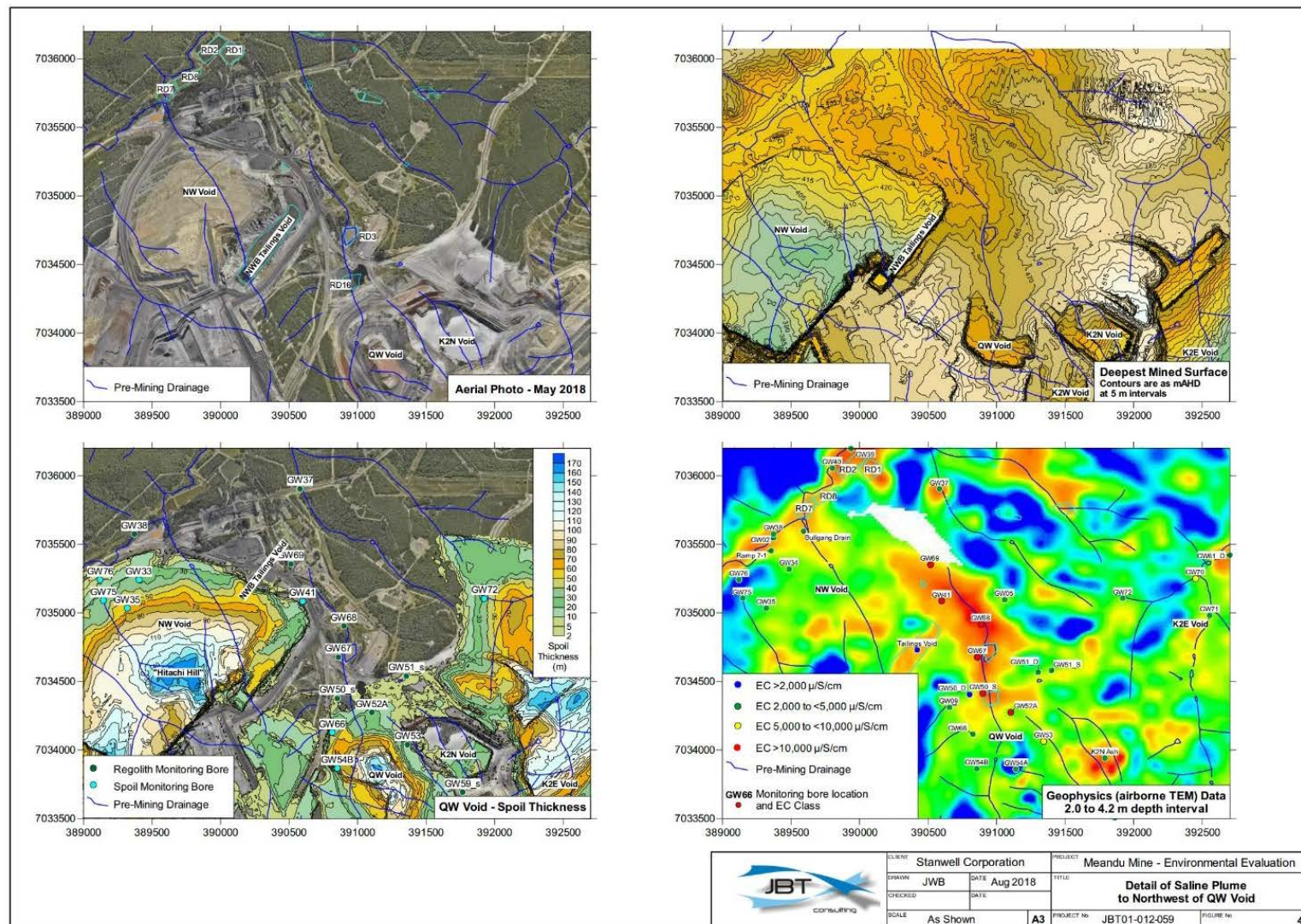
Groundwater monitoring as well as geophysical imagery has identified saline water from an area adjacent to the Queen West Backfilled Pit.

5.2.1.2 GROUNDWATER SEEPAGE

The existence of a high electrical conductivity ($>10,000 \mu\text{S/cm}$) groundwater plume along an area that is down-gradient of the Queen West void has been interpreted, based mainly on analysis of groundwater electrical conductivity and geophysics data. The saline plume extends from an area near the Queen West void (note that the Queen West void is not thought to be the source), with affected groundwater flowing through shallow regolith along a natural drainage line towards retention dams RD1 and RD2 (which are both to the east of Meandu Creek). Figure 5.5 contains four plots that can be used to review the location and mechanisms for seepage, with observations as follows:

- The upper left plot shows an aerial photo, taken in May 2018. The plot shows the location of the Queen West void area, which has been filled with spoil. Also shown on the plot are the locations of the adjacent K2N ash void, the North-West B TSF, North-West void, site retention dams (e.g. RD1, RD2) and pre-mining drainage pathways.
- The upper right plot shows contours of the deepest mined surface for the mine area, focussing on the Queen West void. The plot shows the mined extent of the Queen West void and the adjacent K2W and K2N voids, which are currently used for ash disposal. It is noted that a connection exists between the K2W ash void and the Queen West void via a low point in the ridge between the two voids, which is at a RL of approximately 474 mAHD. The level of ash in the K2W void rose above RL474 mAHD in early 2013, allowing for the possibility of seepage from the K2W void to the spoil within the Queen West void after this date.
- The lower left plot shows the extent and thickness of spoil in the Meandu Mine area, including the area of the Queen West void. The spoil attains a maximum thickness of approximately 150 m beneath the highest point of the Queen West spoil dump. It is also noted that the spoil thickness reduces to zero just north of the Queen West void (north of monitoring bore GW50_s) and that the area to the north of GW50_s comprises natural material within a pre-mining drainage line.
- The lower right plot contains features as follows:
 - The plot contains a background of airborne geophysics data, which shows a high electrical conductivity feature that extends from north of the Queen West void, along the natural drainage line and towards retention dams RD1 and RD2. Note that there is a data gap (white area) north of GW69, where no data was collected as the helicopter could not fly over the mine infrastructure area. However, the land-based geophysics extended into this area and shows high-conductivity features in this area, therefore it is interpreted that the plume extends along the natural drainage line through this area and towards RD1 and RD2. It is noted that there is no visible evidence of seepage at the ground surface in the area where the plume is inferred, with seepage interpreted to be occurring via the groundwater system in the shallow regolith.
 - The plot includes groundwater electrical conductivity data, where the bore location symbols have been colour-classed to show data within particular electrical conductivity ranges. From this data it is noted that the electrical conductivity of bores within the Queen West spoil (e.g. GW54A, GW54B, GW66) is relatively low (less than $4,000 \mu\text{S/cm}$). By contrast, bores to the north of the Queen West void that are screened within regolith that is within or adjacent to the pre-mining drainage line record electrical conductivity values above $10,000 \mu\text{S/cm}$, with bore GW50_s (interpreted to be close to the source) recording an electrical conductivity $>20,000 \mu\text{S/cm}$. The high electrical conductivity ($>10,000 \mu\text{S/cm}$) concentrations start at GW52A and are recorded in all regolith monitoring bores that are down-gradient of GW52A and within/adjacent to the pre-mining drainage line.

Based on interpretation of available data it is concluded that the spoil within the Queen West void is unlikely to be the source of the high electrical conductivity groundwater, but that the source is close to monitoring bore GW50_s. It should be noted that it is interpreted, based on water quality data, that the high electrical conductivity plume is not related to AMD and also that the plume is unrelated to groundwater quality impacts within the Black Creek catchment that are discussed below in Section 5.2.2.



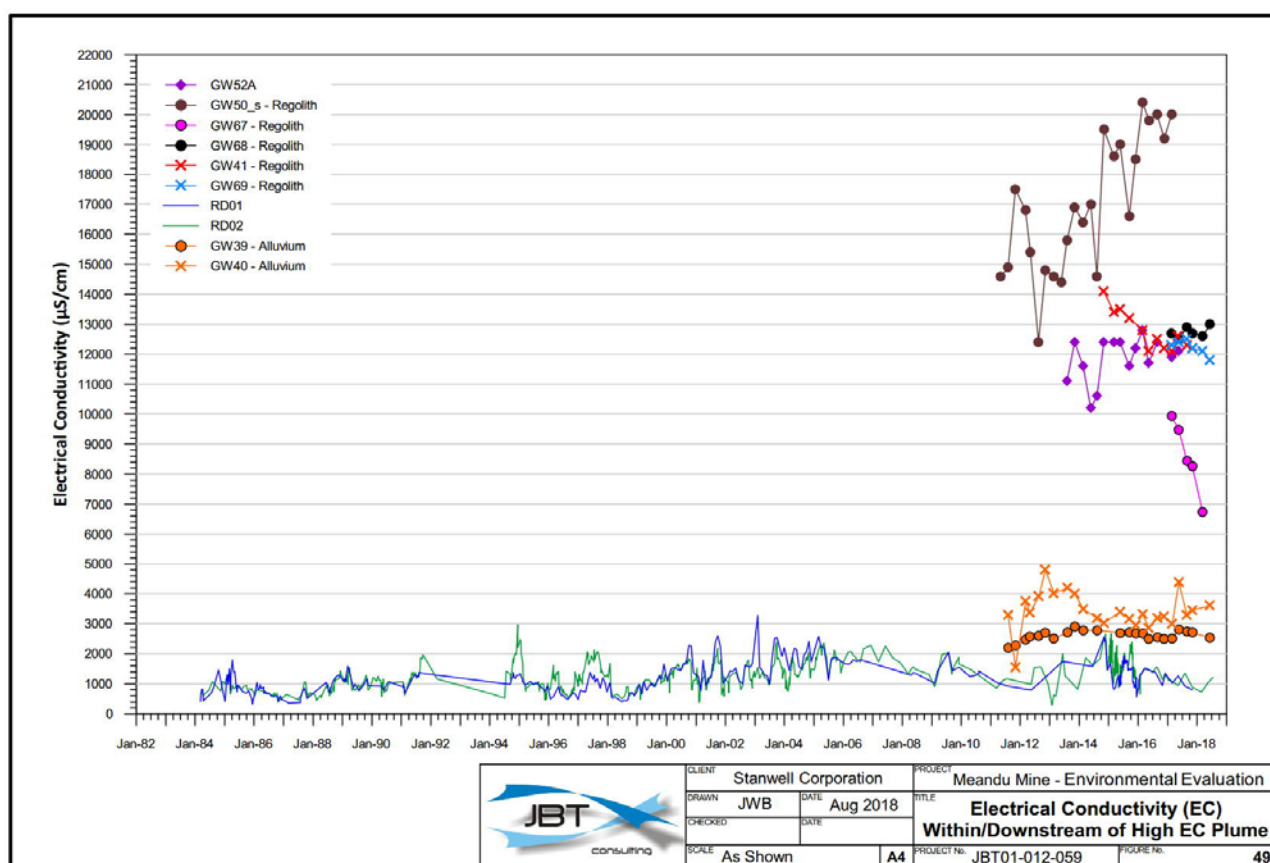
Source: JBT Consulting 2018 (Appendix F)

Figure 5.5 Detail of the Queen West void and potential seepage pathways

5.2.1.3 POTENTIAL FOR ENVIRONMENTAL IMPACTS

A preliminary assessment of the potential for high electrical conductivity groundwater from within the plume to adversely impact the EVs of Meandu Creek is presented in this section. Figure 5.6 shows electrical conductivity data for groundwater bores that are within the plume, as well as down-gradient sites RD1, RD2 and alluvial bores GW39 and GW40, which are within the Meandu Creek alluvium adjacent to RD2. Observations from this figure include:

- The bore that records the highest electrical conductivity is GW50_s (which is assessed to be located close to the source). The electrical conductivity has been increasing over the period for which monitoring is available, from ~15,000 $\mu\text{S/cm}$ to ~20,000 $\mu\text{S/cm}$.
- At sites downgradient of GW50_s the electrical conductivity decreases to ~12,000-13,000 $\mu\text{S/cm}$.
- Electrical conductivity data for RD1 and RD2 is available from 1984 to present. Electrical conductivity has varied in both RD1 and RD2 since the commencement of monitoring, but that the present day electrical conductivity is similar to electrical conductivity that was recorded in 1984 (i.e. generally ranging between 800 and 1,200 $\mu\text{S/cm}$). The increase in electrical conductivity from <1,000 to >2,000 $\mu\text{S/cm}$, that is observable between 1998 and 2007 is interpreted to be related to drought conditions that were prevalent at that time.
- Groundwater monitoring bores GW39 and GW40, which are screened within the Meandu Creek alluvium, generally record a higher electrical conductivity than RD1/RD2, with the electrical conductivity in GW40 being more variable than in GW39. GW40 is further upstream than GW39 and GW39 is assessed to be impacted to some degree by water backing up from Meandu Creek Dam. Therefore, the electrical conductivity at GW40 may reflect more natural variation, while the electrical conductivity range at GW39 is likely to be somewhat modulated by the water quality of Meandu Creek Dam.



Source: JBT Consulting 2018 (Appendix F)

Note: Sampling point in the legend have been arranged in order, starting from the top end of the plume (at bore GW52A) and finishing at alluvial bores GW39 and GW40.

Figure 5.6 Electrical conductivity data within bores and retention dams downstream of the high electrical conductivity plume originating near Queen West void

From review of the data discussed above, it is interpreted that, although the geophysics tends to indicate that the plume is migrating towards RD1 and RD2 (refer Figure 5.5), there is no discernible impact to water quality within RD1 and RD2 to date from the high electrical conductivity groundwater within the plume. A potential reason for the apparent lack of water quality impact on RD1 and RD2 is the relatively low rate of seepage within the plume.

Based on a preliminary assessment JBT has calculated the groundwater inflow rate to RD1/RD2 to be between 0.3 and 1.3 L/second (0.025 to 0.1 ML/day) (refer Appendix F). This flow rate would be relatively insignificant when compared to surface water inflows to both dams over the course of a year.

From the preliminary assessment, it is concluded that, even if the saline plume has extended to RD1/RD2, the potential rate of inflow to the dams is calculated to be low and, based on available water quality data, it is evident that the plume has not made a discernible impact to date on the electrical conductivity of dams RD1 and RD2. It may be further concluded that, due to the relatively low seepage rates and the presence of retention dams to intercept groundwater flow, the risk to the environmental values of Meandu Creek is also low.

5.2.1.4 ONGOING MONITORING

Based on interpretation of available data it is concluded that the spoil within the Queen West void is unlikely to be the source of the high electrical conductivity groundwater, but that the source is close to monitoring bore GW50_s. Further monitoring will be undertaken in this area. Drilling of additional groundwater bores will likely be a requirement of this monitoring though the number and location of bores is yet to be established. However once established, any additional monitoring bores should be incorporated into the Meandu Mine monitoring network for long-term monitoring and assessment.

5.2.2 BLACK CREEK CATCHMENT

Based on the results from the aerial geophysical survey a zone of relatively high electrical conductivity is evident in the spoil areas to the north of K2E Pit and bores within the Black Creek drainage channel (e.g. around bores GW61_s, GW61_d, GW73 and GW74). The interpretation in this area is complicated by the presence of high voltage transmission lines. However, the results from the geophysics survey correlate with bore electrical conductivity data and appear to correlate with the presence of prior and current drainage channels that could act as conduits for seepage. The K2E Pit and a rehabilitated tailings storage facility (K2) are located in this area. The K2 TSF was operated as a valley fill storage facility from 1986 to 1995. Tailings were pumped to the TSF from the CHPP.

Potential impacts on groundwater quality within the Black Creek catchment are interpreted based on water quality data. However, data from the majority of bores in this area is relatively recent (with data available from November 2016 with the exception of GW61_s and GW61_d, where data is available from 2009) and the water quality trends between bores within the catchment are not consistent (refer to following discussion). Therefore, additional monitoring to establish trends is required before conclusions can be made.

5.2.2.1 SEEPAGE

Figure 5.7 contains four plots that can be used to understand the location and potential mechanisms for water quality impacts, with observations as follows.

The upper left plot shows contours of current topography (December 2016). The plot also shows the location of the K2E rehabilitation area (rehabilitation of in-pit and out of pit spoil dump areas), the current K2E pit, pre-mining drainage, the extent of the K2 TSF (now buried beneath spoil), the location of groundwater monitoring bores and the location of the surface water divide in this area.

The upper right plot shows contours of the deepest mined surface for the mine area, focussing on the K2E void. The plot shows the mined extent of the K2E void, with the current (active) K2E pit to the south of the image. From review of the upper left (current topography) and upper right (deepest mined surface) it is observed that:

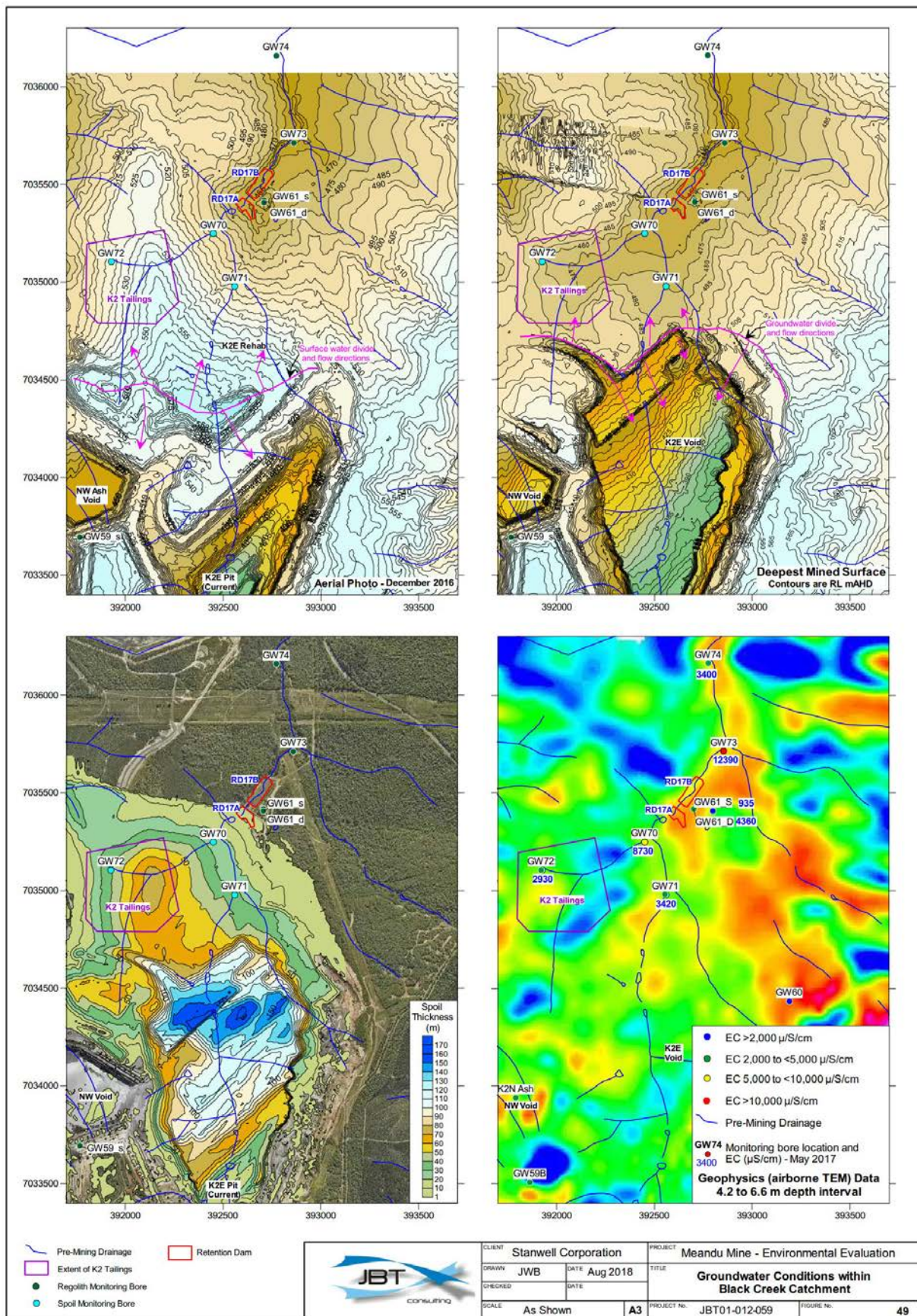
- The approximate location of the surface water catchment divide for the K2E spoil is shown on the upper left plot. In general, surface runoff could be expected to be directed either to the north from this point (into the Black Creek catchment) or to the south towards the current K2E Pit.
- The groundwater catchment for the current K2E Pit differs from the surface water catchment, with the approximate location of the groundwater catchment divide shown on plot. From review of the upper right plot of Figure 5.7 it can be observed that the limit of mining in the K2E Pit is further north than the surface water divide. Therefore, all recharge water that reaches the base of spoil above the K2E void will be drained to the south towards the current K2E Pit. The approximate groundwater catchment divide is shown towards the south, as all recharge that reports to the K2E void will drain to the south towards the current K2E Pit.

The lower left plot shows the extent and thickness of spoil in the area of the K2E void, with spoil being dumped over the K2 TSF and extending to the north as far as retention dam RD17A. The spoil attains a maximum thickness of approximately 75 m above the K2 TSF.

The lower right plot contains features as follows:

- The plot shows aerial geophysics (EM) data for the interval 4.2 to 6.8 m below surface. The feature that is most evident are the zones of relatively high electrical conductivity (red zones), which correlate with the location of pre-mining drainage. The high electrical conductivity zones commence in the western area of the image, in an area that is unmined. Basalt exists at surface in the west of the mining area and, based on geophysics data, is interpreted to exist in the sub-surface for some distance to the east. The high electrical conductivity zones are interpreted to be indicative of basaltic clays that are present throughout the surface drainage system in this area. The high electrical conductivity zones do not correlate with groundwater salinity, as discussed below.
- The plot shows electrical conductivity data, where the bore location symbols have been colour-classed to show data within particular electrical conductivity ranges. The electrical conductivity ($\mu\text{S}/\text{cm}$) from February/May 2017 is shown below each bore. From this data it is noted that the electrical conductivity of bores within the Black Creek catchment is variable, ranging from $<1,000 \mu\text{S}/\text{cm}$ at GW61_s to $>12,000 \mu\text{S}/\text{cm}$ at GW73. The electrical conductivity at GW73 is higher than at any site up-gradient or down-gradient from the bore. The water quality data for GW73 also indicates high sulfate at this site; however, the concentration is consistent with the high electrical conductivity (i.e., sulfate is not interpreted to be elevated as a percentage of other major ions). It is noted that GW73 is located at the confluence of a number of pre-mining drainage channels (which are also current drainage channels as the site is located in an unmined area). The reason for the high electrical conductivity at this location is uncertain and will require further monitoring.
- Bore GW74, which is down-gradient of GW73, records an electrical conductivity of $\sim 3,400 \mu\text{S}/\text{cm}$ (February/May 2017). However, the most notable water quality feature of this bore is that the pH is generally ~ 4.0 , with the bore also recording relatively high concentrations of dissolved aluminium and dissolved zinc.

The groundwater quality trends (high electrical conductivity, low pH, high aluminium and zinc concentrations) are not consistent between bores in the Black Creek catchment and it is notable that bores GW73 and GW74 are constructed within natural material (regolith) that is down-gradient of spoil (a potential source of contaminants) but that the bores that are constructed within the up-gradient mined spoil and tailings (e.g. GW70, GW72, GW61_s) do not tend to record elevated concentrations of the same parameters (or low pH). It is further noted that water quality data is available from bores GW70, GW72, GW73 and GW74 over a relatively short period (November 2016 to present, at quarterly intervals) and that additional data will assist the interpretation of water quality trends within the catchment.



Source: JBT Consulting 2018 (Appendix F)

Figure 5.7 Groundwater conditions within Black Creek catchment

5.2.2.2 ADDITIONAL MONITORING

It is therefore recommended by JBT that additional monitoring is undertaken into the source of the contaminants in GW73 (high electrical conductivity) and GW74 (low pH, high aluminium and zinc concentrations), with the monitoring focussing on the potential source of the contaminants, which may potentially be derived from mine-impacted areas (i.e. spoil or tailings), from areas that are unimpacted by mining to the east (i.e. from the natural drainage lines that drain the ridgetop basalt) or from the area of the Tarong and Tarong North power stations.

Drilling of additional bores and further monitoring commitments will likely be a requirement for this area though the number and location of bores is yet to be established. However once established, any additional monitoring bores should be incorporated into the Meandu Mine monitoring network for long-term monitoring and assessment and in line with requirements for the groundwater monitoring program outlined in the EA (EPMPL00709113).

It should be noted that it is interpreted, based on water quality data, that the potential impacts on groundwater quality are not interpreted at this stage to be related to AMD and are not related to the high electrical conductivity plume that is discussed above in Section 5.2.1.

6 CHARACTERISATION OF THE RECEIVING ENVIRONMENT

SECTION OVERVIEW

This section identifies and characterises the receiving environment, which may potentially be impacted by AMD from the Meandu Mine. It describes the values of the land, surface waters and groundwater surrounding and in the vicinity of the mine. It specifically addresses requirement B2 of the Notice:

B2 An appropriately qualified person(s) as defined in this Notice must identify and characterise the environmental values that may be impacted by AMD from Meandu Mine. This characterisation must include land and groundwater environmental values that may be impacted by AMD from Meandu Mine.

The characterisation of Meandu Creek must:

- (i) identify any Environmental Values (EVs) and Water Quality Objectives (WQOs) scheduled for Meandu Creek under the EPP Water*
- (ii) if none are identified propose EVs/WQOs where required for Meandu Creek*
- (iii) provide a description of the existing qualities, characteristics and resilience of Meandu Creek*
- (iv) with reference to items (i) to (iii) above determine the mine-affected water release quality that must be achieved to protect the relevant EVs of Meandu Creek.*

The primary sources of information for this section are the Surface Water assessment (Appendix G) undertaken by Ecological Service Professionals Pty Ltd (ESP) and Groundwater Data Review and Conceptual Groundwater Model (Appendix F) undertaken by JBT Consulting Pty Ltd (JBT).

Focus has been on the characterisation of Meandu Creek as it receives most of the licenced discharge from the Meandu Mine and is the primary pathway of affected water from the mine to the receiving environment. The characterisation of Meandu Creek has included:

- the identification of any Environmental Values (EVs) and Water Quality Objectives (WQOs) for Meandu Creek
- describing of the existing qualities, characteristics and resilience of Meandu Creek
- determining the mine-affected water release quality that must be achieved to protect the relevant EVs of Meandu Creek.

There are currently no assigned EVs in Schedule 1 of the EPP (Water) for Meandu Creek. Relevant EVs for the purpose of this environmental investigation were assigned from those outlined in Section 6(2) of the EPP (Water), with reference to other relevant sources, such as the Burnett Mary Water Quality Improvement Plan, available literature, previous technical reports and field surveys. Based on the assessment undertaken the following EVs were applied to Meandu Creek:

- Meandu Creek upstream of Meandu Mine is ephemeral and dry at the time of the 2017 survey. This section of the creek is not impacted by operations at Meandu Mine and as such no EVs or WQOs have been proposed.
- Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam as well as Black Creek Dam and Black Creek upstream of Black Creek Dam form part of the water management systems for Meandu Mine and the Tarong and Tarong North power stations, and thus, the industrial use EV has been assigned to these sections.
- EVs assigned to Meandu Creek downstream of Meandu Creek Dam were aquatic ecosystems (moderately disturbed), irrigation, farm supply, stock watering, human consumption, primary recreation, secondary recreation, and industrial use.

6.1 REGIONAL SETTING

6.1.1 TOPOGRAPHY

The average altitude of the area surrounding the Meandu Mine is approximately 480 m. The region is predominantly undulating hills of low relief, characterised by steep upper slopes and gentle summits and ridges. These hills are spurs of the Cooyar Range (altitude 600 m), to the south-east of the mining area. Flat-lying basalt flows and associated sediments form the generally subdued scarp of the Cooyar Range. Remnants of sandstones and conglomerates of the coal measures form isolated knobs and subdued hill scarps.

To the east of the current surface rights area the topography is heavily undulating and well drained. The main access road (Ridge Road), separating the east side of the mine and the Hoop Pine plantation (Yarraman State Forest), has been formed along the crest of a deeply weathered basalt ridge. The ridge is reasonably level, with upper slopes typically between 5% and 10%, mid slopes between 15% and 20% and more gentle gradients at the toe of the slope towards the ephemeral drainage line known as Rocky Creek.

The topography of the mine itself has been altered significantly by mining operations. The topography of the Meandu Mine (based on current operations) is shown in Figure 6.1.

6.1.2 LAND USES

Meandu Mine is located within a rural area where land use is characterised by mining, power generation, forestry, grazing, cropping, and remnant and regrowth vegetation. Immediately to the east and south of the Meandu Mine is the Yarraman State Forest, which is characterised by Hoop Pine plantation interspersed with remnant vegetation. Tarong National Park lies to the west of the Meandu Mine site. There are also swathes of privately owned remnant and regrowth vegetation adjacent to the north-western side of the mine. To the north of the mine are the Tarong and Tarong North power stations (owned and operated by Stanwell) and the Tarong State Forest.

6.1.1 CLIMATE

Meandu Mine lies within the subtropical climate zone, as classified by the Bureau of Meteorology (BoM 2018). The Australian subtropical climate is seasonal with the highest rainfall and evaporation occurring during summer months.



Map: PS102396_Figxx_MineCont_r1v2

Author: NK/HC

Date: 11/09/2018

Approved by: AOK

Data source: © State of Queensland (Department of Natural Resources and Mines) 2017.



0 325 650
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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3



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Figure 6.1 Topographic map of Meandu Mine

6.1.1.1 TEMPERATURE

Temperature data for the region was obtained from the BoM Kingaroy Airport Station (040922), located approximately 30 km from the Meandu Mine. The station was opened in 2001. Summary mean maximum and minimum temperature data from this station for the period 2001 to 2018 is presented in Figure 6.2.

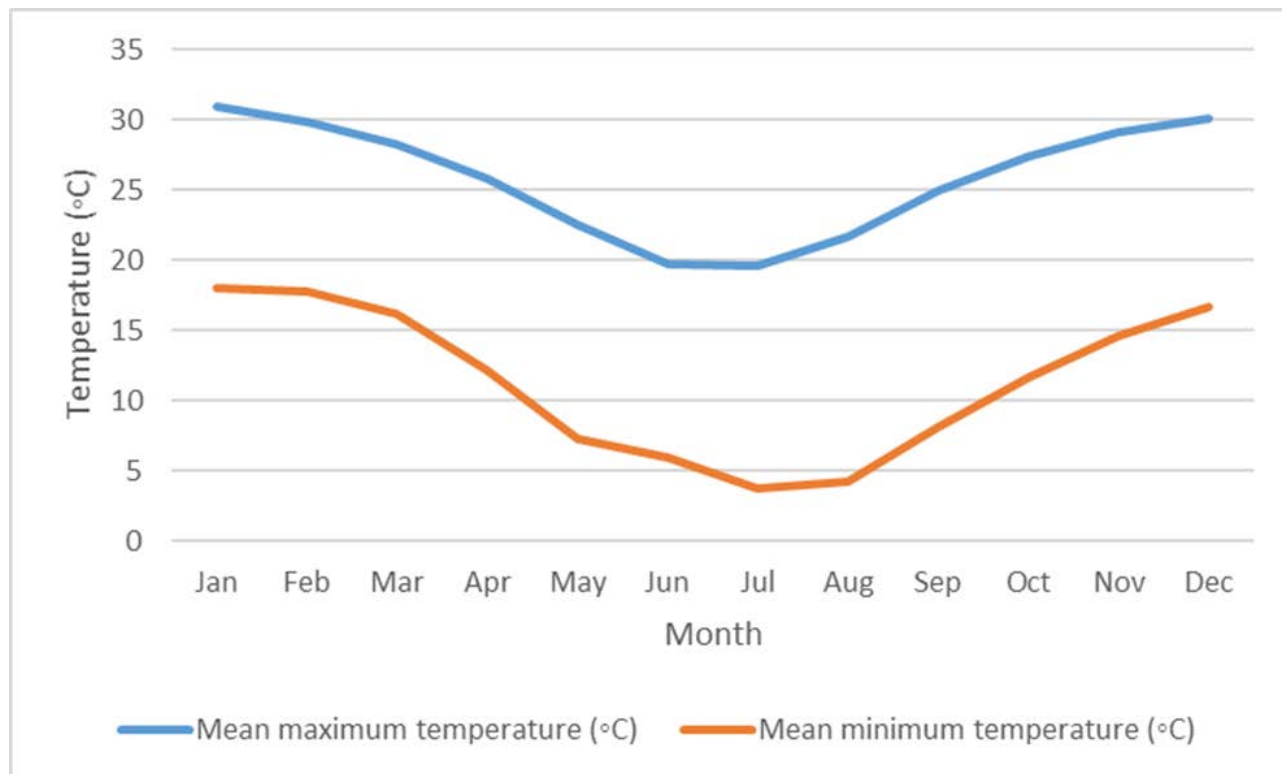


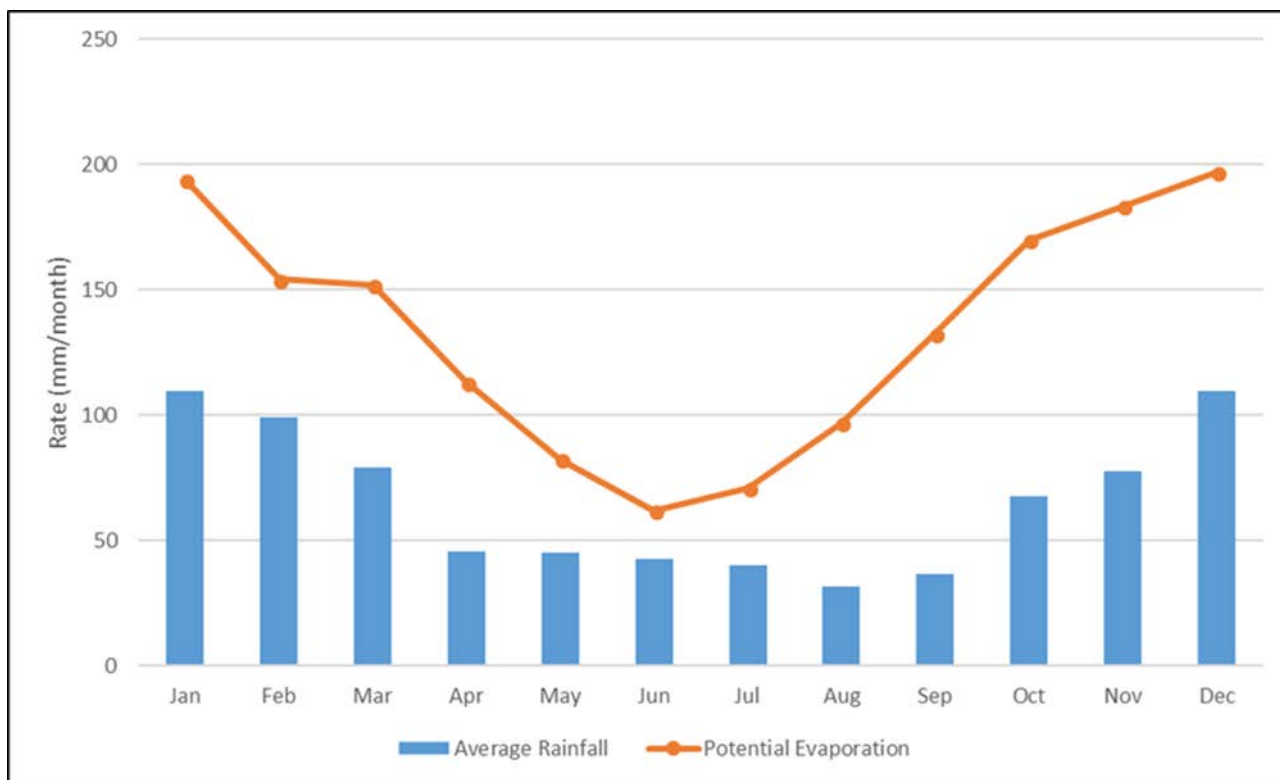
Figure 6.2 Mean maximum and minimum temperatures – Kingaroy Airport Station (040922)

6.1.1.2 RAINFALL

Historical rainfall data was obtained from the BoM Tarong Rainfall Station (040199), located approximately 7.5 km north-west of the Meandu Mine. The data record is available for the period September 1920 to 2017 and the metadata indicates records are 99% complete. On average, approximately 60% of rainfall at Tarong occurs between November and March (Figure 6.3).

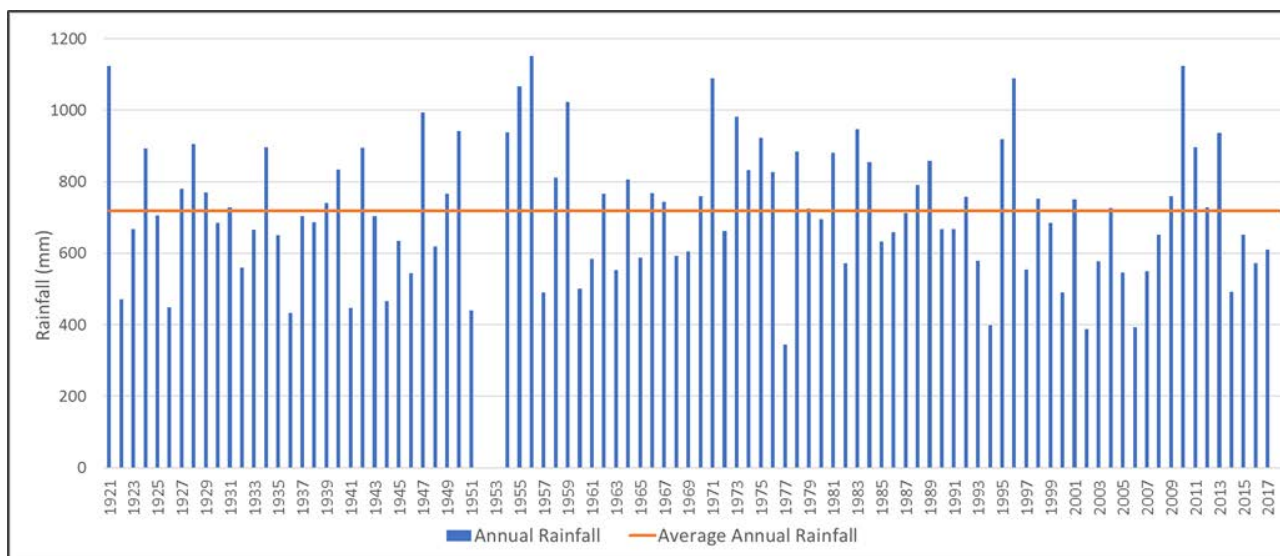
Annual rainfall is variable. The long-term yearly average rainfall for the Tarong Rainfall Station (040199) (1920 to 2017) is 719 mm. Inter-annual variability has ranged between 344 mm (in 1977) and 1,152 mm (in 1956) (Figure 6.4).

In more recent years (2009 to 2017) average yearly rainfall was 730.2 mm with a wet-season (November to March) average of 447.6 mm (BoM 2017). During this period, high average rainfall totals were recorded for the 2010-2011 (1335.2 mm) and 2012-2013 (1035 mm) years. Wet season totals for these years (taken to be the period between November and March) were also greater than the average annual total (862.8 mm and 847 mm respectively). Since the higher than average rainfall and flooding in early 2013 associated with ex-tropical cyclone Oswald, the subsequent period (through until June 2017) has experienced below average rainfall both yearly and wet season totals. There was a large rainfall event in March 2017, which was associated with rainfall from ex-tropical cyclone Debbie.



Source: Golder 2018 (Appendix H)

Figure 6.3 Measured average rainfall and potential evaporation at Tarong Rainfall Station (040199)



Source: Golder 2018 (Appendix H)

Figure 6.4 Measured annual rainfall – Tarong Rainfall Station (040199)

6.1.1.3 EVAPORATION

Additional climate data was also obtained from the Queensland Government's Scientific Information for Land Owners (SILO) Data Drill (Queensland Government 2018). The Data Drill accesses grids of data interpolated from point observations by the BoM including evaporation records. The SILO data was obtained for location latitude -26.8, longitude 151.9. Potential evaporation exceeds rainfall in most months (Figure 6.3).

6.1.2 SURFACE WATER

Meandu Mine is located within the headwaters of the catchments of Meandu Creek, Black Creek and Rocky Creek. Black Creek is a small tributary of Meandu Creek, which joins Meandu Creek north of the Tarong and Tarong North power stations, downstream of the lease boundary. Meandu Creek flows to the north and is a tributary of Barker Creek, which flows to the Bjelke-Petersen Dam (Lake Barambah) some 100 km downstream of Meandu Creek Dam. Meandu Creek and Barker Creek are part of the Burnett River basin. The Burnett River ultimately drains to the coast through the city of Bundaberg. Rocky Creek lies to the east of the surface rights area. Rocky Creek flows to the east and joins with Yarraman Creek, which is located within the Brisbane River basin. The Brisbane River ultimately drains to the coast through the city of Brisbane. The natural landform in the location of the mine generally slopes gently from the south-east to the north-west towards Meandu Creek.

The watercourses surrounding Meandu Mine are shown in Figure 6.5 and described in the following sections. Most of the licensed water discharged from Meandu Mine is directed to Meandu Creek Dam via Meandu Creek, with some water also discharging to Black Creek Dam.

6.1.2.1 MEANDU CREEK

Upstream of Meandu Creek Dam, Meandu Creek is an ephemeral watercourse with several disjointed, non-flowing pools. These upper reaches of Meandu Creek (upstream of the mine) are a stream order 2, with poorly defined channels that are naturally ephemeral (i.e. they convey runoff after rainfall, but water rarely pools).

The section of the creek adjacent to Meandu Mine (and within the mining lease) has been significantly modified through the creation of the Meandu Creek Dam and three creek diversions to facilitate mining operations. This section of the creek (including the waters of Meandu Creek Dam) form part of the overall water management systems for Meandu Mine and Tarong and Tarong North power stations.

The waters of the receiving environment downstream of Meandu Creek Dam (including Meandu Creek, and Barker Creek downstream of the confluence with Meandu Creek) have a perennial flow regime as a result of releases from Meandu Creek Dam (except during extreme drought conditions when releases may cease). Barker Creek upstream of the confluence with Meandu Creek has an ephemeral or intermittent flow regime, only flowing after rainfall.

Based on the differing nature of and influences on the Meandu Creek system, for the purposes of this assessment Meandu Creek has been separated into the following reaches:

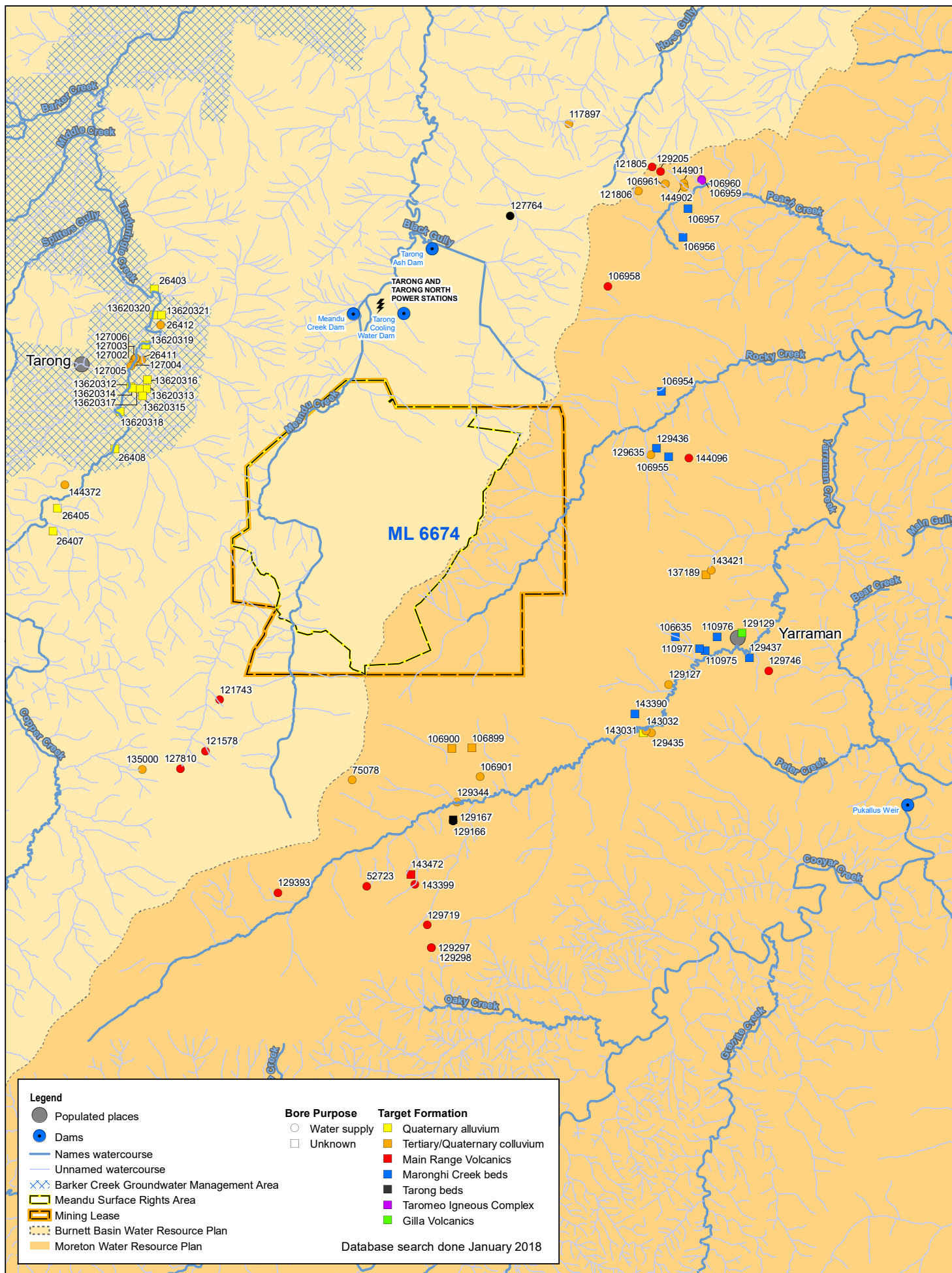
- Meandu Creek upstream of Meandu Mine (ephemeral and upstream of mining operation)
- Meandu Creek upstream of Meandu Creek Dam (direct impact from mining operations)
- Meandu Creek downstream of Meandu Creek Dam (perennial and downstream of mining and power station operations).

These reaches are shown on Figure 6.6.

6.1.2.2 MEANDU CREEK DAM

With the exception of some drought situations, Meandu Creek Dam receives continual blow-down water from the Tarong and Tarong North power stations, overflow water from the Cooling Water Dam, stormwater runoff from Meandu Creek and the Tarong and Tarong North power stations site as well as stormwater runoff and licensed discharges from Meandu Mine. The dam has a capacity of approximately 3,000 ML and discharges water at a relatively constant rate (typically 15 ML/day) to Meandu Creek, which was an ephemeral system prior to commencement of discharge in 1985.

Water from Meandu Creek Dam is subsequently released to the receiving environment of Meandu Creek via a release valve at the dam wall (monitoring site W3). Under normal operating conditions, there is a continual release of water; in the absence of rainfall and catchment inflows, these releases are the main source of water for Meandu Creek downstream of Meandu Creek Dam. Release volumes are regulated by water levels within the dam, as well as the needs of downstream water users, who are licenced by the Department of Natural Resources, Mines and Energy (DNRME) to take water when releases are being made from Meandu Creek Dam. Water release needs for these users are determined in conjunction with the Meandu and Barkers Creek Water Advisory Committee.



Map: PS102396_FigJ_Water_r1v1

Author: NK/TW/HC

Date: 11/09/2018

Approved by: LR



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Coordinate system: GDA 1994 MGA Zone 56
Scale ratio correct when printed at A3

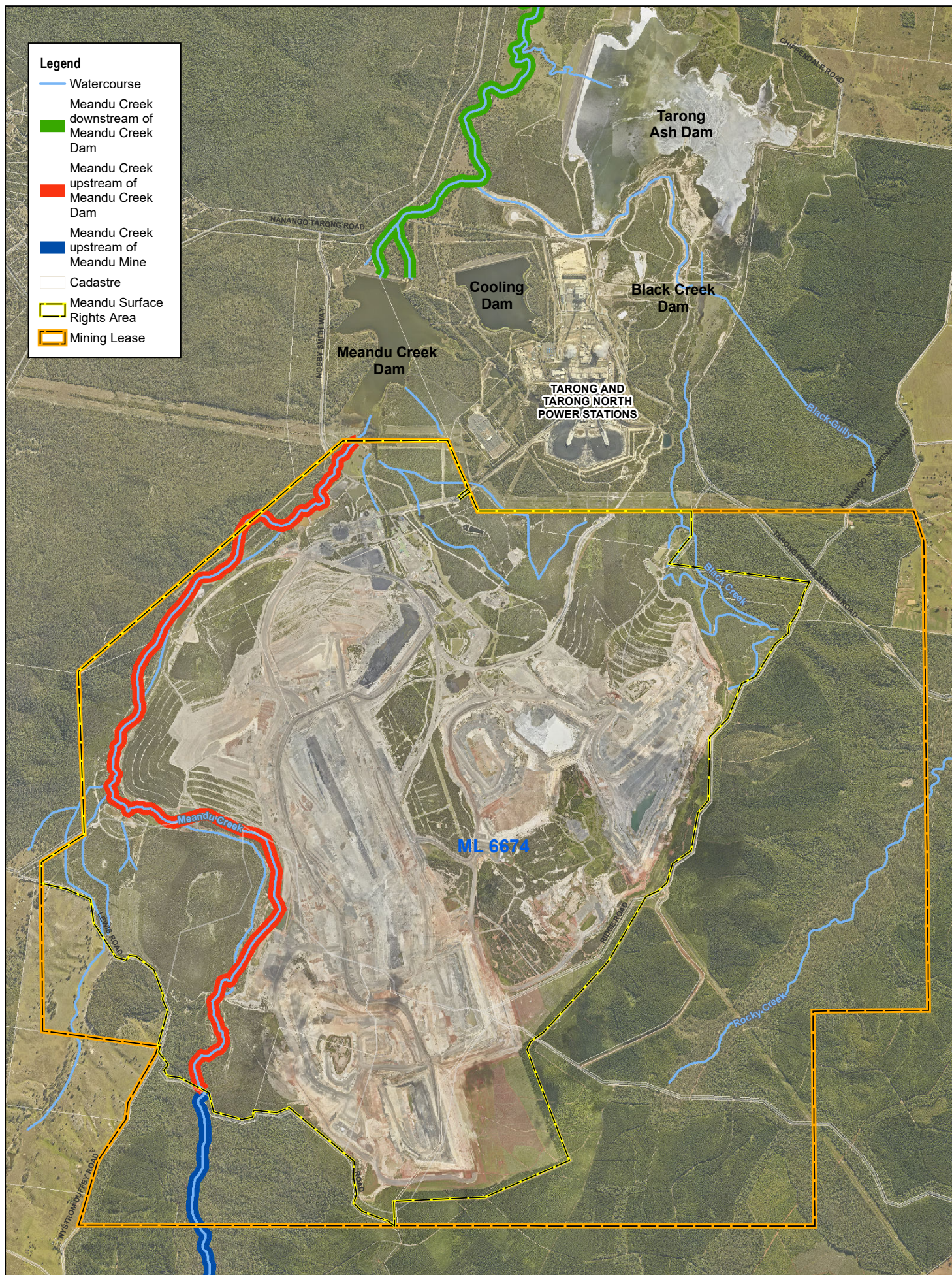


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Figure 6.5 Water resource planning areas, watercourses and groundwater users surrounding the Meandu Mine

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Map: PS102396_FigK_MeanduCK_r1v5

Author: NK/HC

Date: 11/09/2018

Approved by: AOK

Data source: © State of Queensland (Department of Natural Resources and Mines) 2017.



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Coordinate system: AGD 1984 AMG Zone 56

Scale ratio correct when printed at A3



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Figure 6.6 Reaches of Meandu Creek

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6.1.2.3 BLACK CREEK AND BLACK CREEK DAM

Black Creek Dam is located immediately upstream of the Tarong and Tarong North power stations Ash Dam (refer Figure 6.5). This 1,350 ML dam was constructed in 1987 and intercepts runoff from the upstream catchment. Water in Black Creek Dam is used at the Tarong and Tarong North power stations. Black Creek Dam is an integral part of the ash disposal system because of its effect on the Ash Dam water balance. In 2015, the Black Creek Dam diversion channel was constructed to direct overflows from the Black Creek Dam around the Ash Dam to Meandu Creek. As Black Creek has been substantially modified from its natural state and is used for industrial purposes, it was de-gazetted as a watercourse under the *Water Act 2000* by the former Department of Natural Resources and Mines (DNRM) (now DNRME).

6.1.2.4 ROCKY CREEK

Rocky Creek is an ephemeral drainage line that meanders steeply in a north-easterly direction towards Yarraman Creek. Rocky Creek flows briefly only after intense or prolonged rainfall. This is due to its high stream bed grade and location in the upper catchment. Approximately 6 km downstream of the Meandu Mine, a large farm dam has been constructed across the Rocky Creek drainage line. A further 6 km beyond this, Rocky Creek links with Yarraman Creek, which drains further to the north-east for approximately 8 km before linking with the larger Cooyar Creek. Yarraman and Cooyar creeks have several small permanent to semi-permanent pools in their stream beds.

The water management system for the Meandu Mine diverts all mine-affected water towards Meandu Creek and Black Creek catchments and away from the Rock Creek catchment.

6.1.3 GROUNDWATER

Table 4.1 summarises the hydrogeology of Meandu Mine and surrounds. The table includes a description of each geological unit, including a summary of known groundwater occurrence within that unit. It also includes reference to mine spoil, which is an anthropogenic unit specific to the Meandu Mine site. The unit is mentioned as it forms a groundwater unit within the mine site, and influences groundwater flow patterns and water quality.

Groundwater bores in Queensland are registered in the DNRME groundwater database. Based on a January 2018 database search, there are 62 registered bores used for water supply or an unknown purpose located within approximately 10 km of the Meandu Mine. The locations of these registered bores are shown on Figure 6.5.

6.2 WATER RESOURCE PLANNING AREAS

Extraction of water from water resources (both surface water and groundwater) is regulated within water resource planning areas under the *Water Act 2000*. The Meandu Mining Lease is located within the Barker Creek subcatchment of the Burnett Basin water resource planning area and the Upper Brisbane subcatchment of the Moreton water resource planning area. The Barker Creek subcatchment also incorporates the Barker Creek Groundwater Management Area. As shown on Figure 6.5, the Meandu Mine is located to the south-east of this groundwater management area.

6.3 ENVIRONMENTAL VALUES AND WATER QUALITY OBJECTIVES

The Environmental Protection (Water) Policy 2009 (EPP (Water)) under the *Environmental Protection Act 1994*, establishes Environmental Values (EVs) for natural waters in Queensland. EVs relate to specific values of waterways, determined by physical, biological, social, economic and historical features. Water quality objectives (WQOs) are quantitative measures established to protect the assigned EVs. Achieving the relevant WQOs assists with ensuring that the corresponding EVs and uses of the waterway are protected.

No specific EVs have been prescribed under the EPP (Water) for waterways in the Burnett Basin water resource planning area. As such, relevant EVs must be assigned from those outlined in Section 6(2) of the EPP (Water) (refer Table 6.1), referring to other relevant sources for the area including the Australian Water Quality Guidelines (ANZECC & ARMCANZ 2000); Queensland Water Quality Guidelines (EHP 2013) and the Burnett Mary Water Quality Improvement Plan (WQIP) (BRMG 2015). The Burnett Mary WQIP was developed to address the specific threat from increased loads of sediments, nutrients and pesticides from land based activities to the receiving marine and coastal assets of the Great Barrier Reef, the Great Sandy Strait and the Great Sandy biosphere and incorporates draft EVs and WQOs for the Burnett River catchment, including Meandu Creek upstream of Meandu Creek Dam, water of Meandu Creek Dam and Meandu Creek downstream of Meandu Creek Dam.

Final EVs and WQOs have been adopted for the Upper Brisbane River subcatchment of the Moreton water resource planning area and are listed under Schedule 1 of the EPP Water.

Table 6.1 summarises the EVs for waterways and identifies those considered appropriate the waterways surrounding Meandu Mine.

Table 6.1 *Environmental values considered appropriate for the surface waters surrounding Meandu Mine*

ENVIRONMENTAL VALUE	DESCRIPTION	BARKER CREEK SUB-CATCHMENT			UPPER BRISBANE RIVER (COOYAR CREEK) SUB-CATCHMENT
		UPSTREAM OF MEANDU CREEK DAM	DOWNSTREAM OF MEANDU CREEK DAM	BLACK CREEK	
Aquatic ecosystems	The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways and riparian areas (e.g. biodiversity, ecological interactions, plants, animals, key species and their habitat, food and drinking water).		✓		✓
	High ecological value waters - Ecosystems in which the biological integrity of the water is effectively unmodified or highly valued.				
	Slightly disturbed waters - Ecosystems that have the biological integrity of high ecological value waters with slightly modified physical or chemical indicators but effectively unmodified biological indicators ¹ .				
	Moderately disturbed waters – Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity ¹ .		✓		✓

ENVIRONMENTAL VALUE	DESCRIPTION	BARKER CREEK SUB- CATCHMENT			UPPER BRISBANE RIVER (COOYAR CREEK) SUB- CATCHMENT
		UPSTREAM OF MEANDU CREEK DAM	DOWNSTREAM OF MEANDU CREEK DAM	BLACK CREEK	
	Highly disturbed waters - Ecosystems that are significantly degraded by human activity and have lower ecological value than high ecological value waters or slightly or moderately disturbed waters.				
Irrigation	Suitability of water supply for irrigation (e.g. irrigation of crops, pastures, parks, gardens and recreational areas)		✓		✓
Farm water supply/use	Suitability of domestic farm water supply, other than drinking water (e.g. water used for laundry and produce preparation)		✓		✓
Stock watering	Suitability of water supply for production of healthy livestock		✓		✓
Aquaculture	Health of aquaculture species and human consuming aquatic foods (such as fish, molluscs and crustaceans) from commercial ventures				✓
Human consumers of aquatic foods	Health of humans consuming aquatic foods, such as fish, crustaceans and shellfish from natural waterways.		✓		✓
Primary recreation	Health of humans during recreations which involves direct contact and a high probability of water being swallowed (e.g. swimming, surfing, windsurfing, diving and water-skiing)		✓		✓
Secondary recreation	Health of humans during recreation which involves indirect contact and low probability of water being swallowed (e.g. wading, boating, rowing and fishing).		✓		✓
Visual recreation	Amenity of waterways for recreation which does not involve any contact with water (e.g. walking and picnicking adjacent to a waterway).				✓

ENVIRONMENTAL VALUE	DESCRIPTION	BARKER CREEK SUB-CATCHMENT			UPPER BRISBANE RIVER (COOYAR CREEK) SUB-CATCHMENT
		UPSTREAM OF MEANDU CREEK DAM	DOWNSTREAM OF MEANDU CREEK DAM	BLACK CREEK	
Drinking water supply	Suitability of raw drinking water supply. Assumes minimal treatment of water is required (e.g. coarse screening and/or disinfection).				✓
Industrial use	Suitability of water supply for industrial use (e.g. food, beverage, paper, petroleum and power industries, mining and minerals refining/processing).	✓	✓	✓	✓
Cultural and spiritual values	Aesthetic, historical, scientific, social or other significance to the present generation or past or future generations.				✓

Note 1: The Queensland Water Quality Guidelines (QWQG; EHP 2013) does not distinguish between slightly disturbed and moderately disturbed systems. These two categories are instead combined into a single category, slightly to moderately disturbed (SMD) systems, which are defined as ecosystems where: aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity; and the biological communities remain in a healthy condition and ecosystem integrity is largely retained.

Further details regarding assigning EVs and WQOs to the waters surrounding the Meandu Mine are outlined in the following sections.

6.3.1 MEANDU CREEK UPSTREAM OF MEANDU CREEK DAM (INCLUDING WATERS OF THE DAM), BLACK CREEK AND BLACK CREEK DAM

Meandu Creek upstream of Meandu Creek Dam and Black Creek form part of the overall water management systems for Meandu Mine and Tarong and Tarong North power stations. This section of Meandu Creek has been significantly modified through the creation of the Meandu Creek Dam, Black Creek Dam, and Tarong Ash Dam, the diversion of Meandu Creek and the construction of the Black Creek diversion channel. Based on this, 'industrial use' is the EV currently applicable to Meandu Creek upstream of Meandu Creek Dam, the waters of Meandu Creek Dam, Black Creek and Black Creek Dam.

Although the aquatic ecosystems EV is listed in the Burnett Mary WQIP as applying to waters of Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam, these waters are highly disturbed, and form part of the water management systems for the Meandu Mine and Tarong power stations. Therefore, the aquatic ecosystems EV is not considered to be applicable to this reach. Water is managed for industrial use and to protect the integrity of water quality and aquatic ecosystems in the receiving environment (i.e. Meandu Creek downstream of Meandu Creek Dam). Public access to Meandu Creek Dam, Meandu Creek within the mining lease, Black Creek and Black Creek Dam is prohibited.

Current compliance limits outlined in the EAs for the mine and power stations are considered appropriate for management of these waters; published WQOs do not strictly apply while the mine and power stations are operational, but may provide a general guideline against which water quality / aquatic ecosystem health can be compared.

6.3.2 MEANDU CREEK DOWNSTREAM OF MEANDU CREEK DAM

The Burnett-Mary Water Quality Improvements Plan (WQIP) identifies draft EVs relevant to the major waterways in the catchment, including those within the Burnett River Basin. Table 6.1 outlines the EVs that are considered appropriate for Meandu Creek downstream of Meandu Creek Dam, based on the WQIP as well as findings from available literature, previous technical reports and the current field survey.

Previous assessments have classified the aquatic ecosystems of Meandu Creek as “highly disturbed”, for the following reasons (IMEMS 2011):

- Land use in the upper and lower catchments has been modified by forestry and primary industry activities
- The upper catchment accommodates Meandu Mine and the Tarong and Tarong North power stations, all with licensed water discharges into Meandu Creek
- The Meandu Creek Dam, constructed on Meandu Creek, collects catchment stormwater runoff as well as licensed water discharges from the Tarong and Tarong North power stations and Meandu Mine
- Due to controlled releases from Meandu Creek Dam, lower Meandu Creek now experiences long periods of continual flow rather than the original intermittent flow typical of ephemeral streams in the area
- For much of the year, the majority of water flowing in lower Meandu Creek consists of water discharged from Meandu Creek Dam.

The flow regime and water quality within Meandu Creek has been substantially modified due to the construction of the Meandu Creek Dam in 1982 (and subsequent licensed water discharges). Over time however, it is likely that the aquatic floral and faunal communities inhabiting downstream reaches have adapted to these altered conditions with the continuous flows and altered water quality conditions changing the composition of these communities. Results from field surveys (March 2017) indicate that aquatic habitats in Meandu Creek are in moderate to good condition and support a diversity of aquatic flora and fauna (refer further to Section 8).

The aquatic ecosystems of Meandu Creek downstream of Meandu Creek Dam are not significantly degraded or are of a lower ecological value than surrounding waters (i.e. Barker Creek) as would be the case for highly disturbed waters. Therefore, the system is currently considered to meet the definition of ‘moderately disturbed’ (i.e. the biological integrity of the water is adversely affected by human activity to a relatively small but measurable degree).

Acknowledging the EVs for Meandu Creek downstream of Meandu Creek Dam (as presented in Table 6.1), WQOs for the receiving environment have been selected from the following hierarchy of sources:

- The Burnett-Mary WQIP, which defaults to the QWQGs (EHP 2013) for central east coast upland waters.
- Aquatic ecosystems EV (physico-chemical parameters and nutrients) - the QWQGs as apply to slightly-moderately disturbed systems such as the receiving environment.
- Aquatic ecosystems EV (toxicants) - the AWQG (ANZECC & ARMCANZ 2000) using the trigger values outlined in Table 3.4.1 of the AWQG that are applicable to slightly-moderately disturbed systems (95% level of protection).
- Human consumer, stock watering and farm supply EVs – the AWQG.
- Primary recreation EV – the Guidelines for Managing Risks in Recreational Waters (NHMRC 2008).

In selecting these WQOs, consideration has also been given to:

- Release contaminant trigger investigation levels and receiving waters contaminant trigger levels from the Model Water Conditions for Coal Mines in the Fitzroy Basin (version 6.01, 7 March 2017); to provide a context for the WQOs historically applied to the Meandu Creek, and currently applied to the receiving environment of coal mines in the adjacent basin
- Site specific data, where no other guideline was available or where other guidelines were considered inappropriate.

The WQOs applied to the receiving environment (Meandu Creek downstream of Meandu Creek Dam) are summarised in Table 6.2. Note that WQOs for the following EVs have not been included in the assessment:

- Industrial use – no WQOs are provided in the AWQG; although they have been outlined in previous versions of these guidelines, they vary depending on industry and this value is usually protected by other values, such as aquatic ecosystems (ANZECC & ARMCANZ 2000).
- Secondary recreation – guidelines generally relate to bacteria, cyanobacteria and algae concentrations, which are not relevant to this assessment.

Table 6.2 Water quality parameters and relevant published EVs and associated WQOs

PARAMETER	UNIT	WQO	ENVIRONMENTAL VALUE	SOURCE
PHYSICOCHEMICAL				
Temperature	°C	16-34	Primary recreation	NHMRC 2008
Dissolved oxygen	% saturation	70-110	Site-specific data	Based on the observed values and trends at the site over 10 years of monitoring data, the relative background dissolved oxygen of other sampling points in the Meandu Creek/Barker Creek catchment and the fact that, even at 70% saturation, the dissolved oxygen does not tend to fall below 6 mg/L
pH	pH units	6.5 -9.0	Fitzroy Basin Model Mine Conditions	Model water conditions for coal mines in the Fitzroy Basin (EHP)
Electrical conductivity	µS/cm	2037	Site-specific data	Calculated using 80th percentile of data from receiving environment sites W2 and SW16 (2007-2017)
Turbidity	NTU	25	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013)
Total dissolved solids	mg/L	2000	Stock watering	WQOs for livestock drinking water in ANZECC & ARMCANZ (2000)
Fluoride	µS/cm	2000	Stock watering	WQOs for livestock drinking water in ANZECC & ARMCANZ (2000)
MAJOR ANIONS				
Chloride	mg/L	-	-	-
Sulfate	mg/L	1000	Stock watering	WQO for stock watering (ANZECC & ARMCANZ 2000) has been chosen in preference to the Fitzroy Basin Model Condition, as the model condition is based on the Australian Drinking Water Guideline, and drinking water has not been identified as an EV for the study area
Alkalinity	mg/L	-	-	-

PARAMETER	UNIT	WQO	ENVIRONMENTAL VALUE	SOURCE
MAJOR CATIONS				
Calcium	mg/L	1000	Stock watering	WQOs for livestock drinking water in ANZECC & ARMCANZ (2000).
Magnesium	mg/L	-	-	-
Sodium	mg/L	-	-	-
Potassium	mg/L	-	-	-
NUTRIENTS				
Oxides of nitrogen	mg/L	0015	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013).
Total nitrogen	mg/L	0.25	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013).
Total phosphorous	mg/L	0.03	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013).
METALS AND METALLOIDS				
Aluminium	µg/L	55	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000).
Arsenic	µg/L	13	Aquatic ecosystems	Trigger value for AsV used, as it is the most stringent trigger value available for arsenic outlined in ANZECC & ARMCANZ (2000).
Boron	µg/L	370	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000).
Cadmium	µg/L	$0.2 \times (H/30)^{0.89}$	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000). Modified for water hardness.
Chromium A	µg/L	$1.0 \times (H/30)^{0.82}$	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000). Modified for water hardness.
Cobalt	µg/L	90	Aquatic ecosystems	Based on the low-reliability trigger value from ANZECC & ARMCANZ (2000).

PARAMETER	UNIT	WQO	ENVIRONMENTAL VALUE	SOURCE
Copper	µg/L	1.4 x (H/30) ^{0.85}	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000). Modified for water hardness.
Iron	µg/L	300		Based on the low-reliability trigger value from ANZECC & ARMCANZ (2000).
Lead	µg/L	3.4 x (H/30) ^{1.27}	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000). Modified for water hardness.
Manganese	µg/L	1900	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000).
Mercury	µg/L	0.06	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000).
Molybdenum	µg/L	34	Aquatic ecosystems	Based on the low-reliability trigger value from ANZECC & ARMCANZ (2000).
Nickel	µg/L	11 x (H/30) ^{0.85}	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000). Modified for water hardness.
Selenium	µg/L	5	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000).
Vanadium	µg/L	10	Fitzroy Basin Model Mine Conditions	Model water conditions for coal mines in the Fitzroy Basin (EHP).
Zinc	µg/L	8 x (H/30) ^{0.85}	Aquatic ecosystems	WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013), which defaults to the AWQG (2000). Modified for water hardness.

Source: Derived from Table 3.2 of ESP 2018 (Appendix G)

In most instances, the most stringent WQO for each parameter was considered appropriate to protect all EVs in the receiving environment. However, in some cases (e.g. pH, percent saturation of dissolved oxygen, electrical conductivity and turbidity), less stringent WQOs were adopted given the known ambient water quality conditions in comparative

waterways in the wider region, or long-term water quality values in the receiving environment that have been demonstrated to support diverse and healthy aquatic ecosystems (e.g. electrical conductivity).

6.3.2.1 GROUNDWATERS

The conceptual model for the groundwater system at Meandu Mine (Section 4.2) considers that groundwater flowing towards Meandu Creek (including groundwater seepage from the North-West void where AMD has been identified) is captured by either the Meandu Creek alluvium or by seepage to the ground surface to be collected via site drains and/or retention dams. In terms of groundwater management, it is generally considered that groundwater that occurs within alluvium is managed as surface water; therefore the groundwater EVs for Meandu Creek, as well as for Black Creek, are taken to be the same as the surface water EVs that have been defined above and in Appendix G (ESP 2018).

For alluvial aquifers occurring along Meandu Creek, groundwater quality should not compromise the identified EVs and WQOs for surface waters as identified above.

7 SURFACE WATER INVESTIGATIONS RELEVANT TO THIS EIR

SECTION OVERVIEW

This section describes the surface water assessments investigation undertaken by ESP and presented in Appendix G to investigate the potential for AMD-related environmental harm from operations at the Meandu Mine site on water quality, sediment quality and aquatic flora and fauna in the receiving environment. Specifically, it addresses requirements B4(i) and B4(ii) of the Notice:

B(4) An appropriately qualified person(s) as defined by the Notice must undertake studies to determine whether AMD at Meandu Mine has impacted on or has the potential to impact on the environmental values of groundwater and/or surface waters including Meandu Creek. The studies must include:

- (i) water quality investigation to determine any impacts on environmental values of groundwater and surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine*
- (ii) water quality investigations to determine future potential impacts on environmental values of groundwater and surface waters (Meandu Creek) resulting from AMD at Meandu Mine.*

Groundwater requirements are addressed in Section 4.

As identified in Section 6, the waterways of interest for this environmental investigation are Meandu Creek, Meandu Creek Dam and Black Creek as they receive the licenced discharge from the Meandu Mine. Surface water releases from the mine are not directed towards Rocky Creek.

The assessment summarises the results from two field surveys (March 2017 and April 2018 (sediment only)) as well as historical water quality monitoring data provided by Stanwell from both the Meandu Mine and Tarong and Tarong North power stations for the period October 1978 to August 2017. Water quality sampling and monitoring by Stanwell has continued beyond this date ranges.

Based on the assessments conducted, there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment. Where water quality conditions remain unchanged (i.e. remain within the historical range and/or comply with WQOs where applicable, and are monitored and managed in accordance with the current EA (EPML00709113) and/or Meandu Creek REMP, potential AMD impacts on aquatic environmental values are considered unlikely.

7.1 HISTORICAL WATER QUALITY MONITORING

This section summarises the findings from a review of historical water quality monitoring based on a complete water quality monitoring data base provided by Stanwell.

7.1.1 UPSTREAM OF MEANDU CREEK DAM

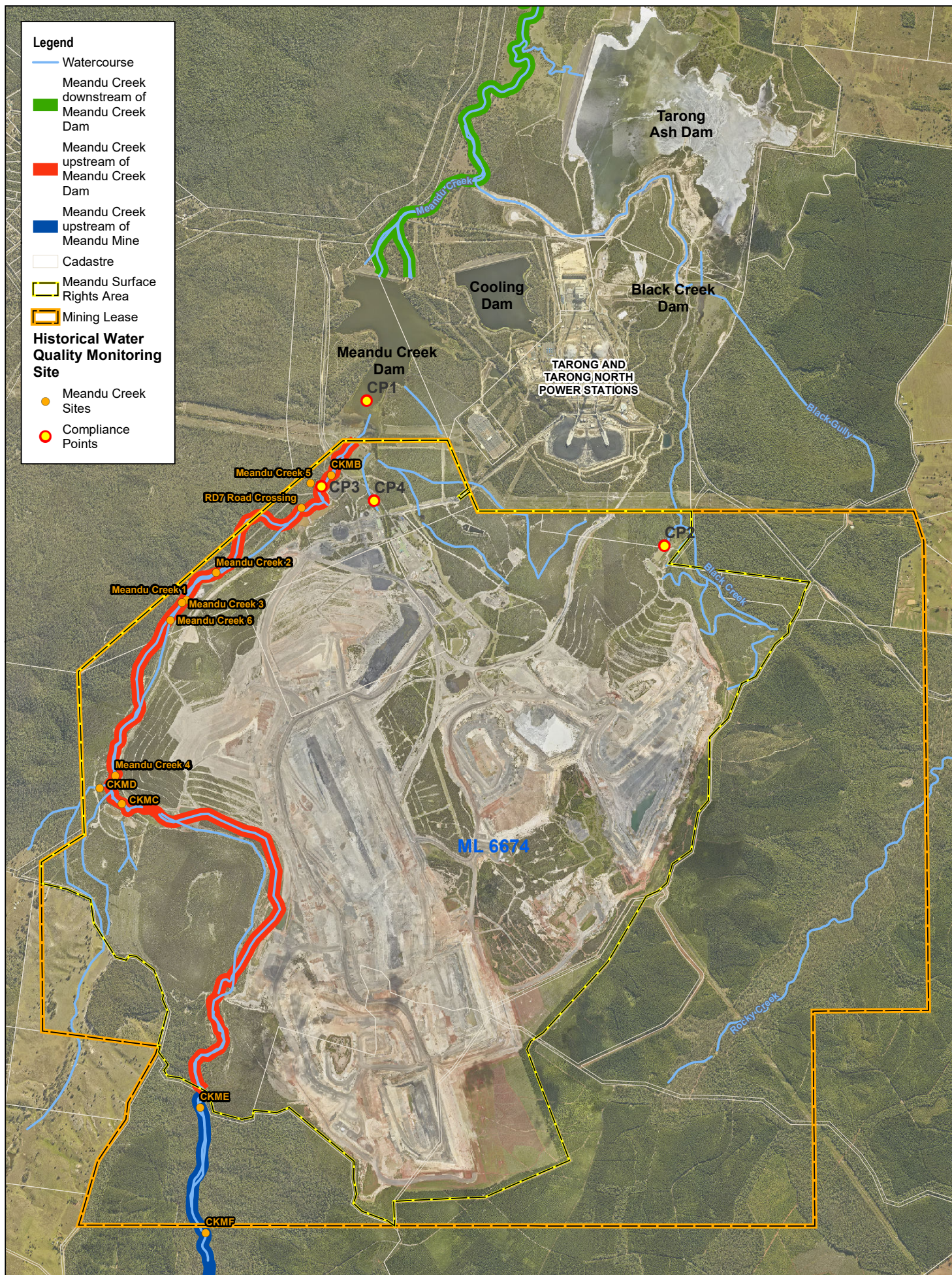
7.1.1.1 MONITORING SITES

Surface water quality monitoring has been undertaken at Meandu Mine since 1978. Water quality has been monitored at numerous sites throughout the mine water system (refer Section 2) and in Meandu Creek. A summary of the surface water quality monitoring sites in Meandu Creek upstream of Meandu Creek Dam is outlined in Table 7.1 with approximate site locations shown on Figure 7.1.

Table 7.1 Summary of surface water quality monitoring sites upstream of Meandu Creek Dam, including sampling date ranges

LOCATION	SITE	DESCRIPTION	SAMPLING DATE RANGE
COMPLIANCE SITES			
Meandu Creek Dam	CP1	Meandu Creek Dam at Meandu Creek Inflow	1997–2017
Meandu Creek upstream of Meandu Creek Dam	CP3	Meandu Creek at V-Notch Weir	2000–2017
	CP4	Meandu Creek tributary (clean water drain)	2003–2017
MEANDU CREEK SITES			
Meandu Creek upstream of Meandu Creek Dam (adjacent to mine)	RD7 Creek Crossing	Main Meandu Creek crossing behind RD7	2014–2015
	Meandu Creek-1	Waterhole behind RD9	2014–2017
	Meandu Creek-2	Waterhole to the west of RD9	2014–2017
	Meandu Creek-3	Waterhole west of RD10	2015–2017
	Meandu Creek-4	Main waterhole on bend downstream of RD14B	2015–2016
	Meandu Creek-5	Waterhole west of RD7 and RD8 between main creek crossing behind RD7 and CP3	2015–2017
	Meandu Creek-6	Waterhole opposite Ramp 7 fill point near RD10	2015–2017
	CKMB	Meandu Creek - below RD2	1978–2008
	CKMC	Meandu Creek - just opposite RD14	1978–1994
	CKMD	Small gully draining into Meandu Creek, just below RD14	1978–1995
	CKMM	Meandu Creek - just opposite RD14	1983–1999
	CKMR	Was on Meandu Creek in vicinity of where RD11 and RD12 have since been built.	1986–1992
	CKMU	N/A	1985–1990
Meandu Creek upstream of Meandu Mine	CKME	Meandu Creek draining forestry catchment - Just below (100 – 200m) southern lease boundary.	1978–1999
	CKMF	Meandu Creek - Forestry dam - in forest catchment well above site 'E'.	1988–2005

Notes: N/A – Indicates site location not provided in water quality database



Map: PS102396_FigL_HistoricalWater_r1v5 Author: NK/HC
 Date: 6/09/2018 Approved by: AOK
 Data source: © State of Queensland (Department of Natural Resources and Mines) 2017.



0 430 860 m
 1:30,000
 Coordinate system: AGD 1984 AMG Zone 56
 Scale ratio correct when printed at A3



Environmental Investigation Report

Figure 7.1 Approximate location of historical water quality monitoring sites

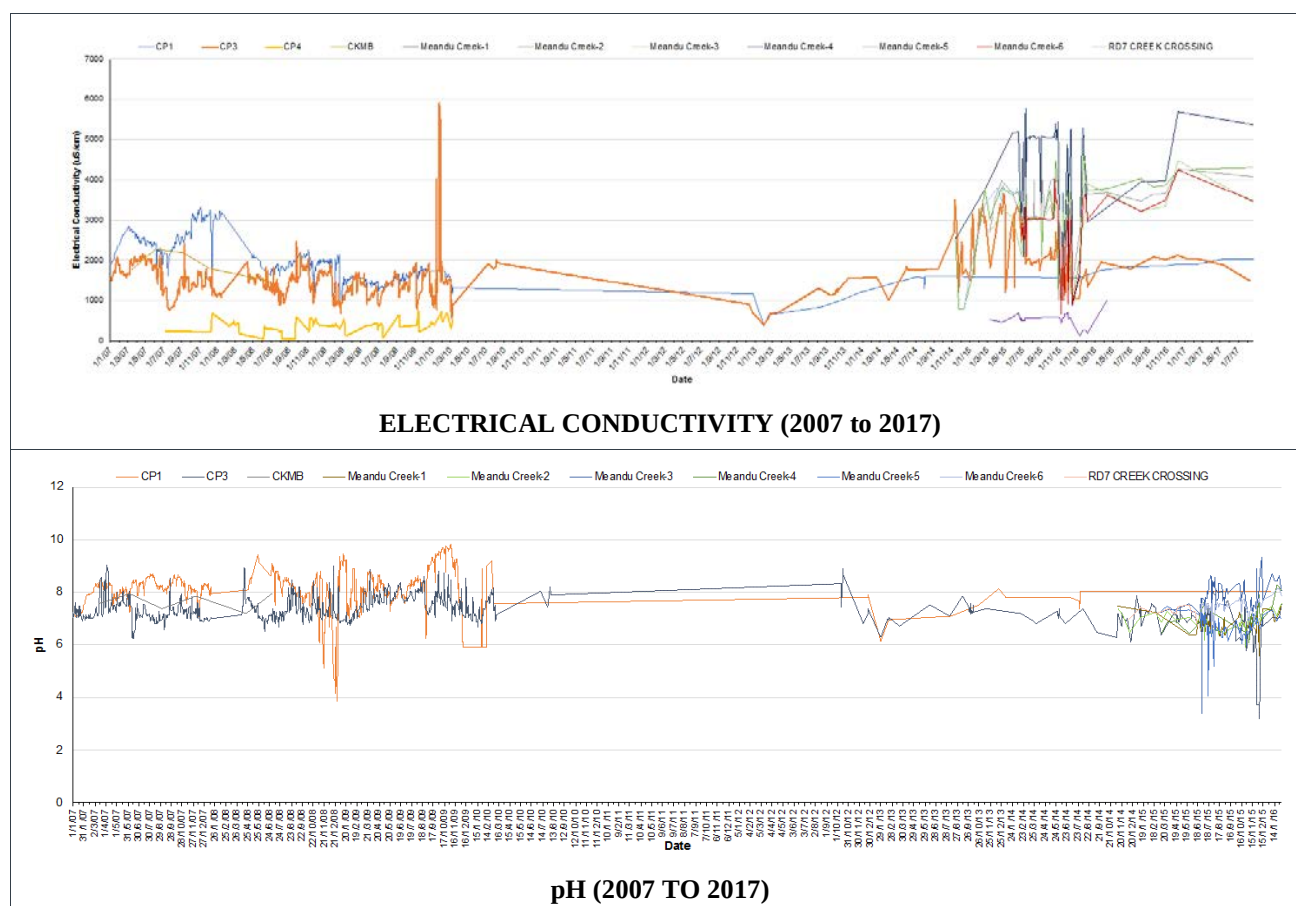
7.1.1.2 MONITORING RESULTS

Summary statistics (including minimums, maximums and 20th, 50th (median), 80th and 95th percentiles) were calculated using the available data (from 1978 to 2017) for each site on Meandu Creek upstream of Meandu Creek Dam. Due to inconsistencies in parameters monitored and uncertainty around monitoring site locations, summary statistics were also calculated for each site for the past 4 years only (2013–2017) (i.e. since elevated electrical conductivity levels at CP3 were noted and additional sampling undertaken).

The following trends were noted when the summary statistics for long-term data (all data since 1978) were compared to summary statistics for the past four years (June 2013 to June 2017):

- Median pH was higher at the Meandu Mine compliance points CP3 and CP1 (which are located near the inflow and within Meandu Creek Dam, respectively) than in Meandu Creek adjacent to Meandu Mine. While there have been occasions where the pH at the compliance points and Meandu Creek sites has been low (e.g. approximately 4 pH units), there has been little change in the median pH in recent years compared to the long-term median (Figure 7.2).
- Electrical conductivity levels were higher in Meandu Creek adjacent to Meandu Mine than at the compliance points (CP3 and CP1 – which are located near the inflow and within Meandu Creek Dam respectively). Median electrical conductivity levels have increased at both locations in the past four years compared with the long-term median.
- Concentrations of sodium and chloride were higher in Meandu Creek adjacent to Meandu Mine than at the compliance points. Median concentrations in the past four years were generally similar to the long-term median.
- Concentrations of sulfate, oxides of nitrogen and most metals (including cobalt, iron, manganese, molybdenum, nickel and zinc) were higher at the compliance points than in Meandu Creek adjacent to the mine.

While not directly applicable to the waters of Meandu Creek adjacent to the mine, WQOs for moderately disturbed aquatic ecosystems provide guidelines below which the environmental values of Meandu Creek are unlikely to be adversely impacted. In most part summary statistics complied with the WQOs, and the EA (EPML00709113) compliance limits (where applicable) apart from electrical conductivity, oxides of nitrogen and some metals (cobalt, iron, zinc and manganese). Monitoring results for these parameters are summarised in Table 7.2 and illustrated in Figure 7.2 and Figure 7.3. Full details are provided in Appendix G.



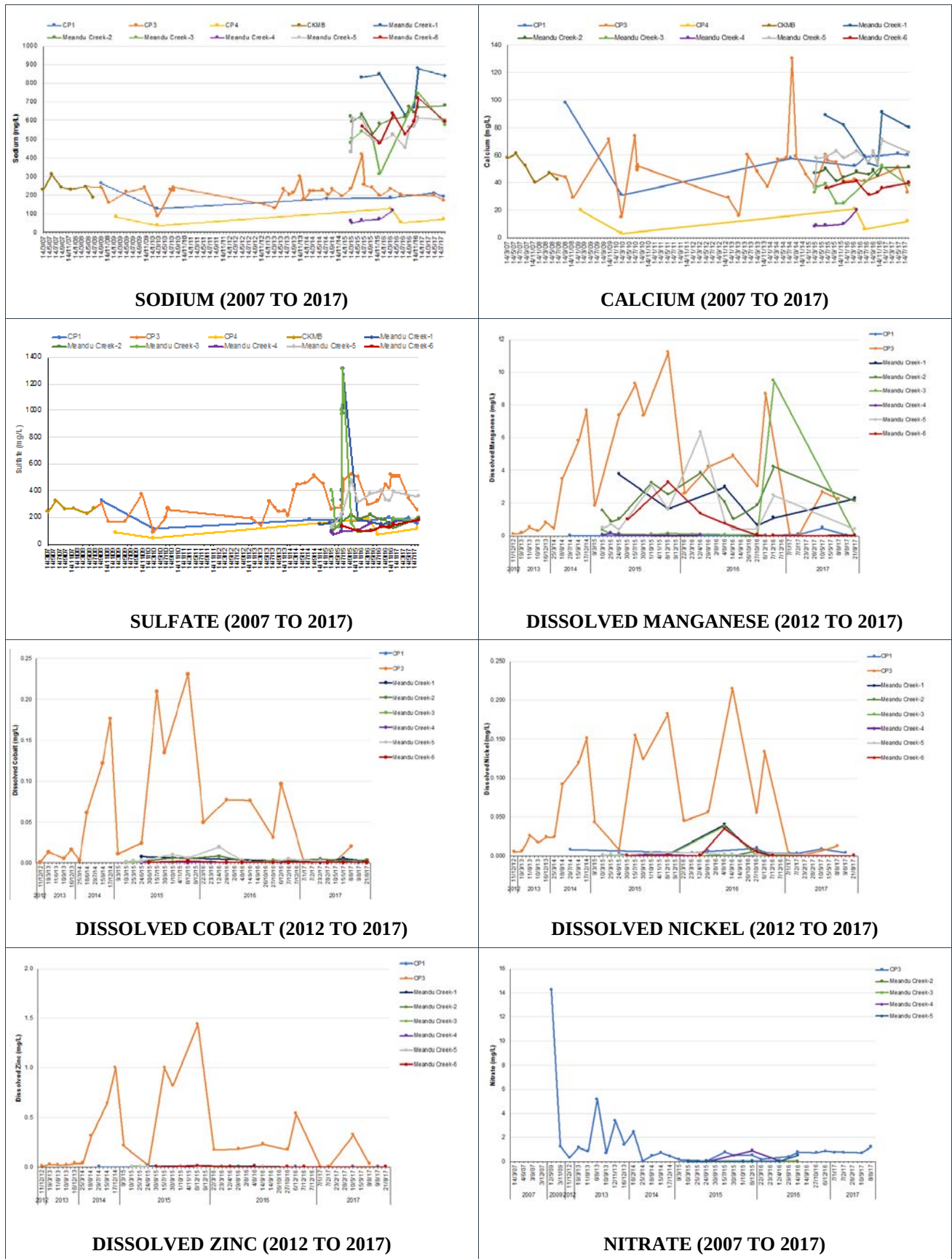
Source: ESP 2018

Figure 7.2 Electrical conductivity and pH in water at sites on Meandu Creek upstream of Meandu Creek Dam (2007 to 2017)

Table 7.2 Summary of historical monitoring results for electrical conductivity, major ions, dissolved metals and nitrate (Meandu Creek upstream of Meandu Creek Dam)

PARAMETER	RESULTS
Electrical conductivity	- Electrical conductivity in sites adjacent to Meandu Mine (including compliance sites) was generally high, when compared with the levels at historical comparative sites CKME and CKMF (draining forestry areas upstream of the mine). - Levels are highly variable over time, likely in response to rainfall and runoff as well as operation of the mine. - Levels were relatively high (up to 5,000 $\mu\text{S}/\text{cm}$) in the 1980s and 1990s, when a number of sites were monitored. More recent monitoring at different sites in Meandu Creek adjacent to Meandu Mine has shown similar results, with electrical conductivity levels of up to 6,000 $\mu\text{S}/\text{cm}$, and a general trend of increasing EC at these sites between 2014 and 2017 (Figure 7.2). - Levels at the compliance sites are generally lower than those at the sites in Meandu Creek adjacent to the mine, and only occasionally exceed 3,000 $\mu\text{S}/\text{cm}$. High electrical conductivity levels at CP1 (in Meandu Creek Dam) in 2007 and 2008 were likely related to the drought conditions experienced at this time, with levels decreasing after drought-breaking rain in the second half of 2008 (EMPS 2013). - Levels have been increasing at site CP1 since early 2013, noting that rainfall has been below average during this period. Given this site is within Meandu Creek Dam, electrical conductivity will also be influenced by cooling water blowdown from the Tarong and Tarong North power stations.

PARAMETER	RESULTS
Major Anions and Cations	- Concentrations of most major anions and cations have varied substantially over time and between sites on Meandu Creek upstream of Meandu Creek Dam. - Concentrations at each site generally showed similar patterns over time. Concentrations of ions on Meandu Creek adjacent to Meandu Mine and at the compliance sites during historical monitoring were higher than those recorded upstream of the mine (e.g. historical monitoring sites CKME and CKMF). - General trend of increasing ion concentrations at site CKMB (Meandu Creek adjacent to the mine) through the 1990s and 2000s, when this site was consistently monitored. - Concentrations of ions in Meandu Creek adjacent to the mine measured more recently (since 2015) have generally been within the range recorded during historical monitoring.
Sulfate	- Concentrations on Meandu Creek adjacent to Meandu Mine and at the compliance sites were higher than those recorded upstream of the mine (e.g. historical monitoring sites CKME and CKMF). - General trend of increasing concentrations at site CKMB (Meandu Creek adjacent to the mine) through the 1990s and 2000s, when the site was consistently monitored. - There has also been a general trend of increasing sulfate concentrations at compliance points CP3 and CP4 in the past 10 years, although this trend was not observed at site CP1 in Meandu Creek Dam.
Metals and metalloids	- Since routine monitoring commenced in 2012, the concentrations of most metals have been low (e.g. below the WQO – although not directly applicable) at sites on Meandu Creek upstream of Meandu Creek Dam (including compliance sites). - Concentrations of some dissolved metals (including aluminium, iron and copper) peaked at some sites in 2015, this trend did not continue in 2016 and 2017.
Dissolved manganese	- Historically, concentration has varied among sites on Meandu Creek upstream of Meandu Creek Dam. - Concentration exceeded the WQO of 1.9 mg/L (although not directly applicable) at several sites on Meandu Creek adjacent to the mine and at site CP3 between 2014 and 2017 (Figure 7.3). - Concentrations often highest at compliance point CP3; however, concentrations of dissolved manganese at site CP1 on Meandu Creek Dam were much lower than those recorded at CP3, and were below the WQO.
Dissolved cobalt, nickel and zinc	- Concentrations were much higher at site CP3 than all other sites, including site CP1 on Meandu Creek Dam, and were variable over time (Figure 7.3). - However, concentrations at site CP3 were mostly below the WQOs (modified for hardness as required) (although not directly applicable).
Nitrate	- Only routinely monitored at five sites on Meandu Creek upstream of Meandu Creek Dam. - Concentrations were consistently high at sites CP3 and Meandu Creek 4 from 2007 to 2017; particularly at site CP3 from 2009 to early 2014 (Figure 7.3). - Median concentration of oxides of nitrogen from 2013 to 2017 exceeded the WQO (0.015 mg/L) (although not directly applicable), primarily due to the high levels of nitrate at these sites (concentrations of nitrite were generally below LOR). - Concentrations of nitrate were low at other sites on Meandu Creek upstream of the dam (i.e. Meandu Creek 2, 3 and 5); however, few data points are available for these sites (<10 data points available for each site). - Nitrate was not monitored at site CP1 in Meandu Creek Dam.



Source: ESP 2018

Figure 7.3 Electrical conductivity, major ions, dissolved metals and nitrate (Historical monitoring results)

7.1.2 MEANDU CREEK DAM

7.1.2.1 MONITORING SITES

Surface water quality monitoring has been undertaken by operators of the Tarong and Tarong North power stations (i.e. Stanwell and previously Tarong Energy) at the Meandu Creek Dam release point (site W3) since 1985. Water quality is monitored regularly in accordance with the Meandu Creek Monitoring Protocol, which has recently been updated to the Meandu Creek Receiving Environment Monitoring Program (ESP 2018). The location of W3 is shown on Figure 7.4. Summary statistics were calculated for all available data for W3, as well as for the past 4 years only (2013–2017) (i.e. since elevated electrical conductivity levels at CP3 were noted and additional sampling undertaken).

Data for key parameters (i.e. those that are relevant to AMD such as pH, electrical conductivity, the concentrations of ions (e.g. sulfate) and the concentrations of dissolved metals)) were also graphed for interpretation of trends over time.

A one-off survey of water quality at five sites in Meandu Creek Dam (near the centre of the dam and in the vicinity of the dam wall) was completed in December 2016 (ESP 2016). Samples were collected from within 0.5–1.0 m of the bottom of the dam (i.e. the samples were representative of bottom waters). These results were compared with the historical water quality results.

7.1.2.2 MONITORING RESULTS

The following trends were noted for the Meandu Dam release point (W3) when the past 4 years of data (2014 to 2017) were compared with the entire dataset:

- Similar median electrical conductivity levels and ion concentrations between the two time periods, but a reduction in maximum electrical conductivity levels and the maximum concentration of major ions
- An increase in the median concentration of nitrate
- A reduction in the concentrations of dissolved arsenic, boron and molybdenum
- A slight increase in the concentrations of cobalt and nickel; as well as an apparent increase in the concentrations of selenium and vanadium, although this was influenced by an increase in the laboratory LOR in recent years.

While not directly applicable to the waters of Meandu Creek Dam, the summary statistics were mostly within the WQOs (applicable to the Meandu Creek downstream of Meandu Creek Dam), with exceptions of electrical conductivity, turbidity, nitrate, dissolved metals (aluminium, arsenic and iron).

Electrical conductivity levels in Meandu Creek Dam are related to rainfall and dilution, with higher electrical conductivity during low rainfall periods / drought and lower electrical conductivity during and after significant wet seasons (JBT Consulting 2017). For example, electrical conductivity was higher than the WQO during the 2007/2008 drought period and lower during the 2010/2011 and 2012/2013 floods. High turbidity is also linked with high rainfall (and subsequent runoff of sediment-laden water to the dam).

The results of the one-off December 2016 survey (which involved sampling of bottom waters in Meandu Creek Dam) were within the range of water quality values recorded during the historical monitoring. While not directly applicable to the waters of the dam, all results were within the relevant WQOs. Electrical conductivity was relatively high in December 2016, and similar to the 95th percentile value for the past 4 years (2014–2017). This was related to the low dam levels at the time of survey, due to a lack of recent rainfall and inflows to the dam (ESP 2016).

7.1.3 DOWNSTREAM OF MEANDU CREEK DAM

7.1.3.1 MONITORING SITES

In addition to the Meandu Creek Dam release point (site W3), surface water quality monitoring has also been undertaken by operators of the Tarong and Tarong North power stations (i.e. Stanwell / Tarong Energy) at sites W2 (5 km downstream of Meandu Creek dam) since 1984 and SW16 (20 km downstream of Meandu Creek Dam) since 1998. The locations of these sites are shown on Figure 7.4.

The results for Meandu Creek downstream of Meandu Creek Dam (sites W2 and SW16) were compared with the relevant WQOs for the receiving environment, as outlined in Table 6.2.

7.1.3.2 MONITORING RESULTS

The summary statistics for site W2 and SW16 mostly complied with the WQOs, including all median values; except for median concentrations of nitrate, which exceeded the WQO for oxides of nitrogen. In some cases, the 95th percentile value exceeded the WQO, as described below:

- Electrical conductivity at both W2 and SW16 for the entire monitoring period, and at site SW16 in the past 4 years.
- Turbidity during the entire monitoring period. High turbidity is linked with high rainfall (and subsequent runoff of sediment-laden water to the dam).
- pH during the entire monitoring period at site SW16 (but not in the last 4 years)
- Dissolved aluminium during the entire monitoring period (but not the past four years), due to occasional spikes in dissolved aluminium concentrations. Median concentrations were below the WQO.
- Dissolved arsenic and iron during the entire monitoring period (but not the past four years, due to a trend of decreasing concentrations). Median concentrations were below the WQO.

As site SW16 is located 20 km downstream of Meandu Creek Dam, surrounding land uses as well as releases from Meandu Creek Dam influence water quality at this location.

Water quality downstream of Meandu Creek Dam is monitored regularly in accordance with the Meandu Creek Monitoring Protocol (recently updated to the Meandu Creek Receiving Environment Monitoring Program), with detailed assessments of the data occurring every three years. The most recent three-yearly assessment concluded that concentrations of some parameters (notably electrical conductivity / major ions and arsenic, chromium and copper) are higher in Meandu Creek downstream of Meandu Creek Dam compared to concentrations in the waterways of the region (ESP 2017). This is related to the higher concentrations of these parameters in the cooling water blowdown (related to operation of the Tarong and Tarong North power stations and the presence of copper chrome arsenate (CCA)-treated timber in the stations) that is usually discharged to Meandu Creek Dam, and subsequently to the receiving environment (ESP 2017). However, concentrations in Meandu Creek downstream of Meandu Creek Dam were below the relevant WQOs, and other land uses in the receiving environment also influence water quality.

7.2 MARCH 2017 SURVEY

A field survey was completed from 23 to 29 March 2017. Weather conditions were mostly fine for the duration of the survey apart from some light showers immediately prior to and at the beginning of the field survey (8 mm of rainfall was recorded at BoM station 40199 from 22 to 25 March).

7.2.1 SURVEY SITES

Surveys were completed at 33 sites distributed throughout the region, including potentially impacted sites as well as comparative (control) sites. The location of each site along with the indicators surveyed is described in Table 7.3 with sites identified on Figure 7.4.

Table 7.3 *Survey sites and indicators surveyed at each site (March 2017)*

LOCATION	SITE	INDICATORS SURVEYED					
		WATER QUALITY	SEDIMENT QUALITY	HABITAT ASSESSMENT	MACRO-INVERTEBRATES	AQUATIC PLANTS	FISH
COMPARATIVE SITES							
Barker Creek	C1	Y	Y	Y	Y	Y	Y
Barker Creek	C1B	Y	Y	Y	Y	Y	Y
Barker Creek	C2/SW19	–	Y	Y	–	–	–
Barker Creek	C3	–	Y	Y	–	–	–
Barambah Creek	SW36	Y	Y	Y	Y	Y	Y
MEANDU CREEK UPSTREAM OF MEANDU MINE							
Meandu Creek	MCUS1	–	Y	Y	–	–	–
Meandu Creek	MCUS2	–	Y	Y	–	–	–
MEANDU CREEK UPSTREAM OF MEANDU CREEK DAM (ADJACENT TO MEANDU MINE)							
Meandu Creek Diverted Reach	MCA1/MC6	Y	Y	Y	Y	Y	Y
Meandu Creek Diverted Reach	MCA2/MC1	Y	Y	Y	Y	Y	Y
Meandu Creek Diverted Reach	MCA3/MC5	Y	Y	Y	Y	Y	Y
Meandu Creek Diverted Reach	CM2	Y	Y	Y	Y	N	N
BLACK CREEK SITES							
Black Creek	BC1	Y	Y	Y	N	N	N
Black Creek	BC2	Y	Y	Y	N	N	N
MEANDU CREEK DAM SITES							
Meandu Creek Dam	MCDS1	N	Y	Y	N	N	N
Meandu Creek Dam	MCDS2	N	Y	Y	N	N	N
Meandu Creek Dam	MCDS3	N	Y	Y	N	N	N
Meandu Creek Dam	MCDS4	N	Y	Y	N	N	N
Meandu Creek Dam	MCDS5	N	Y	Y	N	N	N
Meandu Creek Dam	MCDS6	N	Y	Y	N	N	N
Meandu Creek Dam	MCDS7	N	Y	Y	N	N	N
Meandu Creek Dam	MCDS8	N	Y	Y	N	N	N
Meandu Creek Dam	MCDS9	N	Y	Y	N	N	N

LOCATION	SITE	INDICATORS SURVEYED					
		WATER QUALITY	SEDIMENT QUALITY	HABITAT ASSESSMENT	MACRO-INVERTEBRATES	AQUATIC PLANTS	FISH
Meandu Creek Dam	MCD1	N	N	Y	Y	N	N
Meandu Creek Dam	MCD2	N	N	Y	Y	N	N
Meandu Creek Dam	SWI1	N	N	Y	Y	N	N
Meandu Creek Dam	SWI2	N	N	Y	Y	N	N
MEANDU CREEK DOWNSTREAM OF MEANDU CREEK DAM							
Meandu Creek Discharge Point	MCDOUT	Y	Y	Y	Y	N	N
Meandu Creek	MC500	Y	Y	Y	Y	Y	Y
Meandu Creek	MC2	Y	Y	Y	Y	N	N
Meandu Creek	MC5/W2	Y	Y	Y	Y	Y	Y
Meandu Creek	MC15	Y	Y	Y	Y	Y	Y
Meandu Creek	MC20/SW16	Y	Y	Y	Y	Y	Y
Meandu Creek	MC25	Y	Y	Y	Y	Y	Y

Notes:

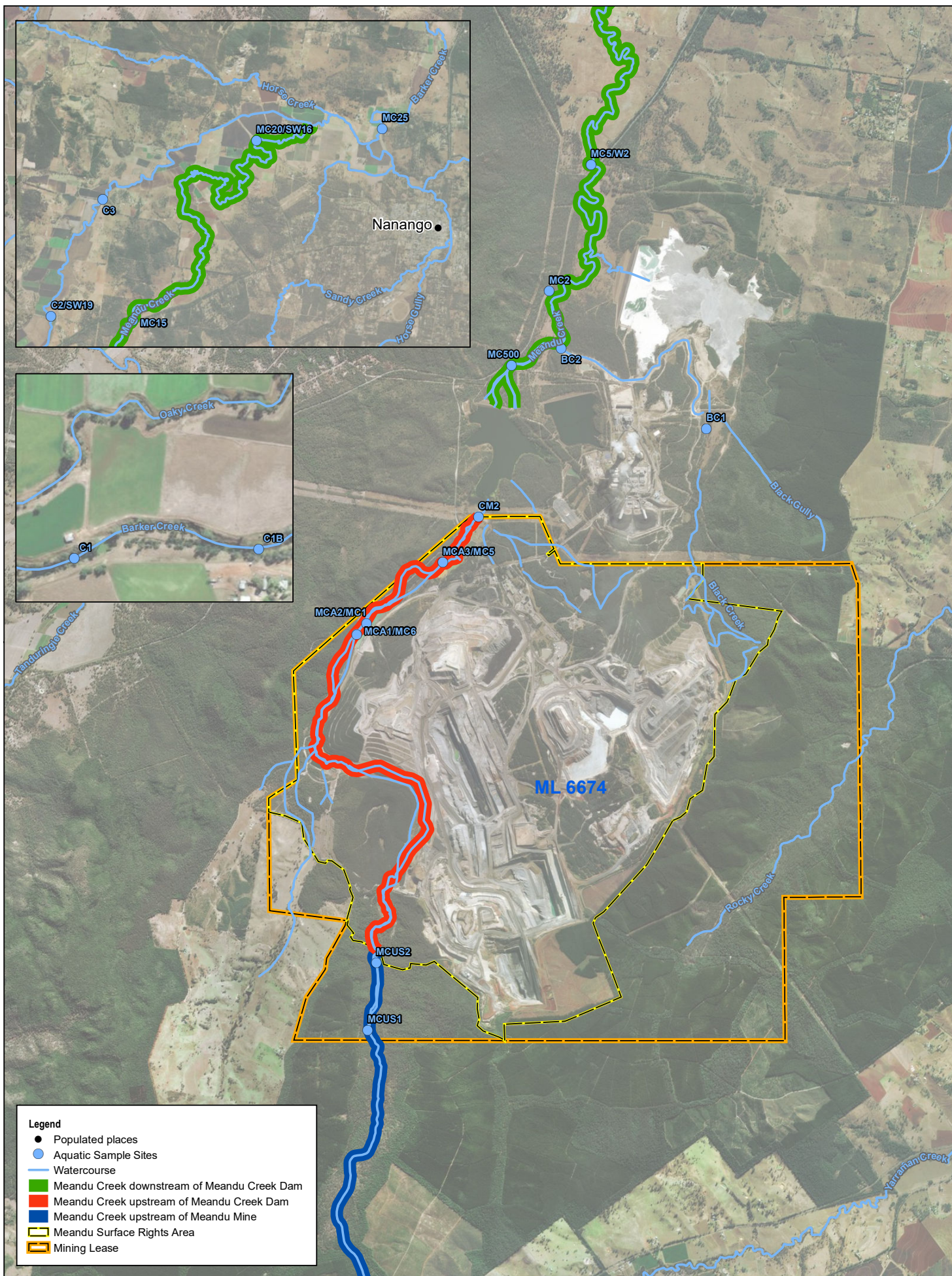
Y: indicates parameter sampled at this site

N: indicates parameter not planned for survey at this site

–: indicates parameter unable to be sampled due to dry site

7.2.1.1 SITES ON MEANDU CREEK UPSTREAM OF MEANDU MINE

Two upstream sites (MCUS1 and MCUS2) on Meandu Creek at varying distances upstream of mining operations were selected based on sites previously sampled as part of the Meandu Creek Monitoring Protocol (refer Table 7.3 and Figure 7.4). The two selected sites were dry during the survey. Due to the characteristics of Meandu Creek upstream of mining operations (i.e. dry) the upstream sites provided little context for the results of surveys within other reaches of Meandu Creek. Additionally, due to the varying characteristics between the sections of Meandu Creek (i.e. the ‘intermittent’ section upstream of Meandu Creek Dam versus the ‘perennial’ section downstream of Meandu Creek Dam), it was necessary to include a variety of comparative sites to allow an assessment of the results at potentially impacted sites in the context of conditions at sites within the region that are not influenced by water released from the Meandu Mine or Tarong and Tarong North power stations.



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Figure 7.4 Meandu Creek survey sites (March 2017)
Source: ESP 2018

7.2.1.2 COMPARATIVE SITES

Five comparative sites were surveyed (C1; C1B; C2/SW19; C3 and SW36). Three of these were selected based on sites previously sampled on Barker Creek as part of the Meandu Creek Monitoring Protocol (C1, C2/SW19 and C3). While Barker Creek is a similar stream order to Meandu Creek, it is an intermittent creek generally characterised by disconnected pools with a substantial number of dry reaches. It was identified that these sites were suitable for comparison with the results from the intermittent reaches of Meandu Creek upstream of Meandu Creek Dam. However, two of the three sites were dry at the time of the survey and could not be used for full aquatic surveys. As a result, a fourth additional site on Barker Creek nearby to (but disconnected from) an already established site (site C1) was also added (site C1B) to provide additional comparative data (refer Table 7.3 and Figure 7.4).

A fifth comparative site was also adopted (site SW36) (refer Table 7.3 and Figure 7.4). Although technically downstream of Meandu Mine, site SW36 on Barambah Creek (downstream of Bjelke-Petersen Dam) was considered a good option for a comparative site for the receiving environment sites in Meandu Creek (i.e. sites downstream of the Meandu Creek Dam), based on shared habitat characteristics (i.e. site SW36 is located on a perennial waterway downstream of a dam, with a similar flow regime and aquatic habitat). It is located approximately 100 km downstream of the Meandu Creek Dam discharge point, and has been considered a comparative site in previous aquatic environmental studies for the Tarong and Tarong North power stations (EMPS 2013).

7.2.1.3 SITES ON MEANDU CREEK UPSTREAM OF MEANDU CREEK DAM (ADJACENT TO MEANDU MINE)

Four sites on Meandu Creek upstream of Meandu Creek Dam and adjacent to Meandu Mine were selected based on sites currently monitored as part of the standard monitoring protocol (MCA1/MC6; MCA2/MC1; MCA3/MC5 and CM2) (refer Table 7.1 and Figure 7.1). This section of the creek is characteristic of a typical intermittent waterway with several disjointed, non-flowing pools along the channel. The selected sites included both natural sections of the creek and diverted sections of the creek, where there are semi-permanent pools of water that are periodically pumped out, currently into RD7 (and in the future to RD27), for water management.

7.2.1.4 BLACK CREEK SITES

Two sites on Black Creek were included in the survey (BC1 and BC2), to gain an understanding of the current water and sediment quality conditions of Black Creek, and to identify any additional influences that may be impacting the aquatic ecosystems in the Meandu Creek receiving environment. Sites were selected on Black Creek at Black Creek Dam, and at the most downstream section of Black Creek before the confluence with Meandu Creek (refer Table 7.3 and Figure 7.4).

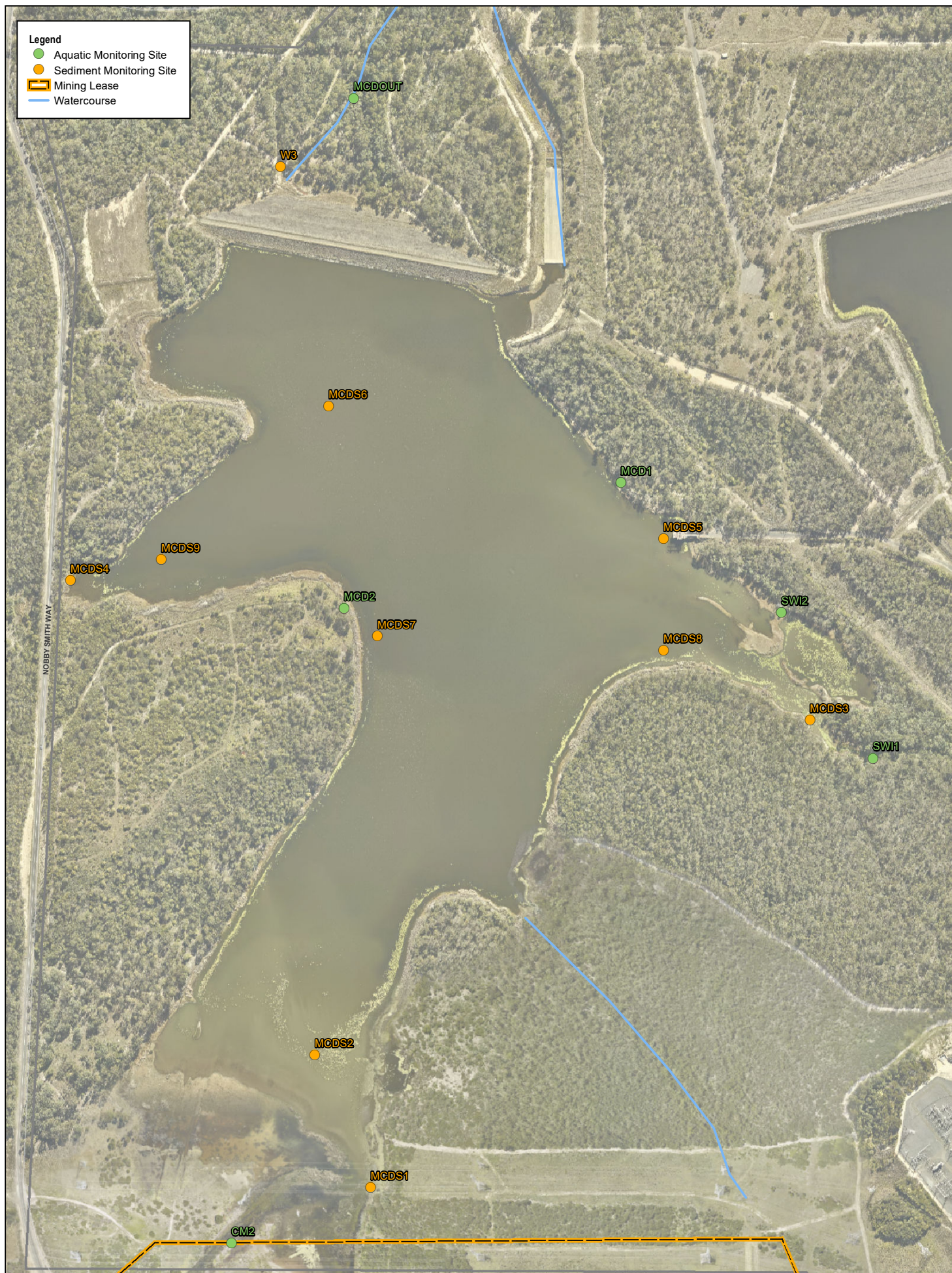
7.2.1.5 MEANDU CREEK DAM SITES

Thirteen sites on Meandu Creek Dam were surveyed (refer Table 7.3 and Figure 7.5). These sites are established monitoring sites under the Meandu Creek Receiving Environment Monitoring Program (ESP 2018), and are located at various points around the dam that capture runoff from various sources including Meandu Mine and the power stations.

7.2.1.6 MEANDU CREEK DOWNSTREAM OF MEANDU CREEK DAM (RECEIVING ENVIRONMENT SITES)

Seven receiving environment sites on Meandu Creek and Barker Creek (downstream of the confluence with Meandu Creek) were selected based on sites previously sampled as part of the Meandu Creek Monitoring Protocol (MCDOUT; MC500; MC2; MC5/W2; MC15; MC20/SW16 and MC25). The seven selected sites ranged in distance from 500 m downstream of the Meandu Creek Dam discharge location (W3), to 25 km downstream. Sites were closer together nearer to the discharge location, to assist in determining the spatial extent of any impacts associated with releases from the dam (refer Table 7.3 and Figure 7.4).

As a result of releases from Meandu Creek Dam, the receiving environment experiences long periods of continual flow, making it more characteristic of a perennial waterway as opposed to an ephemeral or intermittent waterway (which is typical in the region).



7.2.2 INDICATORS SURVEYED

The following indicators were selected as potential indicators of AMD impacts to aquatic ecosystems:

- water quality
- sediment quality
- aquatic habitat
- aquatic plants
- macroinvertebrate communities
- fish.

Not all indicators were surveyed at each site, depending on the aquatic habitat present and available data from other studies (e.g. routine water quality monitoring completed under the Meandu Creek Monitoring Protocol, and fish surveys completed in Meandu Creek Dam in December 2016 and December 2017). The indicators surveyed at each site are shown in Table 7.3.

Details of the survey methodology used on site for each of these indicators is outlined in Section 2 of Appendix G.

7.2.3 WATER QUALITY RESULTS

The parameters assessed during the March 2017 field survey were assigned to one of four categories based on recorded concentrations. The categories were:

- Recorded concentrations were below or equal to the laboratory LORs in all samples. Parameters falling into this category were:
 - dissolved aluminium and cadmium
 - total and dissolved chromium, copper, lead, mercury, selenium and vanadium.
- Recorded concentrations were below the applicable WQOs at all sites, and / or did not differ consistently between sites and locations. Parameters falling into this category were:
 - pH
 - dissolved oxygen
 - turbidity
 - calcium
 - total nitrogen and total phosphorus
 - total and dissolved cobalt and zinc.
- Recorded concentrations were high at one or more site/s upstream of Meandu Creek Dam, and/or on Black Creek, and higher downstream of Meandu Creek Dam compared to comparative sites. However, the concentrations of these parameters in Meandu Creek downstream of Meandu Creek Dam were not above the relevant WQOs assigned to protect environmental values. Parameters within this category include:
 - total and dissolved arsenic and boron
 - sulfate.
- Recorded concentrations were high at one or more site/s upstream of Meandu Creek Dam, and/or on Black Creek and higher at sites downstream of Meandu Creek Dam compared to comparative sites. The concentrations of some of these parameters were also above the relevant WQOs at one or more sites (where applicable). Parameters in this category are discussed in further detail in the following section and included:
 - electrical conductivity
 - total dissolved solids
 - total hardness

- major ions – chloride, sodium, magnesium and potassium (note: while no WQO available, the concentrations were high at sites on Meandu Creek upstream of Meandu Creek Dam and concentrations at all sites on Meandu Creek downstream of Meandu Creek Dam were higher than the range at comparative sites).
- nitrate and nitrite
- total aluminium and iron
- total and dissolved manganese and nickel.

7.2.3.1 ELECTRICAL CONDUCTIVITY, MAJOR IONS AND NITRATE/NITRITE

ELECTRICAL CONDUCTIVITY

Electrical conductivity was high at BC1 (on Black Creek) and at all sites upstream of Meandu Creek Dam adjacent to the mine (excluding CM2 – near Meandu Creek Dam inlet) and exceeded the WQO of 2,037 $\mu\text{S}/\text{cm}$, noting that this WQO does not apply to sites on Meandu Creek and Black Creek and upstream of Meandu Creek Dam (for which the designated EV is industrial use). This is consistent with the results of historical surveys, which indicated that electrical conductivity was generally high at sites adjacent to Meandu Mine, but lower at the inflow to Meandu Creek Dam (e.g. Meandu Mine compliance site CP3).

Recorded electrical conductivity at sites downstream of Meandu Creek Dam were below the WQO of 2,037 $\mu\text{S}/\text{cm}$ ranging between 1,589 $\mu\text{S}/\text{cm}$ and 1,628 $\mu\text{S}/\text{cm}$ and at all comparative sites ranging between 892 $\mu\text{S}/\text{cm}$ and 987 $\mu\text{S}/\text{cm}$ (Figure 7.6).

TOTAL DISSOLVED SOLIDS

The concentration of total dissolved solids was high at most sites on Meandu Creek upstream of Meandu Creek Dam (except site CM2) and Black Creek site BC1. Although it exceeded the WQO at these sites, it should be noted that this WQO does not strictly apply to sites within these reaches (for which the designated EV is industrial use). Concentrations of total dissolved solids in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) were within the upper range (e.g. 80th percentile) of concentrations recorded during historical monitoring.

The concentration of total dissolved solids at sites on Meandu Creek downstream of Meandu Creek Dam and comparative sites were below the WQO. However, the concentration of total dissolved solids at sites downstream of Meandu Creek Dam ranged between 1,210 mg/L and 1,260 mg/L, which was higher than the range at comparative sites (between 708 mg/L and 801 mg/L) (refer Figure 7.6). Concentrations in sites downstream of Meandu Creek Dam were consistent with the upper range (80th percentile) concentrations recorded during historical surveys.

Similar to electrical conductivity, total dissolved solids are a measure of ions in water, but include inorganic and organic compounds. There is no WQO for the protection of aquatic ecosystems, as electrical conductivity is used as a more appropriate measure for aquatic animals (Volume 4 of ANZECC & ARMCANZ 2000); the WQO used in this case applies to agricultural use (specifically livestock drinking water). Given the concentrations in Meandu Creek downstream of Meandu Creek Dam are below the WQO, it is unlikely that the concentrations of total dissolved solids are at a level that would cause acute or chronic effects to livestock exposed to the water.

TOTAL HARDNESS

Total hardness was high at all sites across all locations (including comparative sites), indicating that water hardness is naturally high in the study area. Concentrations were highest at Black Creek (BC1) followed by sites on Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine). Overall, total hardness was higher at sites on Meandu Creek than at comparative sites (refer Figure 7.6).

Hardness is a measure of the dissolved calcium and/or magnesium salts in water and is used as a measure of the corrosion potential of waters on metal surfaces. As this relates predominantly to agricultural uses of water, there is no WQO for the protection of aquatic ecosystems. Soft water tends to be more corrosive than hard water, and it is recommended that waters are above 60 mg/L for farm use (Volume 4 of ANZECC & ARMCANZ 2000). Furthermore, the uptake and toxicity of several metals in freshwater animals is significantly reduced with higher water hardness (Volume 2 of ANZECC and ARMCANZ 2000). In this regard, the high water hardness in the study area is likely to have a protective

effect on the aquatic ecosystem, and reduces the risk of impacts to the aquatic ecosystem from high concentrations of some metals.

CHLORIDE

There is no applicable WQO for chloride. Concentrations of chloride were highest at Black Creek (BC1 - 1,460 mg/L). The concentration of chloride in Meandu Creek ranged between 405 mg/L and 493 mg/L, which was higher than the range at comparative sites (between 260 mg/L and 315 mg/L) (refer Figure 7.6). Concentrations of chloride in March 2017 were similar to the long-term medians recorded in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) and downstream of Meandu Creek Dam.

SODIUM

There is no applicable WQO for sodium. Concentrations of sodium were highest at Black Creek (BC1 - 834 mg/L), and high at most sites on Meandu Creek upstream of Meandu Creek Dam (consistent with the 80th percentile value from long-term monitoring of Meandu Creek adjacent to the mine). The concentration of sodium in Meandu Creek downstream of Meandu Creek Dam ranged between 225 mg/L and 234 mg/L, which was higher than the range at comparative sites (between 88 mg/L and 111 mg/L) (refer Figure 7.6) but within the upper range (80th percentile) of historical results for the receiving environment.

MAGNESIUM

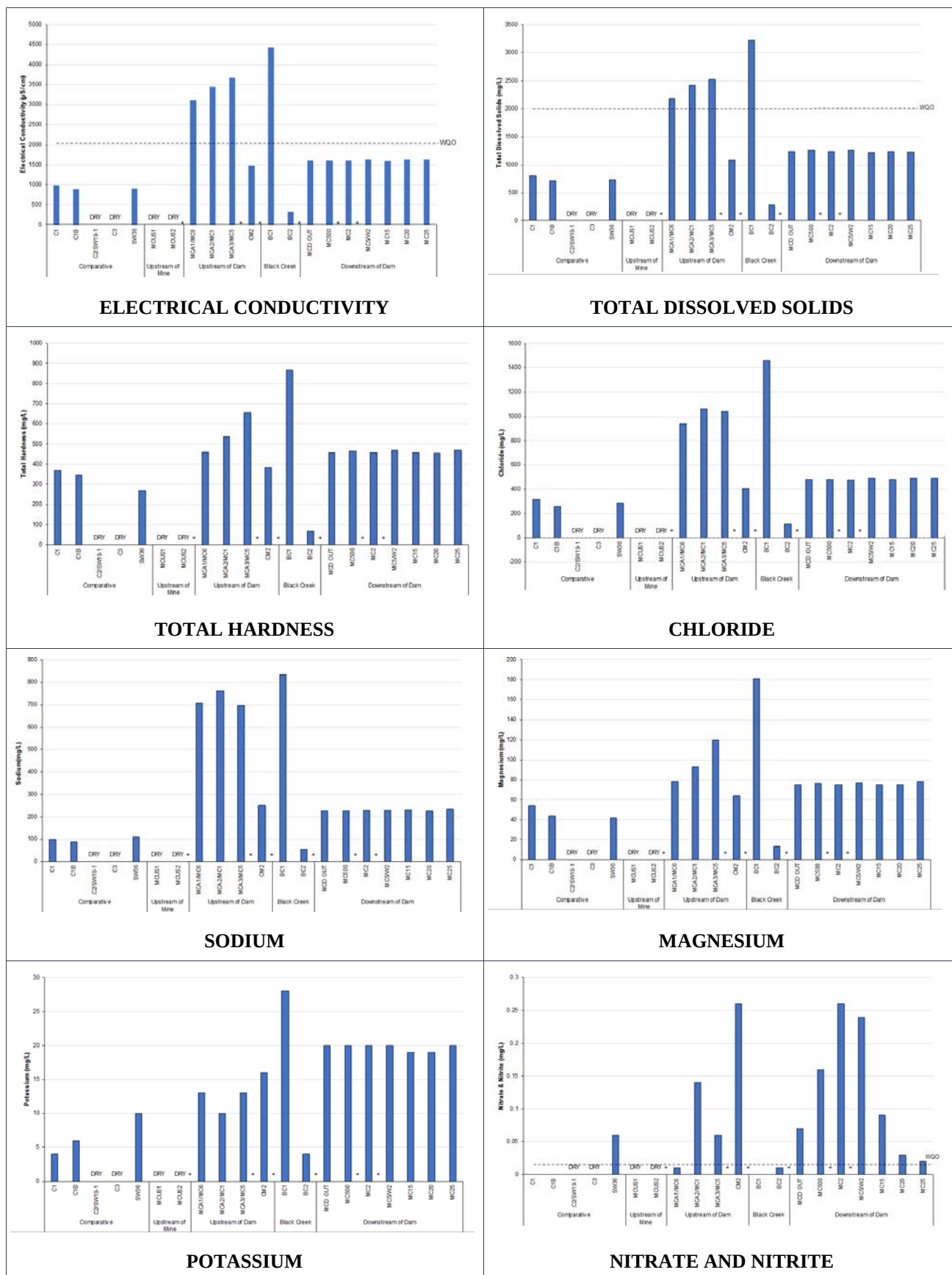
There is no applicable WQO for magnesium. Concentrations of magnesium were highest at Black Creek (BC1 - 181 mg/L). The concentration of magnesium in Meandu Creek ranged between 75 mg/L and 120 mg/L, which was higher than the range at comparative sites (between 42 mg/L and 54 mg/L) (refer Figure 7.6). Concentrations in March 2017 were similar to the upper range of values (80th percentile) recorded historically for Meandu Creek upstream and downstream of Meandu Creek Dam.

POTASSIUM

There is no WQO for potassium. Concentrations were highest at Black Creek (BC1 - 28 mg/L), and in Meandu Creek downstream of Meandu Creek Dam. Concentrations in Meandu Creek ranged between 10 mg/L and 20 mg/L and were above the range at comparative sites (between 4 mg/L and 10 mg/L) (refer Figure 7.6). Concentrations of potassium in Meandu Creek upstream and downstream of Meandu Creek Dam were consistent with the long-term median or 80th percentile values recorded during historical monitoring.

NITRATE AND NITRITE

The concentrations of nitrate and nitrite (oxides of nitrogen) ranged between 0.01 mg/L and 0.26 mg/L and were above the WQO at most sites where they were detected, including comparative site SW36 (noting that this WQO does not directly apply to Meandu Creek upstream of Meandu Creek Dam and on Black Creek, and is to be used as a guide only) (refer Figure 7.6). The concentration of oxides of nitrogen was also below the LOR at the Barker Creek comparative sites. Concentrations at sites on Meandu Creek within the first 20 km downstream of the Meandu Creek Dam outlet up to site MC20 were above the concentration at comparative site SW36 (0.06 mg/L). As concentrations increased with distance downstream of the Meandu Creek Dam outlet (MCDOUT), it is likely that there are catchment sources of nitrate and nitrite influencing concentrations in Meandu Creek.



Source: ESP 2018

Figure 7.6 Electrical conductivity, major ions and nitrate/nitrite results (March 2017 survey)

7.2.3.2 METALS AND METALLOIDS

ALUMINIUM

The concentration of total aluminium was high at site CM2 on Meandu Creek upstream of Meandu Creek Dam and BC2 on Black Creek compared to other sites (refer Figure 7.7). Overall, the concentrations at sites downstream of Meandu Creek Dam ranged between 50 µg/L and 340 µg/L and most were within or below the range of comparative sites (between 90 µg/L and 190 µg/L), except at site MC15 where the concentration was highest.

Aluminium is common naturally occurring element (ANZECC & ARMCANZ 2000). The relatively high concentrations at comparative sites indicate that total aluminium concentrations are likely to be naturally high in the study area. The high concentration at MC15 is also likely to be from a localised source; given that this was an isolated spike in the results, and concentrations at sites upstream and downstream of MC15 were within the range of the comparative sites.

The concentration of dissolved aluminium at all sites was below the LOR and WQO (i.e. the bioavailable concentrations of aluminium were negligible) at all sites.

IRON

The concentration of total iron was high at both comparative sites on Barker Creek (C1 and C1B), at all sites on Meandu Creek upstream of Meandu Creek Dam (except at site MCA1/MC6), both sites on Black Creek, and at two sites on Meandu Creek downstream of Meandu Creek Dam (MC5/W2 and MC15). Overall, the concentrations of total iron ranged between 150 µg/L and 1480 µg/L at sites on Meandu Creek upstream of Meandu Creek Dam and ranged between 90 µg/L and 430 µg/L at sites downstream of the dam.

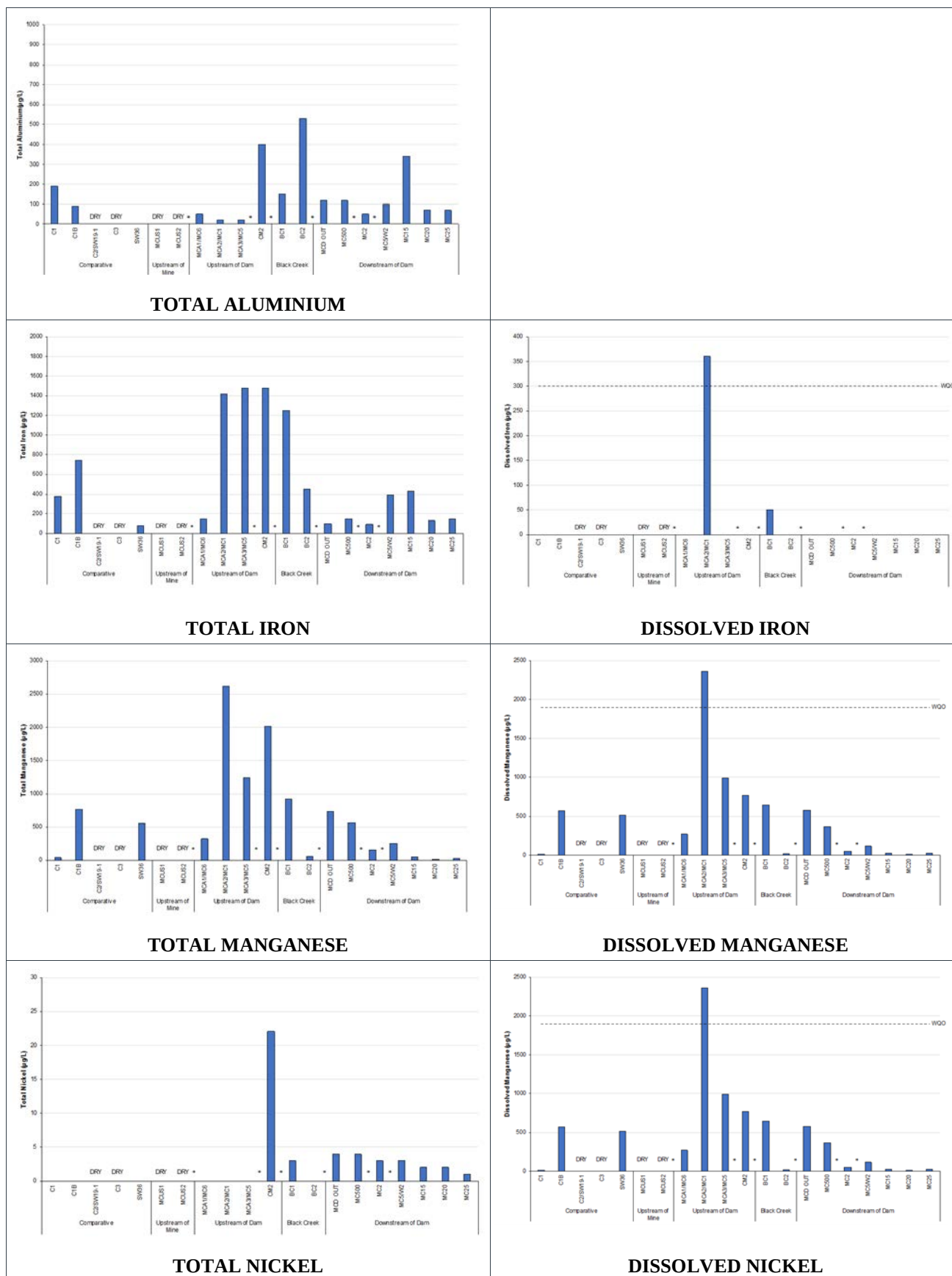
The concentrations at sites on Meandu Creek upstream of Meandu Creek Dam (excluding MCA1/MC6) and Black Creek site BC1 were above the range at the comparative sites (between 80 µg/L and 740 µg/L), and the concentrations at sites on Meandu Creek downstream of Meandu Creek Dam were within or below the range of comparative sites (refer Figure 7.7).

The concentrations of dissolved iron were below the LOR at all sites except at site MCA2/MC1 on Meandu Creek upstream of Meandu Creek Dam, where it was higher than the WQO at 360 µg/L; and at Black Creek site BC1 where it was detected but below the WQO at 50 µg/L (noting that this WQO is to be used as a guide only, and is not directly applicable to the reaches of Meandu Creek and Black Creek upstream of Meandu Creek Dam, for which the designated EV is industrial use).

MANGANESE

The concentrations of total manganese were high at sites MCA2/MC1 and CM2 on Meandu Creek upstream of Meandu Creek Dam compared to all other sites. The concentrations of total manganese at sites on Meandu Creek upstream of Meandu Creek Dam ranged between 324 µg/L and 2,620 µg/L and ranged between 10 µg/L and 733 µg/L at sites on Meandu Creek downstream of Meandu Creek Dam. The concentrations at sites on Meandu Creek upstream of Meandu Creek Dam (excluding MCA1/MC6) and Black Creek site BC1 were above the range at comparative sites (between 36 µg/L and 749 µg/L) and the concentrations at sites downstream of Meandu Creek Dam were within or below the range of comparative sites (refer Figure 7.7).

The concentrations of dissolved manganese were above the WQO at site MCA2/MC1 on Meandu Creek upstream of Meandu Creek Dam (noting that this WQO is to be used as a guide only, and is not directly applicable to upstream of Meandu Creek Dam) and were below the WQO at all other sites. Similar to total manganese, the concentrations of dissolved manganese at sites on Meandu Creek upstream of Meandu Creek Dam (excluding MCA1/MC6) and Black Creek site BC1 were above the range at comparative sites, and the concentrations at sites on Meandu Creek downstream of Meandu Creek Dam were below the WQO and within or below the range of comparative sites. Concentrations of dissolved manganese at sites on Meandu Creek upstream of Meandu Creek Dam were within the range previously recorded during historical monitoring. Manganese is not routinely monitored in Meandu Creek downstream of Meandu Creek Dam.



Source: ESP 2018

Figure 7.7 Metal and metalloid results (March 2017 survey)

NICKEL

The concentration of total nickel was high at site CM2 on Meandu Creek upstream of Meandu Creek Dam, which is consistent with the high concentrations historically recorded at Meandu Mine compliance site CP3. However, the concentration of dissolved nickel was below the WQO at this site. Total and dissolved nickel was also detected (but below the WQO) at Black Creek site BC1 (although the WQO is for moderately disturbed aquatic ecosystems is not directly applicable to the highly disturbed waters of Black Creek).

Total and dissolved nickel was detected at all sites on Meandu Creek downstream of Meandu Creek Dam but at concentrations below the WQO. The concentrations of total and dissolved nickel were below the LOR at all comparative sites (refer Figure 7.7).

7.2.4 SEDIMENT

During the March 2017 survey, a single sediment sample was collected at all sites from within low-flow stream banks using either a small trowel for sites on creeks or a benthic grab sampler for sites on Meandu Creek Dam. At the April 2018 survey, three replicate single sediment samples were collected from all sites within low-flow stream banks using either a small trowel (for sites on creeks) or a benthic grab sampler operated from a vessel (for sites on Meandu Creek Dam and Bjelke-Peterson Dam).

Data available on sediment quality from previous monitoring and other studies completed on Meandu Creek were also reviewed and summarised.

7.2.4.1 SEDIMENT QUALITY GUIDELINE VALUES

Sediment quality results from both historic and current sampling events were reviewed and compared with the relevant Sediment Quality Guideline Values (SQGVs) outlined in the Revision of the Sediment Quality Guidelines (Simpson et al. 2013). These values are presented in Table 7.4.

Table 7.4 Relevant sediment quality guidelines values for parameters measured during field surveys

PARAMETER	UNIT	SQGV	SQG – HIGH
METALS AND METALLOIDS			
Aluminium	mg/kg	–	–
Arsenic	mg/kg	20	70
Boron	mg/kg	–	–
Cadmium	mg/kg	1.5	10.0
Chromium	mg/kg	80	370
Cobalt	mg/kg	–	–
Copper	mg/kg	65	270
Iron	mg/kg	–	–
Lead	mg/kg	50	220
Manganese	mg/kg	–	–
Mercury	mg/kg	0.15	1.00
Molybdenum	mg/kg	–	–
Nickel	mg/kg	21	52
Selenium	mg/kg	–	–
Vanadium	mg/kg	–	–
Zinc	mg/kg	200	410

– no SQG exists for this parameter

Source: Simpson et al. 2013

7.2.4.2 HISTORICAL SEDIMENT QUALITY

Sediment has historically been sampled at sites within Meandu Creek, with routine monitoring of sediment quality in Meandu Creek Dam commencing in 2014. Sediment sampling is conducted every three years at two sites on Meandu Creek (at the Meandu Creek Dam discharge point into Meandu Creek (W3) and 5 km downstream of the discharge point (W2)) and at nine sites on Meandu Creek Dam, in accordance with the Meandu Creek REMP (ESP 2018) (previously Meandu Creek Monitoring Protocol).

Total copper, chromium, arsenic, mercury, nickel and zinc were recorded in high concentrations in the sediment at sites in Meandu Creek Dam in 2014 (JBT 2014; Footprints 2014). While concentrations of these parameters exceeded the SQGV in Meandu Creek Dam, it should be noted that the SQGV does not necessarily indicate concentrations that are toxic to biota; rather it is a trigger for further investigation of background levels and bioavailability. Concentrations of these metals at sites on Meandu Creek downstream of Meandu Creek Dam did not exceed the SQGV (except for nickel), indicating that there was no impact on sediments in the receiving environment (JBT 2014; Footprints 2014). The concentration of nickel at sites on Meandu Creek upstream of the mine also exceeded the SQGVs, indicating that the background concentrations within the catchment are already high, and that an alternative source of nickel (which may be natural) may exist (JBT 2014; Footprints 2014).

Depth profiles revealed a trend that indicated heavy metals have been/are currently accumulating in the sediments of Meandu Creek Dam (i.e. it is acting as a sink) (Footprints 2014). This trend was evident with arsenic, chromium, copper, mercury and nickel. Under normal operating conditions, the presence of these metals is not of great concern, however it was noted in previous studies that should there be an event that results in the sediments being disturbed, oxidised and subsequently mobilised and released downstream to Meandu Creek, there may be potential impacts to aquatic health of the downstream system (Footprints 2014a).

7.2.4.3 SEDIMENT QUALITY MARCH 2017 AND APRIL 2018 SURVEYS

Parameters were assigned to one of three categories based on concentrations recorded during the March 2017 field survey. The categories were:

- Recorded concentrations were below or equal to the laboratory LORs and SQGVs in all sediment samples. Parameters within this category included boron, cadmium and mercury.
- Recorded concentrations were below the SQGV at all sites, and / or did not differ between sites and locations. Parameters within this category included aluminium, chromium, iron, selenium and vanadium. All of these parameters were considered to be naturally high in the sediment of the study area based on concentrations recorded from the sediments at comparative sites.
- Recorded concentrations were above the SQGV at one or more sites. Parameters within this category included arsenic, copper, lead, nickel and zinc.

Results for metals and metalloids in the April 2018 survey were generally similar to those from the March 2017 survey, with concentrations of arsenic, copper, lead, nickel and zinc above the SQGV at one or more sites. Further discussion on these parameters is provided in the following sections.

ARSENIC

March 2107: The concentration of arsenic was highest, and above the SQGV (but below the SQG-high), at site MC500 (33 mg/kg) on Meandu Creek downstream of Meandu Creek Dam. The concentration of arsenic at sites on Meandu Creek downstream of Meandu Creek Dam (where it was detected) ranged between 6 mg/kg and 33 mg/kg, and was above the concentration at comparative site SW36 (5 mg/kg) (concentrations were below the LOR at all other comparative sites and sites on Meandu Creek upstream of the mine). Arsenic was detected in sediment at sites on Meandu Creek upstream of Meandu Creek Dam, Black Creek sites and in Meandu Creek Dam; concentrations ranged between 5 mg/kg and 10 mg/kg.

April 2018: The 95th percentile concentration of total arsenic was above the SQGV at most sites on Meandu Creek Dam (except MCDS2) and at site MC500 downstream of Meandu Creek Dam (Figure 7.8). The 95th percentile concentrations remained below the SQG-high. The 95th percentile arsenic concentrations were equal to or below the LOR at all comparative sites and sites on Meandu Creek upstream of the mine, and all sites downstream of MC500 (i.e. from 5 km downstream). Arsenic is sparingly soluble in acid and thus total concentrations rather than dilute acid extractable concentrations were compared to guidelines.

COPPER

March 2017: The concentration of copper was highest, and above the SQGV at site MC5/W2 (82 mg/kg) on Meandu Creek downstream of Meandu Creek Dam followed by site MC500 (75 mg/kg) in this same reach; however, concentrations remained below the SQG-high.

Overall, the concentration of copper in sediment at sites on Meandu Creek downstream of Meandu Creek Dam (where it was detected) ranged between 6 mg/kg and 82 mg/kg and was either within or higher than the range at comparative sites or sites on Meandu Creek upstream of the mine (between 6 mg/kg and 33 mg/kg). While copper was detected in sediment at all sites on Meandu Creek upstream of Meandu Creek Dam, Black Creek site BC1 and in Meandu Creek Dam; copper was not detected in the water at any site.

April 2018: the 95th percentile concentration of total copper was above the SQGV (but below the SQG-high) at half of the sites on Meandu Creek Dam (i.e. MCDS4 and MCDS5). It was below the SQGV at all other sites but was slightly higher than the range at comparative sites and sites upstream of the mine at sites MCDOUT and MC500 downstream of Meandu Creek Dam. The 95th percentile concentration of dilute acid extractable copper (considered to be the potential bioavailable concentration) was also above the SQGV at site MCDS4.

LEAD

March 2017: The concentration of lead was highest and above the SQGV at site MCA1/MC6 (55 mg/kg) on Meandu Creek upstream of Meandu Creek Dam, but did not exceed the SQG-high.

Overall, the concentrations of lead at sites on Meandu Creek downstream of Meandu Creek Dam (where it was detected) ranged between 10 mg/kg and 23 mg/kg and were above or equal to the range of comparative and sites on Meandu Creek upstream of the mine (between 8 and 10 mg/kg) (but well below the SQGV). Concentrations of lead at sites on Meandu Creek upstream of Meandu Creek Dam (except at site MCA1/MC6), Black Creek sites and in Meandu Creek Dam ranged between 10 mg/kg and 22 mg/kg and were above or equal to the range of comparative sites and sites on Meandu Creek upstream of the mine. Lead was below the LOR in the water at all sites. Sediment depth profiles completed in Meandu Creek Dam in 2014 indicated that lead concentrations in sediment were increasing over time, although at the time of the survey they were not considered a contaminant of concern because concentrations were below SQGV at all sites surveyed (Footprints 2014a). The source of lead has not been identified.

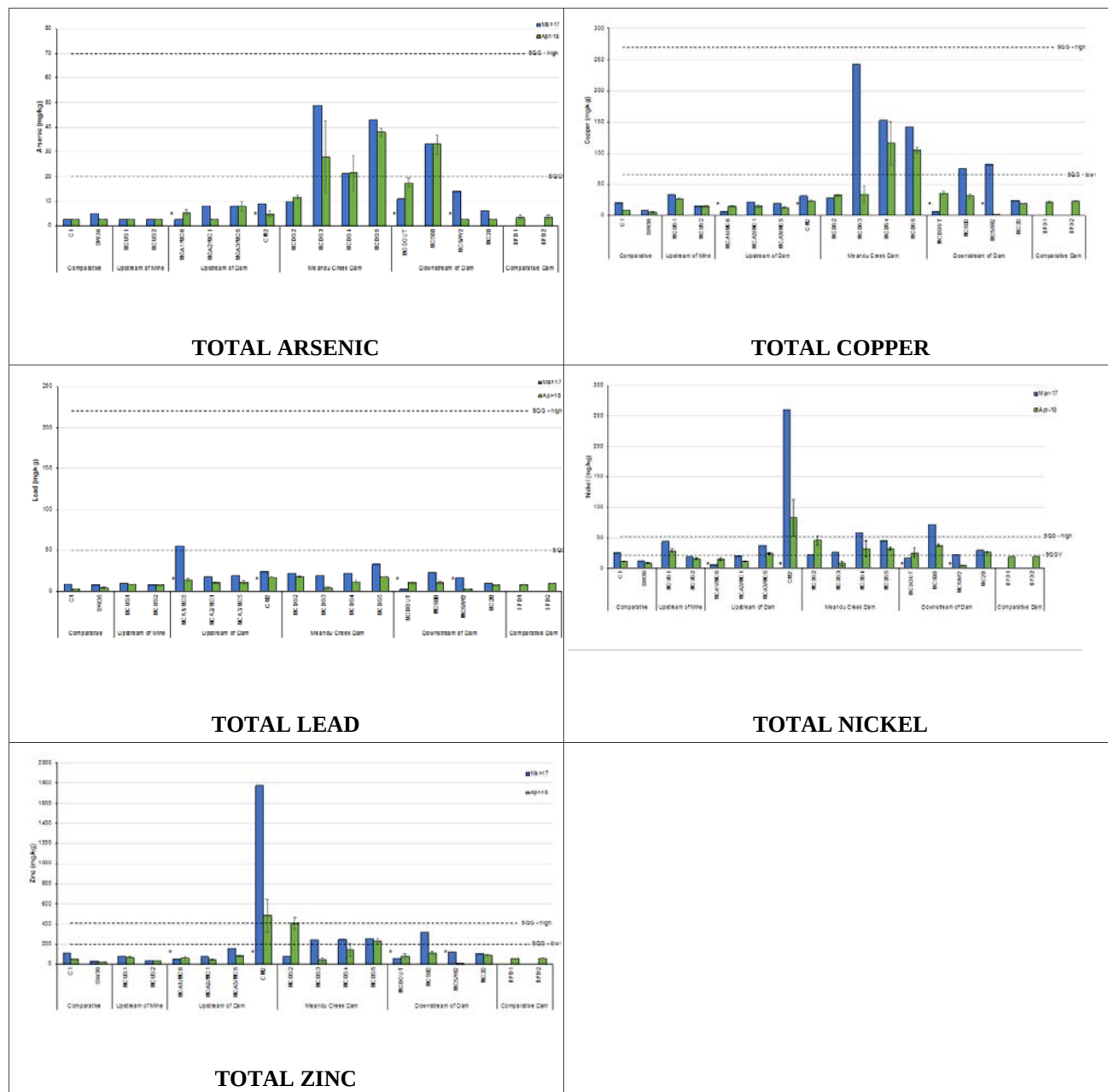
April 2018: The 95th percentile concentration of total lead was slightly higher at most sites upstream of, within, and immediately downstream of Meandu Creek Dam than at comparative sites and sites upstream of the mine. Regardless of these differences, it was below the SQGV at all sites.

NICKEL

March 2017: The concentration of nickel was highest, and above the SQGV at site CM2 (261 mg/kg) on Meandu Creek upstream of Meandu Creek Dam and site MC500 (71 mg/kg) on Meandu Creek downstream of Meandu Creek Dam. Nickel concentrations have historically exceeded the SQGV at a number of locations, with potential sources including local geology, metal leaching from condensers at Tarong Power Station (prior to their replacement with titanium) and mine-affected water as well as cycling of raw water from Boondooma Dam.

April 2018: The 95th percentile concentration of total nickel was highest at site CM2 upstream of Meandu Creek Dam (where it was above the SQG-high). It also exceeded the SQGV at site MCUS1 upstream of the mine, site MCA3/MC5 upstream of Meandu Creek Dam, most sites on Meandu Creek Dam, and sites MCD-OUT, MC500 and MC20/SW16 in Meandu Creek downstream of Meandu Creek Dam. The 95th percentile concentration of dilute acid extractable nickel (considered to be the potential bioavailable concentration) was also above the SQGV at sites CM2 upstream of the dam,

MCDS2 and MCDS4 on Meandu Creek Dam and MC500 in Meandu Creek downstream of Meandu Creek Dam. Regardless of these occasionally high concentrations of nickel, there was molar excess of acid volatile sulfides over simultaneously extracted metals at all sites downstream of the Meandu Creek Dam, within Meandu Creek Dam, and most sites upstream of the dam (except for CM2). Therefore, it is considered that metals were not bioavailable to aquatic organisms at all sites downstream of Meandu Creek Dam, and most other sites except site CM2 (Simpson & Batley 2016).



Source: ESP 2018

Figure 7.8 Total arsenic, copper, lead, nickel and zinc concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018

ZINC

March 2017: The concentration of zinc was highest at site CM2 on Meandu Creek upstream of Meandu Creek Dam (1780 mg/kg, above the SQG-high), and site MC500 on Meandu Creek downstream of Meandu Creek Dam (319 mg/kg, above the SQGV). Zinc was detected at all other sites in concentrations below the SQGV (Figure 7.8). However, for the most part (with the exception of site MC500), concentrations of zinc downstream of Meandu Creek Dam were within the range recorded at the comparative and upstream sites.

April 2018: The 95th percentile concentration of total zinc was highest at site CM2 upstream of Meandu Creek Dam and MCDS2 on Meandu Creek Dam (where it exceeded the SQG-high). It also exceeded the SQGV at sites MCDS4 and MCDS5 on Meandu Creek Dam. The 95th percentile concentration of dilute acid extractable zinc (considered to be the potential bioavailable concentration) was above the SQG-high at site CM2 and the SQGV at sites MCDS2 and MCDS5, but below the SQG at all sites downstream of Meandu Creek Dam. There was also molar excess of acid volatile sulfides compared to simultaneously extracted metals at all sites downstream of Meandu Creek Dam, within Meandu Creek Dam, and most sites upstream of the dam (except for CM2). This indicates that metals are likely to be bound in sulfide complexes and have limited bioavailability to aquatic flora and fauna at all sites except site CM2.

GENERAL SEDIMENT QUALITY TRENDS

MEANDU CREEK UPSTREAM OF MEANDU CREEK DAM

During both the March 2017 and April 2018 surveys, the concentrations of several parameters were much higher at site CM2 on Meandu Creek upstream of Meandu Creek Dam than at all other sites, including cobalt; manganese; molybdenum; nickel and zinc.

Site CM2 is located at the Meandu Mine inlet to Meandu Creek Dam. This site is located on a section of Meandu Creek that is downstream from the mine, and receives discharges from RD7 and RD8. The site was characterised as a narrow pool with substrate dominated by silt. Cumbungi (bulrush) was present and significantly dense along the banks and within the waterway of the site. Cumbungi is known to have significant sediment-trapping abilities by slowing water flow and trapping suspended sediment in their root systems (Stephens & Dowling 2002). It is likely that the presence of Cumbungi at site CM2 is causing a build-up of fine sediments that are potentially impacted by mining activities. The high concentrations of metals in sediment at site CM2 are likely to be a result of the settlement of fine sediments, which adsorb organic and heavy metal contaminants to a high degree (Volume 2, ANZECC & ARMCANZ 2000).

Potential bioavailable concentrations (i.e. acid dilute extractable concentrations) of nickel and zinc exceeded the SQG-high. Sediments at this site did not contain a molar excess of acid volatile sulfides compared to simultaneously extracted metals, therefore these metals may be bioavailable to aquatic organisms at this site (Simpson & Batley 2016). Bioavailable concentrations of all other metals and metalloids (as indicated by acid dilute extractable metals) and were below the SQGV (where available) at all other sites upstream of Meandu Creek Dam.

MEANDU CREEK DAM

Concentrations of arsenic, chromium and copper (March 2017) and arsenic, chromium, copper, nickel and zinc (April 2018) exceeded the SQGV at up to three sites in the dam (sites MCD3, 4 and 5). Sites MCDS3 and MCDS5 are located near inputs from the Tarong and Tarong North power stations. The presence of arsenic, chromium and copper in the sediments of the dam may be related to the use of CCA-treated timber at the Tarong and Tarong North power stations. Sediment depth profiles completed in Meandu Creek Dam in 2014 also indicated that the accumulation of copper in sediments in the dam had been occurring over a long timeframe, and is most likely a result of historical leaching associated with the aluminium/brass alloy piping that was used in the cooling towers (Footprints 2014a).

Site MCDS2 is located in Meandu Creek Dam near the inflow from Meandu Creek (which receives discharges from Meandu Mine). Nickel and zinc were detected in concentrations higher than the SQGV at this site; the potential bioavailable concentrations (i.e. acid dilute extractable concentrations) of these metals also exceeded the SQGV. The acid dilute extractable concentration of nickel was also above the SQGV at site MCDS4 and the acid dilute extractable concentration of zinc was also above the SQGV at MCDS5. However, sediment at these sites contained a molar excess of acid volatile sulfides compared to simultaneously extracted metals, therefore it is considered that metals were not bioavailable to aquatic organisms (Simpson & Batley 2016). These metals were also high in sediments at site CM2 in Meandu Creek upstream of the dam.

Concentrations of all metals and metalloids in sediment were not considered bioavailable at sites in Meandu Creek Dam in April 2018.

MEANDU CREEK DOWNSTREAM OF MEANDU CREEK DAM

Concentrations of arsenic, cobalt, copper, manganese, nickel and zinc were generally higher at MC500 compared to other sites downstream of Meandu Creek Dam and comparative sites. At site MC500, the channel morphology was characterised by riffles, pools, bars, bends and sloping banks where sediments are more likely to aggregate (i.e. suspended sediments are more likely to settle at these sites).

Although total concentrations of these metals were high at this site, and in some cases exceeded the SQGV where available (e.g. arsenic, nickel), the maximum bioavailable concentrations (i.e. dilute acid extractable concentrations) were generally low when sampled in April 2018. The exception was nickel, with the maximum bioavailable concentration exceeding the SQGV. However, there was molar excess of acid volatile sulfides compared to simultaneously extracted metals at this site, therefore it is considered that metals were not dissolved (i.e. bioavailable) and are of low risk to aquatic organisms (Simpson & Batley 2016).

7.2.5 AQUATIC HABITAT

A summary of the aquatic habitat within each location surveyed is presented below, and specific habitat observations recorded at each of the sites surveyed is presented in Attachment E of Appendix G.

7.2.5.1 COMPARATIVE SITES

Comparative sites on Barker Creek were characterised as isolated pools disconnected from waterways upstream and downstream (Photo 7.1), or dry creek beds. The riparian vegetation was significantly impacted by vegetation clearing associated with the adjacent land uses (cropping and grazing). In-stream habitats had features providing structure and shelter for aquatic fauna (including bank vegetation, a variety of in-stream vegetation and woody debris) but they lacked a variety of flow regimes (riffles, runs and glides), depth profiles and channel sinuosity (bends, bars and straight sections). External impacts were moderate and mostly associated with the adjacent land clearing that has reduced the presence and continuity of riparian vegetation. Other apparent impacts included stock access and poor connectivity to other waterways.

The comparative site on Barambah Creek (site SW36) was characterised as a flowing pool located approximately 5 km downstream from Bjelke-Petersen Dam. Flows are released from the dam for downstream uses (including drinking water), resulting in a perennial flow regime. The riparian vegetation was impacted by vegetation clearing associated with the adjacent land uses (cropping and grazing) and a road corridor and road bridge that crossed above the site. In-stream habitats had a significant number of features providing excellent structure and shelter for aquatic fauna (including bank vegetation, a variety of in-stream vegetation including submerged aquatic plants, woody debris as well as a variety of flow regimes (including pool, glide, run, and riffle), depth profiles and channel sinuosity (Photo 7.2). External impacts were moderate and mostly associated with adjacent land clearing that has reduced the presence and continuity of riparian vegetation. Some human impact from recreational fishing and camping was also apparent.



Photo 7.1 Isolated pool at comparative site C1B on Barker Creek



Photo 7.2 A wide variety of connected aquatic habitat types at comparative site SW36 on Barambah Creek

7.2.5.2 MEANDU CREEK UPSTREAM OF MINE

Upstream sites on Meandu Creek were characterised as ephemeral drainage channels (Photo 7.3). The riparian vegetation was in good condition due to minimal impacts from the surrounding land use (sites were within the Yarraman State Forest). In-stream habitat was not assessed in the dry conditions, and it is unlikely that the waterways would hold water for long periods even after rain. External impacts were low given the surrounding area was intact native forest; the most apparent impact was humans accessing the State Forest for recreational activities.

7.2.5.3 MEANDU CREEK UPSTREAM OF MEANDU CREEK DAM

The sites located on Meandu Creek upstream of Meandu Creek Dam were characterised as isolated pools disconnected from waterways upstream and downstream. The riparian vegetation was impacted by vegetation clearing associated with the adjacent land use (mining activities) (Photo 7.4). In-stream habitats had a number of features providing some structure and shelter for aquatic fauna, but sites were typically dominated by one or two main habitat features (predominantly in-stream vegetation) and they lacked the variety of habitat associated with different flow regimes and channel sinuosity. External impacts were high and mostly associated with the adjacent land use (Meandu Mine); channel modifications have changed the natural flow and function of the waterway and the natural source of water feeding the sites. It is understood that seepage into the reaches adjacent to the mine is currently managed by pumping out the pools regularly into RD7.



Photo 7.3 Ephemeral drainage channel with good riparian cover at site MCUS2 on Meandu Creek upstream of the mine



Photo 7.4 Poor riparian cover due to vegetation clearing at site CM2

7.2.5.4 BLACK CREEK

The sites on Black Creek were both characterised as large pools significantly altered from their natural states and not connected to waterways further upstream and downstream. The riparian vegetation was impacted by vegetation clearing associated with the adjacent land uses (Tarong and Tarong North power stations) and the construction of the Black Creek diversion channel (Photo 7.5). While Black Creek Dam provides some habitat for aquatic flora and fauna, in the constructed channel downstream of the dam the habitat is entirely engineered.

7.2.5.5 MEANDU CREEK DAM

Meandu Creek Dam was characterised as a constructed waterbody connected to waterways further upstream and downstream via various inlets, outlets and waterway channels. The riparian vegetation condition varied around the perimeter of the dam and consisted of some cleared areas and some well-vegetated areas of intact native forest. The in-stream habitat had a number of features providing structure and shelter for aquatic fauna, including extensive in-stream vegetation and large woody debris. External impacts were high and mostly associated with the adjacent land use (the

Tarong and Tarong North power stations) and the various water sources that feed the dam including Meandu Mine. The water level in the dam was relatively low during the field survey (Photo 7.6). As a result, the location of site SW11 was moved slightly into the wetted channel, as the original sampling location was dry. Macroinvertebrate samples were collected from the wetted margins of the dam, but the sampling locations lacked the typical ‘edge’ habitat (e.g. trailing or aquatic vegetation) that is likely to characterise edge habitat when water levels are higher. In addition, sediment sampling site MCDS4 was dry at the time of survey.



Photo 7.5 Highly modified diversion channel at Black Creek site BC2



Photo 7.6 Low water level at Meandu Creek Dam

7.2.5.6 MEANDU CREEK DOWNSTREAM OF MEANDU CREEK DAM

The sites located within the receiving environment of Meandu Creek and Barker Creek were characterised as flowing pools that were well-connected to waterways further upstream and downstream. The riparian vegetation condition varied and was typically impacted by vegetation clearing associated with the adjacent land uses (cropping and grazing) and/or road corridors and road crossings located at some sites (Photo 7.7). In-stream habitats had a significant number of features providing good structure and shelter for aquatic fauna; including bank vegetation, a variety of in-stream vegetation, woody debris as well as a variety of flow regimes, depth profiles and channel sinuosity. External impacts were moderate to high and mostly associated with the upstream mining and power station activities: continual discharges from Meandu Creek Dam into the receiving environment have changed the natural flows and functions of the waterway. Additionally, land clearing associated with surrounding land uses have reduced the presence and continuity of riparian vegetation to varying degrees at sites.



Photo 7.7 A representative site (MC5 / W2), with a well-connected channel and a variety of aquatic habitat types but some impacts from vegetation clearing and a road bridge

7.2.6 AQUATIC PLANTS

7.2.6.1 COMMUNITY COMPOSITION

In total, 28 plant species comprising 20 families were recorded across all sites and locations. Twenty-one of these species are listed as wetland indicator species (all native species) (EHP 2017a). Four other native plant species that are not listed wetland species were recorded across the survey area on the banks or within the channel and were supporting the aquatic ecosystem by providing habitat.

Three exotic species were recorded across the survey area. However, no weeds of national significance were recorded and no plant species listed as prohibited or restricted invasive plants under the *Biosecurity Act 2014* were recorded.

Water pepper was the most widespread and abundant emergent species commonly growing along the edges and on the banks. Hornwort, common duckweed and curly pondweed were the most widespread floating / submerged species; water fern and hydrilla were the most abundant floating / submerged species.

The majority of the plant species identified during the survey are common and widespread around Queensland. Many are tolerant of waters that are higher in salinity (i.e. occur in coastal areas brackish regions as well as freshwater areas) (Stephens & Dowling 2002). In general, the plant species were providing bank stability and suitable edge habitat and in-stream habitat for aquatic fauna.

7.2.6.2 TAXONOMIC RICHNESS AND PERCENT COVER

Taxonomic richness was lowest on Meandu Creek upstream of Meandu Creek Dam (site MCA3/MC5), where only two species were recorded (refer Figure 7.9). Taxonomic richness was highest at site MC25 on Meandu Creek downstream of Meandu Creek Dam. Taxonomic richness at all other sites in this reach was within the range of comparative sites. Similar species were found at sites across all locations, and there were no obvious signs of poor health on plants at sites on Meandu Creek upstream or downstream of Meandu Creek Dam.

Percent cover of aquatic plants was lowest on Meandu Creek upstream of Meandu Creek Dam (site MCA3/MC5) at less than 10% (refer Figure 7.9). Percent cover at all comparative sites was above 30%, while percent cover at sites on Meandu Creek downstream of Meandu Creek Dam ranged between 20% and 60%. Percent cover at sites MC500 and MC5/W2 (downstream of Meandu Creek Dam, and closest to the dam outlet) was lower than the range of comparative sites. The lower cover of aquatic plants at sites MCA3/MC5, MC500 and MC5/W2 is likely to be related to the habitat characteristics of these sites (such as fast flowing water at sites MC500 and MC5/W2, and surrounding land uses and subsequent condition of aquatic habitat at site MCA3/MC5).

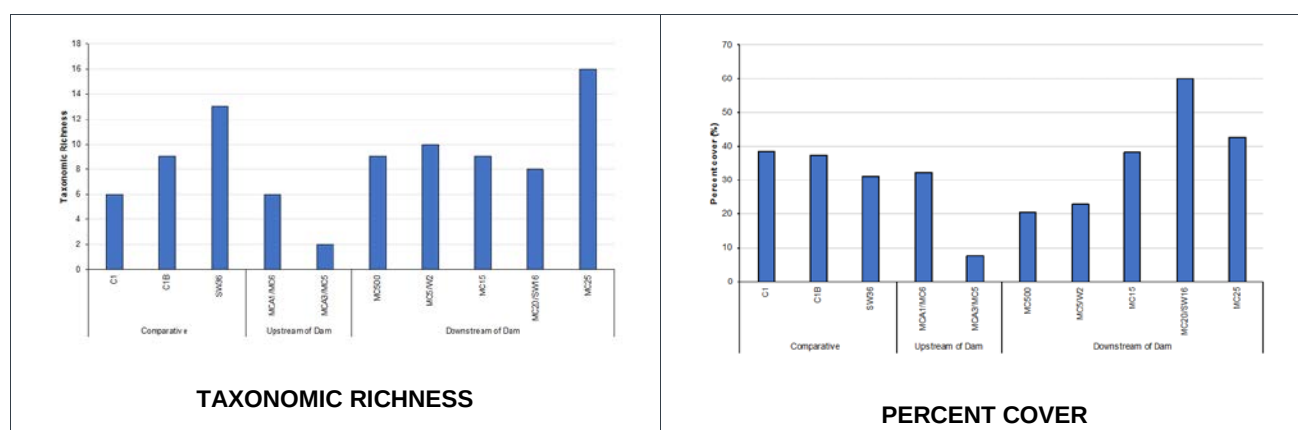


Figure 7.9 Taxonomic richness and percent cover of aquatic plants recorded at sites during the March 2017 field survey

7.2.6.3 GROWTH FORMS

Submerged and floating vegetation were the most abundant growth forms of aquatic plants across the survey area, and comprised over 50% of the total coverage at comparative sites and sites on Meandu Creek downstream of Meandu Creek Dam. Sites on Meandu Creek upstream of Meandu Creek Dam were the exception to this with emergent plant species dominating site MCA1/MC6 and MCA3/MC5. At both these sites, cumbungi was growing excessively around the channel. Cumbungi is a native species and can grow in varying water quality conditions. When present in high densities, cumbungi can become a weed and cause problems to waterways mainly by obstructing water-flow, increasing sedimentation and reducing water quality.

7.2.7 MACROINVERTEBRATES

7.2.7.1 HISTORICAL SURVEY RESULTS

Macroinvertebrates have historically been surveyed at sites within Meandu Creek Dam (including at the Meandu Mine Inlet), Meandu Creek downstream of Meandu Creek Dam and at several comparative sites on Barkers Creek. Routine monitoring has been completed since 1999.

Results from the two most recent surveys (2014 and the current 2017 survey) indicated that macroinvertebrate richness and diversity has increased compared with previous surveys (Table 7.5). The greater number of taxa recorded in the current March 2017 survey may be related to the inclusion of additional sites, seasonal effects, differences in sampling technique and/or an improvement in overall waterway condition.

In general, taxonomic richness has been lowest at sites in Meandu Creek Dam, which is to be expected due to the lower habitat diversity compared with creek sites. Richness at sites on Meandu Creek downstream of Meandu Creek Dam is generally within or greater than the range at the comparative sites. The results from the historical monitoring events have indicated that under normal operating conditions, discharges from Meandu Creek Dam are not adversely impacting the macroinvertebrate communities in the receiving environment (EMPS 2013, Footprints 2014b).

Table 7.5 *Number of taxa (richness) at riverine sites in Meandu and Barker Creek from 2000 to 2017 inclusive*

YEAR	NUMBER OF TAXA ¹
2000	46
2001	53
2002	42
2003	36
2004	47
2005	47
March 2006	47
August 2006	52
March 2007	48
May 2008	38
July 2008	44
May 2009	48
June 2011	37
June 2012	40

YEAR	NUMBER OF TAXA ¹
June 2014	72 (65 Meandu Creek, 48 Barker Creek)
March 2017	98 (86 Meandu Creek; 71 Barker/ Barambah Creek)

(1) Number of taxa for 2000 to 2014 sourced from Footprints 2014b

7.2.7.2 INDICES

Standard macroinvertebrate indices were calculated for each replicate sample, including taxonomic richness, abundance, and the presence of sensitive taxa through calculation of Plecoptera / Ephemeroptera / Trichoptera (PET) richness and SIGNAL 2 scores (Chessman 2003).

ABUNDANCE

In edge habitat, abundance did not significantly differ between locations; however there was spatial variability in abundance within and between sites, with abundance being highest at site MC5/W2 on Meandu Creek downstream of Meandu Creek Dam followed by MC500, and was lowest at dam site SWI1. Abundance at:

- Sites on Meandu Creek downstream of Meandu Creek Dam was within or above the range recorded at the comparative sites
- Sites on Meandu Creek upstream of Meandu Creek Dam was within or above the range recorded at the comparative sites, except at site MCA3/MC5, where abundance was lower than comparative sites
- Dam sites MCD1 and SWI2 was within the range recorded at the comparative sites, while abundance at MCD2 and SWI1 was lower than comparative sites.

Similarly, abundance in bed habitat did not differ significantly between locations. There was variation in abundance within and between sites, with abundance being highest at site MC500 on Meandu Creek downstream of Meandu Creek Dam and was lowest at dam site SWI1. Abundance at:

- Site MC2 on Meandu Creek downstream of Meandu Creek Dam was lower than the range recorded at the comparative sites, but all other sites were within or above the range of comparative sites
- Sites MCA3/MC5 and CM2 on Meandu Creek upstream of Meandu Creek Dam were lower than the range recorded at the comparative sites, but all other sites were within the range of comparative sites
- Dam site SWI1 was lower than the range recorded at the comparative sites.

Given the lack of statistically significant difference in abundance between locations (comparative, Meandu Creek upstream of Meandu Creek Dam, Meandu Creek Dam and Meandu Creek downstream of the dam), and the large range of 'natural' abundances recorded at comparative sites, no negative impacts to macroinvertebrate abundance were noted. Moreover, the high abundance at sites downstream of Meandu Creek Dam indicates that releases from the dam are having a positive influence on macroinvertebrate abundance in the receiving environment, which is most likely due to the flow and stable, perennial and diverse habitat created by the constant releases. Lower abundances at the dam sites may be related to the low water levels at the time of survey, resulting in bare substrate being sampled (as opposed to edge habitat with overhanging, trailing or aquatic vegetation when water levels are higher).

TAXONOMIC RICHNESS

A total of 101 taxonomic groups were identified in the March 2017 survey within Meandu Creek Dam and the Meandu Creek receiving environment (downstream of Meandu Creek Dam), which is significantly greater than the number of taxa identified in surveys of these reaches completed from 2000 to 2014 (where between 36 and 72 taxa were recorded per survey) (Footprints 2014b). The greater number of taxa recorded in the current survey may be related to the inclusion of additional sites, the different sampling technique used and/or an improvement in overall waterway condition. The most abundant groups were non-biting midges (Chironomidae) and seed shrimps (Ostracoda), while the most widespread groups included segmented worms (Oligochaeta), seed shrimps (Ostracoda), biting midges (Ceratopogonidae) and non-biting midges.

Total taxonomic richness (i.e. pooled for all samples collected at each site) was within or above the biological WQO range for edge and bed habitat, indicating that macroinvertebrate richness was within or above the range expected at reference sites throughout the central coast region of Queensland. The exceptions were at site CM2 for edge habitat and most of the dam sites; which is likely due to the poor quality of edge habitat at site CM2 and the low water levels in the dam at the time of survey. Total richness in riffle habitat at sites MCDOUT and MC5/W2 on Meandu Creek downstream of Meandu Creek Dam was 32 and 30 taxa respectively, which exceeds the biological WQO for composite bed habitat. In general, richness at each site was similar to or higher than that recorded in previous surveys (Footprints 2014b).

In edge habitat, taxonomic richness was highest at site MC5/W2 on Meandu Creek downstream of Meandu Creek Dam and was lowest at Dam site MCD2 (Figure 7.10). Taxonomic richness at:

- Sites on Meandu Creek downstream of Meandu Creek Dam was within or above the range recorded at the comparative sites
- Sites on Meandu Creek upstream of Meandu Creek Dam was within the range recorded at the comparative sites, except at site CM2 which was lower than the range at the comparative sites
- Dam sites were below the range of comparative sites except at site SW12, which was within the range of comparative sites.

Richness in edge habitat at sites on Meandu Creek upstream and downstream of Meandu Creek Dam was not significantly different to richness at the comparative sites. Richness was significantly lower at the dam sites compared with the comparative sites and sites downstream of Meandu Creek Dam, which is likely to reflect the low water levels (and the resulting lack of edge habitat) at the time of the survey, as well as low habitat diversity (which is typical of impoundments).

In bed habitat, taxonomic richness was significantly higher in Meandu Creek downstream of Meandu Creek Dam compared with the sites on Meandu Creek upstream of Meandu Creek Dam and dam sites, but richness at each location did not differ significantly from that at the comparative sites. Richness in bed habitat was highest at comparative site SW36 and was lowest at comparative site C1B (i.e. taxonomic richness at all sites on Meandu Creek upstream and downstream of Meandu Creek Dam, and dam sites was within the range recorded at the comparative sites).

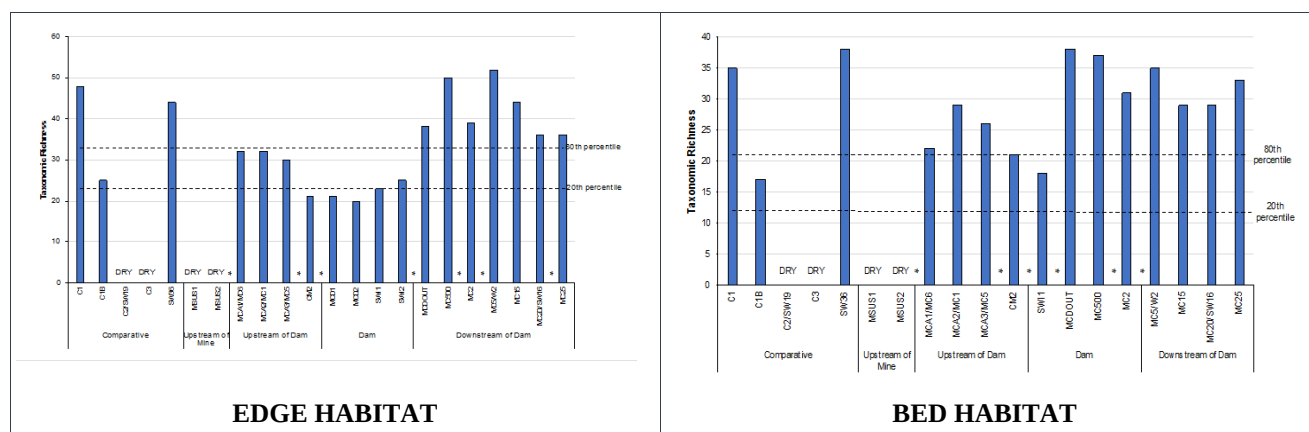


Figure 7.10 Total taxonomic richness in edge and bed habit (March 2017)

SIGNAL 2 SCORES

Total SIGNAL 2 scores (i.e. pooled for all samples collected at each site) were below the biological WQOs at most sites, except for comparative site SW36 (downstream of Bjelke-Petersen Dam) and on Meandu Creek within 15 km downstream of Meandu Creek Dam. This indicates that in general, taxa in the survey area are relatively tolerant of pollution, although Meandu Creek downstream of Meandu Creek Dam in the receiving environment (close to the discharge) supports a greater number of sensitive taxa. SIGNAL 2 scores were also high at comparative site SW36, where flow conditions are similar. This is likely to be related to the perennial flows and the diversity of habitats present at these sites, and is consistent with the results of the 2014 macroinvertebrate survey (Footprints 2014b).

In edge habitat, SIGNAL 2 scores were significantly lower at the dam sites than at the comparative sites and sites on Meandu Creek downstream of Meandu Creek Dam; and significantly lower at the sites on Meandu Creek upstream of Meandu Creek Dam than at the sites downstream of the Dam.

The SIGNAL 2 score was highest at site MC2 on Meandu Creek downstream of Meandu Creek Dam and lowest at Dam site SWI1. SIGNAL 2 scores in edge habitat at:

- Sites MC20/SW16 and MC25 on Meandu Creek downstream of Meandu Creek Dam were below the range recorded at the comparative sites, and all other sites were within or above the range at comparative sites
- Sites MCA1/MC6 and MCA2/MC1 on Meandu Creek upstream of Meandu Creek Dam were below the range recorded at the comparative sites, and sites MCA3/MC5 and CM2 were within the range at comparative sites,
- Dam sites were below the range recorded at the comparative sites.

In bed habitat, SIGNAL 2 scores were significantly lower at sites on Meandu Creek upstream of Meandu Creek Dam than at sites downstream. The SIGNAL 2 score was highest at site MC5/W2 downstream of Meandu Creek Dam and lowest at dam site SWI1.

SIGNAL 2 scores in bed habitat at:

- Sites on Meandu Creek downstream of Meandu Creek Dam were within or close to the range at comparative sites
- Site MCA1/MC6 on Meandu Creek upstream of Meandu Creek Dam were below the range recorded at the comparative sites, but at other sites within this reach were within the range recorded at comparative sites
- Dam sites were below the range recorded at the comparative sites.

SIGNAL 2 / family bi-plots indicated that most sites downstream of Meandu Creek Dam and comparative sites were either in 'reference' condition (favourable habitat and chemically dilute waters – i.e. sites were within quadrant 1 on the bi-plot), or showed some effects from increased salinity and nutrients (which may be natural – i.e. sites were within quadrant 2 on the bi-plot). Sites on Meandu Creek upstream of Meandu Creek Dam and within the dam itself, along with comparative site C1B, were typically indicative of urban, industrial or agricultural pollution or the downstream effects of dams (i.e. flow regulation / changing water levels – i.e. sites were within quadrant 4 on the bi-plot), which is not unexpected for sites both upstream of and in Meandu Creek Dam. No sites were within quadrant 3, which is indicative of toxic pollution or harsh physical conditions (refer Figure 7.10 and Figure 7.11).

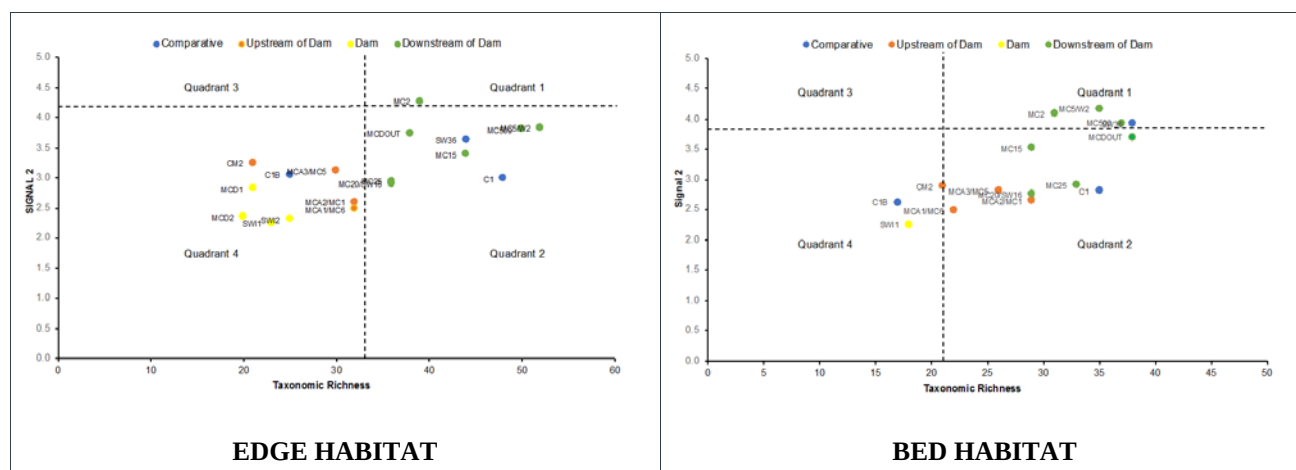


Figure 7.11 SIGNAL 2 / Family bi-plot for edge and bed habitat (March 2017)

Overall, there was a lower diversity and abundance of sensitive macroinvertebrate taxa at sites on Meandu Creek upstream of Meandu Creek Dam compared to sites downstream of Meandu Creek Dam. While this could be related to the water quality at these sites, it could also be due to other factors such as the lack of flow or poor habitat quality, as low SIGNAL 2 scores were also recorded at two of the comparative sites, and differences between these locations were not significant. The low number of sensitive taxa at the dam sites was likely to be related to the low water levels at the time of survey as well as low habitat diversity (which is typical of impoundments). Perennial flows related to releases from the

Meandu Creek Dam have resulted in higher numbers of sensitive taxa (than would be expected to 'naturally' occur in the study area) being present downstream of Meandu Creek Dam.

PET RICHNESS

Total PET Richness (i.e. pooled for all samples collected at each site) was within or exceeded the biological WQO range, except at comparative site C1B, site MCA1/MC6 on Meandu Creek upstream of Meandu Creek Dam and dam site SW1. PET Richness generally exceeded the biological WQO range in Meandu Creek downstream of Meandu Creek Dam and at comparative site SW36, which both receive flows from dam releases. These results are generally consistent with those of previous surveys, although PET Richness downstream of Meandu Creek Dam within 500 m of the outlet has improved since the 2014 survey (Footprints 2014b). PET Richness at sites MCDOUT and MC5/W2 was 7 and 9 respectively; much greater than the biological WQO for composite bed habitat. A stonefly (Plecoptera, family Gripopterygidae) was recorded in riffle habitat at site MC5/W2; stoneflies are relatively rare in the aquatic macroinvertebrate communities of the region and more broadly in Queensland (pers. obs.).

In edge habitat, PET Richness was significantly higher at sites on Meandu Creek downstream of Meandu Creek Dam than at sites upstream of and within the dam. PET Richness was highest at sites MC500, MC2 and MC5/W2 downstream of the dam, and lowest at dam site SW1. PET Richness scores at sites upstream of, downstream of and within Meandu Creek Dam were within the range recorded at comparative sites.

In bed habitat, PET Richness was significantly higher at sites on Meandu Creek downstream of Meandu Creek Dam than at sites upstream of and within the dam. PET Richness was highest at sites MCDOUT, MC500, MC2 and MC5/W2 downstream of the dam, and lowest at dam site SW1. PET Richness scores at sites upstream of, downstream of and within Meandu Creek Dam were within the range recorded at comparative sites.

Overall, there was a lower diversity of PET taxa at sites upstream of Meandu Creek Dam compared to sites downstream of the dam. While this could be related to the water quality at these sites, it could also be due to other factors such as the lack of flow or poor habitat quality, as low PET Richness was also recorded at one of the comparative sites and differences between these locations were not significant. The low number of PET taxa at the dam sites was likely to be related to the low water levels at the time of survey, as well as low habitat diversity (which is typical of impoundments). Perennial flows related to releases from the Meandu Creek Dam have resulted a higher diversity of PET taxa (than would be expected to 'naturally' occur in the study area) downstream of Meandu Creek Dam.

7.2.7.3 ASSEMBLAGE COMPOSITION

EDGE HABITAT

In edge habitat, the assemblages in the dam differed significantly from the assemblages the other locations (i.e. comparative, sites on Meandu Creek upstream of Meandu Creek Dam and sites on Meandu Creek downstream of Meandu Creek Dam). There were also significant differences between sites within each location.

Assemblages at sites downstream of Meandu Creek Dam and comparative sites (particularly sites SW36 and C1) were most similar to each other, with over 90% of the differences in assemblage composition between these locations explained by differences in the abundance of particular taxa, rather than a lack of taxa in any one location.

Most of the differences in assemblage composition between sites on Meandu Creek upstream of Meandu Creek Dam and comparative sites were explained by a higher abundance of macroinvertebrates at comparative sites. More than 40% of the variation between these locations were explained by higher abundances of some common taxa at comparative sites, including an aquatic snail (family Tateidae), non-biting midge larvae (sub-families Chironominae and Tanypodinae) and segmented worms (order Oligochaeta). However, there were some taxa that were present at comparative sites but absent at sites on Meandu Creek upstream of Meandu Creek Dam, including mayflies (family Caenidae – a relatively ubiquitous PET taxa). Sites on Meandu Creek upstream of Meandu Creek Dam also lacked other sensitive PET taxa (e.g. caddisflies, family Calamoceratidae) or taxa that are require flow (e.g. blackfly larvae, family Simuliidae) that were found downstream of Meandu Creek Dam.

BED HABITAT

In bed habitat, the assemblages did not differ significantly between locations, however there was a substantial difference between sites within locations. Assemblages at sites close to dam releases (e.g. sites MCDOUT, MC500 and W2 in the receiving environment and comparative site SW36) had similar assemblages.

Similar to edge habitat, assemblages in the bed habitat at sites upstream of Meandu Creek Dam lacked some of the sensitive taxa or taxa that require flow that were found at the comparative sites and sites downstream of Meandu Creek Dam, including families Caenidae and Leptophlebiidae (mayflies), Simuliidae and family Hydropsychidae (a caddisfly). The assemblage surveyed at the site in the dam lacked a number of taxa present in the other locations.

CORRELATION WITH ENVIRONMENTAL VARIABLES

WATER QUALITY

The water quality variables best correlated (though only considered to be moderately correlated) with macroinvertebrate assemblage composition in edge and bed habitat were electrical conductivity (and therefore, associated ion concentrations), oxides of nitrogen (concentrations of nitrate and nitrite) and the concentrations of total and dissolved arsenic. Specific details are provided in Appendix G.

SEDIMENT QUALITY

The concentration of metals in sediment was only weakly correlated with macroinvertebrate assemblage composition in edge habitat, and not correlated with assemblage composition in bed habitat.

7.2.8 FISH

7.2.8.1 HISTORICAL SURVEY RESULTS

The fish communities of Meandu Creek are not routinely monitored. Annual monitoring of the Tarong and Tarong North power station dams (including Meandu Creek Dam and the Cooling Water Dam) has however been undertaken since 2003 to confirm that there has been no transfer of tilapia (*Oreochromis mossambicus*; a declared noxious species) via pipelines from Boondooma Dam and Wivenhoe Dam to either dam, and to assess the health of populations of stocked species. A total of 13 species from 10 families have been recorded in the dams across all surveys, including:

- Agassiz's glassfish (*Ambassis agassizi*)
- Crimson-spotted rainbowfish (*Melanotaenia duboulayi*)
- Fly-specked hardyhead (*Craterocephalus stercusmuscarum*)
- Bony bream (*Nematalosa erebi*)
- Carp gudgeons (*Hypseleotris* spp.)
- Long-finned eel (*Anguilla reinhardtii*)
- Purple spotted gudgeon (*Mogurnda adspersa*)
- Golden perch (*Macquaria ambigua*)
- Australian bass (*Percales novemaculeata*)
- Freshwater catfish (*Tandanus tandanus*)
- Australian smelt (*Retropinna semoni*)
- Silver perch (*Bidyanus bidyanus*)
- Spangled perch (*Leiopotherapon unicolor*) (ESP 2016, ESP 2017).

The most recent survey (November 2017) recorded a total of 293 native fish, which is slightly higher than the total caught during the 2016 survey (242 individuals) (ESP 2016; ESP 2017). Fish communities consisted of the same species caught in previous surveys except:

- no Agassiz's glassfish or purple spotted gudgeons were caught in 2017, however these were caught in 2016
- the long-finned eel was not caught during the 2016 or the 2017 surveys.

One exotic fish species was caught in Meandu Creek Dam in both 2016 and 2017 surveys: the mosquitofish (*Gambusia holbrooki*). Mosquitofish is a declared noxious species under the *Biosecurity Act 2014*. The current study confirms that mosquitofish are present elsewhere in the catchment.

Analysis of fish tissue specimens completed in 2016 and 2017 revealed that mercury, copper and zinc were present in a number of specimens from a range of species. Cadmium was also present in some specimens in 2016 but was not detected in any specimens in 2017 (ESP 2016; ESP 2017). In 2017, prawn tissue was also analysed for metal concentrations, and copper and zinc were present in all samples taken at both power station dams (ESP 2017). Plant specimens (also analysed in 2017) had copper, lead and zinc present in varying concentrations (ESP 2017).

In 2017, Bjelke Petersen Dam was surveyed as a comparison site. The same species were recorded at the comparative site as were recorded in the power station dams, however two additional species were also recorded; the sleepy cod (*Oxyeleotris lineolatus*), and banded grunter (*Amniataba percooides*). Metal concentrations in fish, prawn and plant specimens were comparable to those in specimens analysed from the power station dams (i.e. the same toxicants were present in specimens at varying concentrations). This indicates that the uptake of metals by biota in dams at the power stations was similar to the comparative dam.

7.2.8.2 MARCH 2017 SURVEY

A total of 5,527 native fish comprising 14 species and 9 families were caught across all sites. Native fish species caught included:

- Agassiz's glassfish (*Ambassis agassizi*)
- Long-finned eel (*Anguilla reinhardtii*)
- Marjorie's hardyhead (*Craterocephalus marjoriae*)
- Fly-specked hardyhead (*Craterocephalus stercusmuscarum*)
- Bony bream (*Nematalosa erebi*)
- Western carp gudgeon (*Hypseleotris klunzingeri*)
- Carp gudgeon (*Hypseleotris* spp.)
- Purple spotter gudgeon (*Mogurnda adspersa*)
- Flathead gudgeon (*Philypnodon grandiceps*)
- Crimson spotted rainbowfish (*Melanotaenia duboulayi*; Photo 7.8)
- Freshwater catfish (*Tandanus tandanus*)
- Australian smelt (*Retropinna semoni*)
- Barred grunter (*Amniataba percooides*)
- Spangled perch (*Leiopotherapon unicolor*).



Photo 7.8

Crimson spotted rainbowfish

In addition to these native fish, 125 exotic fish comprising the following 2 species were caught:

- Mosquitofish (*Gambusia holbrooki*)
- Goldfish (*Carassius auratus*).

Mosquitofish are declared as restricted noxious fish under the *Biosecurity Act 2014* (DAF 2017a). Mosquitofish are an aggressive fish that compete with native fish for resources and prey on the eggs and larvae of native fish and frogs. They breed in high numbers and can rapidly outnumber native fish and dominate aquatic communities (DAF 2016).

Mosquitofish were caught in Meandu Creek downstream of Meandu Creek Dam, as well as at comparative site SW36. Goldfish are a non-indigenous fish that are declared a pest fish when in the wild (DAF 2017b). Goldfish were caught at site MC15 downstream of Meandu Creek Dam as well as at comparative site SW36. Neither exotic species were caught in Barker Creek upstream of the confluence with Meandu Creek, or in Meandu Creek upstream of the Meandu Creek Dam. Both species are listed to occur throughout the Barker and Barambah Creeks drainage sub-basin (EHP 2017b),

therefore it is unlikely that their presence downstream of Meandu Creek Dam in the receiving environment is an impact from Meandu Mine or the Tarong and Tarong North power stations.

The crimson-spotted rainbowfish was the most widespread native fish and was caught at all sites except site MCA3/MC5 on Meandu Creek upstream of Meandu Creek Dam. This species is tolerant of high electrical conductivity, varying pH levels and low dissolved oxygen (Pusey et al. 2004).

The following species were only caught at sites on Meandu Creek upstream and/or downstream of Meandu Creek Dam and were not caught at comparative sites:

- Fly-specked hardyhead
- Bony bream
- Australian smelt.

The following species were only found at comparative sites:

- Long-finned eel; caught in Barambah Creek only (i.e. downstream of Bjelke-Petersen Dam)
- Marjorie's hardyhead; caught in Barker Creek only
- Flathead gudgeon; caught in Barambah Creek only (i.e. downstream of Bjelke-Petersen Dam), and
- Barred grunter; caught in Barambah Creek only (i.e. downstream of Bjelke-Petersen Dam).

Overall, the species that were caught are widespread and common across Australia. None are listed threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or Queensland *Nature Conservation Act 1992* (NC Act). Most are tolerant of varied environmental conditions, especially high conductivity (Pusey et al. 2004). There was a difference in the community composition of fish at sites on Meandu Creek upstream and downstream of Meandu Creek Dam compared to comparative sites, however this was likely due to site-specific differences in aquatic habitat characteristics. It is also possible that Bjelke-Petersen Dam restricts the passage of some species from Barambah Creek to upstream catchment areas.

SPECIES RICHNESS

Species richness of fish was highest at comparative site SW36 and was lowest at site MCA3/MC5, followed by site MCA1/MC6, both on Meandu Creek upstream of Meandu Creek Dam (refer Figure 7.12). While it is possible that poor water quality is affecting the composition of fish communities here, low species richness at these sites may also be due to:

- their location within the catchment (i.e. they were located towards the upstream reaches of Meandu Creek where flow and lasting pools are minimal and conditions are not ideal for fish species to establish)
- a lack of connectivity at these sites to waterways further downstream to allow fish passage to these locations
- lack of habitat available to support a high diversity of species
- changing habitat conditions at the sites as a result of site water management (i.e. water was regularly pumped from site MCA1/MC5 in 2016 and 2017 when water levels were too high, though pumping no longer occurs regularly).

There was also 1 or 2 fewer species present at sites MC5/W2 and MC15 on Meandu Creek downstream of Meandu Creek Dam compared with the comparative sites. However, at these sites there were no substantial differences in water or sediment quality (compared with the other sites in this reach). The lower richness at these sites is more likely to be related to the different availability of habitat at these sites.

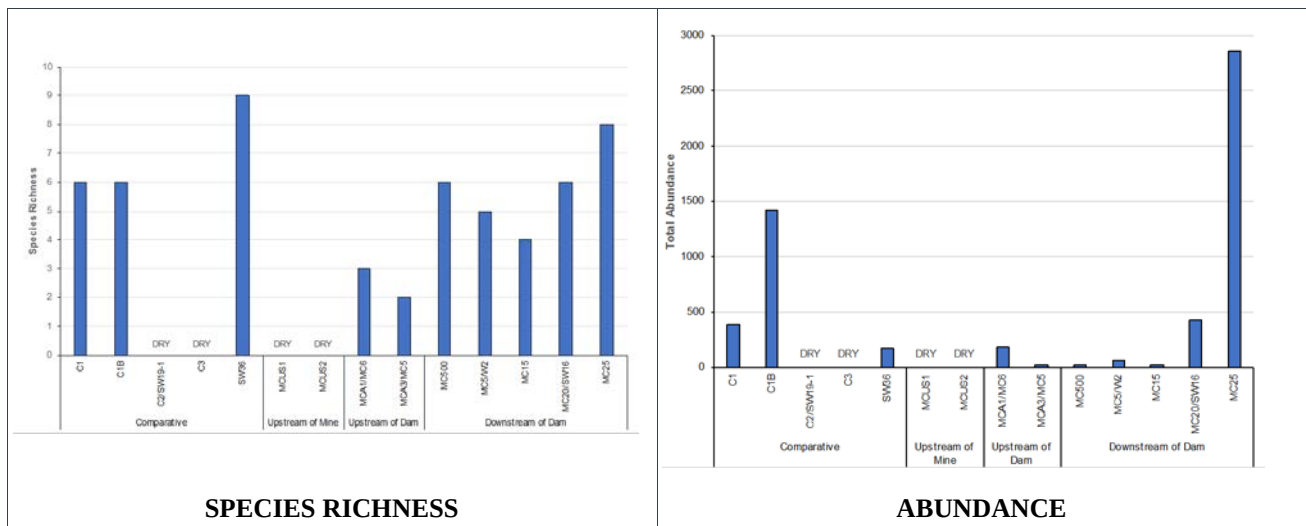


Figure 7.12 Species richness and abundance of native fish caught at each site (March 2017)

ABUNDANCE

The abundance of native fish varied substantially between sites and was lowest at site MCA3/MC5 (14 individuals) on Meandu Creek upstream of Meandu Creek Dam, and highest at site MC25 (2,857 individuals) on Meandu Creek downstream of the dam (refer Figure 7.12). Abundance at comparative sites ranged from 165 to 1,412. Abundance at sites downstream of Meandu Creek Dam closest to the input (i.e. within 15 km of the receiving environment) was below the range recorded at the comparative sites. This is likely to be related to site-specific habitat factors, and also the availability of connected habitat upstream and downstream for fish to disperse to (whereas fish at comparative sites C1 and C1B were concentrated in pools and easier to sample).

The most abundant fish were:

- Fly specked hardyhead: 2,137 individuals caught in total and only at sites on Meandu Creek downstream of Meandu Creek Dam
- Carp gudgeon: 1,452 individuals caught in total and present at comparative sites, and sites on Meandu Creek upstream and downstream of Meandu Creek Dam but most abundant at comparative sites
- Crimson spotted rainbowfish: 1,346 individuals caught in total and present at comparative sites, and sites on Meandu Creek upstream and downstream of Meandu Creek Dam.

Native fish were more abundant than exotic fish at all sites where they were caught. Overall, the abundance of exotic fish was still relatively low throughout the survey area; only 125 exotic individuals were caught in total.

LIFE HISTORY STAGES

Adult fish dominated native fish communities at most sites, except at site MC15 on Meandu Creek downstream of Meandu Creek Dam (where intermediate fish were dominant).

Across all sites there was a low percentage of juvenile fish present, which is likely to be related to the timing of the survey. However, no juveniles were present at sites on Meandu Creek upstream or downstream of Meandu Creek Dam within 20 km of the input. This is likely to be related to site-specific factors such as strong flows and habitat availability for shelter and protection.

7.2.9 OTHER AQUATIC VERTEBRATES

Platypus and turtles were caught incidentally during the March 2017 field surveys. All were released unharmed. One platypus (*Ornithorhynchus anatinus*) was caught at comparative site SW36. Thirteen native turtles comprising of three species and one family were caught including:

- Krefft's River turtle (*Emydura macquarii krefftii*; Photo 7.9)
- Eastern snake-necked turtle (*Chelodina longicollis*)
- Saw-shelled turtle (*Wollumbina latisternum*).

All species captured are common and widespread in Queensland and inhabit broad range of freshwater aquatic habitats including shallow, ephemeral wetlands, flowing streams, deep permanent pools and farm dams. None are listed threatened species under the Commonwealth EPBC Act or Queensland NC Act.

Turtles were caught at all sites on Meandu Creek downstream of Meandu Creek Dam, except at site MC500 (which had fast flow not favoured by the above species) and at comparative site SW36.



Photo 7.9 Krefft's River turtle

8 IMPACTS TO THE RECEIVING ENVIRONMENT

SECTION OVERVIEW

This section determines the potential impacts of AMD from the Meandu Mine to the surface water environmental values of Meandu Creek based on the finding from the desktop and field assessment as presented in Section 7. Specifically, it addresses requirements B4(iii), B6(ii) and (iii) of the Notice:

B4(iii) Identify short-term and long-term measures including (if relevant) further lines of investigation, monitoring requirements, and operational or mine planning measures that should be developed and/or implemented to prevent environmental harm occurring from AMD at Meandu Mine

B6(ii) Identify the level of impact AMD from Meandu Mine has had on environmental values of the receiving environment

B6(iii) Identify potential impacts of AMD from Meandu Mine on environmental values of the receiving environment.

Meandu Creek downstream of the release point CP3 is considered the surface water receiving environment for potential AMD-related impacts. Release point CP3 is located within Meandu Creek upstream of Meandu Creek Dam. During periods of flows, water in this reach flows into Meandu Creek Dam (3,000 ML storage capacity), where it gets diluted with cooling water blowdown and stormwater from the Tarong and Tarong North power stations and released via licensed discharges to Meandu Creek downstream of Meandu Creek Dam.

Overall, based on the information presented, there is currently no evidence of negative impacts to the environmental values of Meandu Creek as a result of AMD from Meandu Mine. The aquatic ecological communities in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam. As discussed in Section 2.6, some initial measures have been made by Stanwell to manage AMD including interim lime-dosing and changes to monitoring and operations. These measures further reduce the risk of environmental harm. If control measures recommended from this environmental investigation (Section 10.2) are implemented and current EA water quality limits adhered to (both Meandu Mine and Tarong and Tarong North power stations), future impacts on environmental values of surface water (Meandu Creek) are considered unlikely.

8.1 CURRENT IMPACTS TO ENVIRONMENTAL VALUES OF MEANDU CREEK

8.1.1 WATER QUALITY

The results from historical surface water monitoring completed at Meandu Mine and the Tarong and Tarong North power stations, and from the March 2017 survey, demonstrate that electrical conductivity levels and the concentrations of major ions (including sulfate), nitrate and some dissolved metals are higher in Meandu Creek adjacent to and downstream of Meandu Mine than at comparative sites within the region. While this may be indicative of an AMD-related impact; other factors such as operation of the Tarong and Tarong North power stations and catchment inputs also influence some of these parameters. Each of these surface water quality parameters are discussed in the following sections.

8.1.1.1 ELECTRICAL CONDUCTIVITY

Electrical conductivity is high in Meandu Creek upstream of Meandu Creek Dam, particularly in the reaches adjacent to Meandu Mine. There has also been a trend of increasing electrical conductivity levels at Meandu Mine compliance points CP3 (Meandu Creek prior to discharge to Meandu Creek Dam) and CP1 (Meandu Creek Dam) in the past four years. While this may be indicative of an AMD-related impact, there may be other contributing factors such as ambient rainfall and catchment inflows, and potentially groundwater seepage, to these reaches of the creek. As discussed in Section 4.3.4,

a high electrical conductivity zone was identified from the airborne geophysics survey along Meandu Creek to the west of the mining area. Review of geophysics data does not indicate a source of high electrical conductivity groundwater to the west of Meandu Creek, therefore the high electrical conductivity at this site may be a result of the residence time for groundwater.

Electrical conductivity is a broad indicator of the amount of dissolved inorganic material in waterways (i.e. total concentration of ions). Effects of electrical conductivity on the aquatic ecosystem are generally based on significant changes to the normal range of waterways (Volume 2 of ANZECC & ARMCANZ 2000). Adverse biological effects are most likely to occur when there are changes to electrical conductivity (more so when there is an increase in the electrical conductivity). Excess salt in freshwater systems can impact aquatic organisms through:

- altering the natural habitat by influencing energy and nutrient cycles, the consumption of oxygen, primary productivity and water clarity (Nielsen et al. 2003)
- modification of species composition of the ecosystem due to changes in the amount and type of food or refuge (ANZECC & ARMCANZ 2000)
- direct toxicity caused by physiological responses, such as changes in ionic and water regulation (Hart et al. 1991, Hart et al. 2003).

The electrical conductivity within Meandu Creek downstream of Meandu Creek Dam is maintained within a narrow range during normal mine and power station operating conditions, because the primary source of water to this reach comes from the continuous controlled and monitored discharges from Meandu Creek Dam. While the electrical conductivity levels recorded in Meandu Creek downstream of Meandu Creek Dam are relatively high compared with the comparative sites surveyed in the region, they have not exceeded the WQO (which is based on the long-term 80th percentile value for the sites downstream of the dam) over the past four years. The results of current and historical aquatic biota monitoring confirm that electrical conductivity levels in Meandu Creek downstream of Meandu Creek Dam are not resulting in negative impacts to aquatic biota.

As such, while AMD from Meandu Mine may have contributed to elevated electrical conductivity levels in the surface waters of Meandu Creek upstream of Meandu Creek Dam in the past four years, other factors such as climatic conditions and operation of the Tarong and Tarong North power stations have a larger influence on the electrical conductivity levels in Meandu Creek Dam. There is currently no evidence that electrical conductivity from mine impacted water is having a negative impact on the environmental values of the receiving environment.

8.1.1.2 SULFATE

Concentrations of sulfate in Meandu Creek (both upstream and downstream of Meandu Creek Dam) are higher than concentrations recorded at comparative sites in the region. There has been a general trend of increasing sulfate concentrations at CP3 and CP4 in the past 10 years, which may be indicative of an AMD-related impact. However, the concentrations of sulfate have historically been below the WQO (which is based on the stock watering guideline, and not directly applicable to the Meandu Creek upstream of Meandu Creek Dam). The trend of increasing sulfate concentrations was not observed at site CP1 in Meandu Creek Dam, where sulfate concentrations are also influenced by operation of the Tarong and Tarong North power stations. Concentrations of sulfate in Meandu Creek Dam have historically been below the WQO (based on the stock watering guideline), as well as the more stringent drinking water guideline.

As such, while AMD from Meandu Mine may have contributed to elevated sulfate concentrations in the surface waters released from the mine, there is no evidence of this impact extending to Meandu Creek Dam or Meandu Creek downstream of Meandu Creek Dam. There is currently no evidence that the concentration of sulfate in mine impacted water is having a negative impact on the environmental values of the receiving environment.

8.1.1.3 NITRATE

Long-term median concentrations of nitrate have historically been higher at CP3 (0.77 mg/L) than at sites in Meandu Creek adjacent to the mine (0.39 mg/L); median concentrations were lower in the past four years than they have been historically. Long-term median concentrations were higher at the Meandu Creek Dam release point (site W3, 0.8 mg/L)

and Meandu Creek 2 km downstream of Meandu Creek Dam (site W2, 1 mg/L) than at the Meandu Mine monitoring sites. Concentrations of oxidised nitrogen in Meandu Creek downstream of Meandu Creek Dam during the March 2017 survey varied between sites, indicating that there were likely to be other (catchment) inputs of oxidised nitrogen (nitrate and nitrite) to Meandu Creek. While nitrate can be an indicator of AMD impacted water, other sources, such as the liberation of elemental geological nitrogen at Meandu Mine, the operation of the Tarong and Tarong North power stations and catchment inputs also influence concentrations of nitrate. Thus, it is not considered to be a key indicator for AMD in this assessment. Based on the information presented, concentrations of nitrate in Meandu Creek are unlikely to be related to AMD, but rather sourced from other inputs.

Nitrate and nitrite are common forms of nitrogen; nitrate is the most commonly available form of nitrogen and is readily assimilated by plants for growth. However, in high concentrations it can cause nuisance plant growth such as algae, which can dominate and change the dynamics of the aquatic ecosystem. Nitrate has also been identified as toxic to certain aquatic crustaceans; causing mortality and detrimental tissue damage to prawns in their early life stages (Volume 2, ANZECC & ARMCANZ 2000).

Chronic effects of nitrate are not expected unless the concentration of nitrate is higher than 0.7 mg/L, which equates to the default slightly-moderately disturbed toxicant trigger value for the protection of 95% of freshwater species (ANZECC & ARMCANZ 2000). The 90% species protection trigger level (applicable to highly disturbed systems) is much higher, at 3,400 mg/L (ANZECC & ARMCANZ 2000). As median concentrations of nitrate are typically close to the 95% species protection trigger level, and well-below the 90% species protection trigger level, it is unlikely that the concentrations of nitrate in Meandu Creek are causing chronic or acute impacts toxicity to most aquatic organisms. The results of current and historical aquatic biota monitoring did not indicate any negative impacts to aquatic biota in Meandu Creek downstream of Meandu Creek Dam.

8.1.1.4 COBALT

Concentrations of dissolved cobalt were much higher at Meandu Mine CP3 than all other sites, including site CP1 on Meandu Creek Dam. Similarly, the concentration of cobalt was highest at site CM2 on Meandu Creek at the Meandu Creek Dam inlet in the March 2017 survey. While not directly applicable, concentrations of dissolved cobalt at sites CP3 were generally below the WQO. Concentrations of cobalt in Meandu Creek Dam and Meandu Creek downstream of the dam are well-below the WQO.

As such, while AMD from Meandu Mine may have contributed to elevated cobalt concentrations in the surface waters released from Meandu Mine, there is no evidence of this impact extending to Meandu Creek Dam or Meandu Creek downstream of Meandu Creek Dam. Concentrations are well-below the WQO for the protection of aquatic ecosystems. There is currently no evidence that the concentration of cobalt from mine impacted water is having a negative impact on the environmental values of the receiving environment.

8.1.1.5 MANGANESE

Historical monitoring results showed that concentrations of dissolved manganese on Meandu Creek upstream of Meandu Creek Dam are variable, but were often highest (and while not directly applicable, above the WQO for ecosystem protection) at CP3. This may be indicating an AMD-related impact. However, concentrations of dissolved manganese at CP1 on Meandu Creek Dam were much lower than those recorded at CP3, and were below the WQO. Whilst manganese has not been routinely monitored in Meandu Creek downstream of Meandu Creek Dam, the results of the March 2017 survey indicated that concentrations of manganese in Meandu Creek downstream of Meandu Creek Dam are within the range recorded at comparative sites, and concentrations of dissolved manganese are below the WQO for the protection of aquatic ecosystems.

As such, while AMD from the Meandu Mine may have contributed to elevated manganese concentrations in the surface waters released from Meandu Mine, there is no evidence of this impact extending to Meandu Creek Dam or Meandu Creek downstream of Meandu Creek Dam. There is currently no evidence that the concentration of manganese from mine impacted water is having a negative impact on the environmental values of the receiving environment.

8.1.1.6 NICKEL

Concentrations of dissolved nickel were much higher at CP3 than all other sites, including site CP1 on Meandu Creek Dam. Similarly, the concentration of nickel was high at site CM2 on Meandu Creek at the Meandu Creek Dam inlet in the March 2017 survey. While not directly applicable, concentrations of dissolved nickel at sites CP3 and CM2 were below the hardness-modified WQO for nickel. Concentrations of nickel in Meandu Creek Dam and Meandu Creek downstream of the dam were higher than those recorded at the comparative sites in the region, but below the hardness-modified WQO.

Nickel can be present in the environment through natural and anthropogenic sources. It is possible that AMD from Meandu Mine may have contributed to the elevated nickel concentrations in the surface waters released from Meandu Mine. However, there are also likely to be catchment sources of nickel to Meandu Creek (e.g. concentrations of nickel in the sediment of Meandu Creek upstream of Meandu Mine were relatively high). There is currently no evidence that the concentration of nickel from mine impacted water is having a negative impact on the environmental values of the receiving environment.

8.1.1.7 ZINC

Concentrations of dissolved zinc were much higher at CP3 than all other sites, including CP1 on Meandu Creek Dam. Similarly, site CM2 on Meandu Creek at the Meandu Creek Dam inlet was the only site where dissolved zinc was detected (i.e. recorded in a concentration higher than the laboratory LoR) in the March 2017 survey. While not directly applicable, concentrations of dissolved zinc at CP3 have generally been below the hardness-modified trigger value for zinc. Long-term median concentrations of dissolved zinc in Meandu Creek Dam and Meandu Creek downstream of the dam are low (close to the laboratory LoR) and below the WQO.

It is possible that AMD from Meandu Mine may have contributed to the elevated zinc concentrations in the surface waters released from the mine. However, there is no evidence of this impact extending downstream to Meandu Creek Dam. There is currently no evidence that the concentration of zinc from mine impacted water is having a negative impact on the environmental values of the receiving environment.

8.1.1.8 SEDIMENT QUALITY

In the March 2017 survey, there was a general trend of higher concentrations of some metals that may be influenced by AMD (cobalt, manganese, nickel and zinc), particularly at site CM2. In the April 2018 survey, concentrations of dilute acid extractable nickel and zinc (representative of the bioavailable fraction) exceeded the sediment quality guideline-high value (SQG-high) at this site; there are no sediment quality guideline values (SQGVs) for cobalt and manganese. Furthermore, there was not a molar excess of acid volatile sulfides compared to simultaneously extracted metals at site CM2, indicating metals are unlikely to be bound in sulfide complexes and may be dissolved and thus bioavailable to aquatic flora and fauna.

Site CM2 was located at the Meandu Mine inlet to Meandu Creek Dam, and as such receives discharges from the mine that may be affected by AMD. The site was characterised as a narrow pool with substrate dominated by silt. Cumbungi (bulrush) was present in dense stands at this site. Cumbungi is known to have significant sediment-trapping abilities by slowing water flow and trapping suspended sediment in their root systems (Stephens & Dowling 2002). The high concentrations of metals in sediment at site CM2 are likely to be a result of the settlement of fine sediments in the channel, from the slowing of water in Meandu Creek as it enters Meandu Creek Dam and passes through the Cumbungi, decreasing in velocity (Volume 2, ANZECC & ARMCANZ 2000).

Concentrations of cobalt, nickel and zinc in Meandu Creek Dam were slightly higher than background concentrations in the catchment, with maximum bioavailable concentrations of nickel and zinc exceeding the SQGV at site MCDS2, where Meandu Creek enters Meandu Creek Dam. In contrast, concentrations of manganese were low in Meandu Creek Dam and within the range of that at comparative sites.

Concentrations of cobalt, manganese, nickel and zinc in the sediment of Meandu Creek within 500 m downstream of Meandu Creek Dam were higher than the background concentrations in the catchment, and above the SQGV for nickel

and zinc at site MC500 (where fine sediments are likely to accumulate due to channel morphology). However, the results of biological surveys, including macroinvertebrates in bed habitat (i.e. living in the sediment) showed no evidence of impacts as a result of higher concentrations of metals in the sediment at these sites. Furthermore, additional analysis of sediment in April 2018 showed that concentrations of metals and metalloids in Meandu Creek downstream of Meandu Creek Dam are unlikely to be bioavailable for uptake by aquatic flora and fauna (i.e. there was a molar excess of acid volatile sulfides compared to simultaneously extracted metals).

In summary, it is possible that AMD from Meandu Mine is contributing to the accumulation of cobalt, manganese, nickel and zinc in the sediment of the Meandu Creek channel between Meandu Mine and Meandu Creek Dam. The dense Cumbungi stands in this channel are likely acting as a sediment trap, resulting in the retention of metals bound to fine sediments (before they enter Meandu Creek Dam).

Historical sediment quality investigations have concluded that Meandu Creek Dam also acts as a sediment trap and a sink for metals (Footprints 2014), with accumulation of the above metals in the dam potentially related to AMD from Meandu Mine. However, other sources of metals in the sediments of the dam include local geology and metal leaching from condensers at Tarong Power Station (prior to their replacement with titanium), as well as the influence of local geology on the cycled water from Boondooma Dam and Wivenhoe Dam. While the concentrations of some metals were higher than background concentrations and the SQGV (where available) in the Meandu Creek, most notably within 500 m of Meandu Creek Dam, there is no evidence to suggest that aquatic flora and fauna are being negatively influenced.

8.1.2 AQUATIC FLORA AND FAUNA

8.1.2.1 AQUATIC PLANTS

Results from aquatic plant surveys indicate that AMD from Meandu Mine is unlikely to be negatively influencing aquatic vegetation downstream of Meandu Creek Dam. Aquatic plants in these reaches are influenced by site-specific factors such as aquatic habitat types and substrate composition.

There was lower taxonomic richness of aquatic plants at sites on Meandu Creek upstream of Meandu Creek Dam than at the comparative sites. It is unclear whether this is related to poor water and sediment quality (including impacts associated with AMD, as discussed above), or poor habitat quality and lower connectivity with natural stream reaches (unrelated to AMD).

8.1.2.2 AQUATIC MACROINVERTEBRATES

There were no statistically significant differences in macroinvertebrate richness, abundance and the presence of sensitive taxa (SIGNAL 2 scores and PET richness) between sites located on Meandu Creek (upstream and downstream of Meandu Creek Dam) and the comparative sites. That is, there was no evidence of an impact to macroinvertebrate assemblages as a result of AMD. Macroinvertebrate indices in Meandu Creek (upstream and downstream of the dam) were within the large range of natural variation in macroinvertebrate assemblages throughout the study area, which included comparative sites in ephemeral pools as well as perennial streams (downstream of Bjelke-Petersen Dam).

A similar range of macroinvertebrate taxa were generally recorded at sites in Meandu Creek upstream of Meandu Creek Dam (i.e. sites adjacent to the mine and downstream of mine discharges) and at the ephemeral comparative sites. This highlights the resilience of the macroinvertebrates of the region, including those in Meandu Creek upstream of Meandu Creek Dam, to high electrical conductivity and high concentrations of some metals in the water and sediment (which were recorded in Meandu Creek adjacent to the mine). Although there were no statistically significant differences in macroinvertebrate indices between sites located on Meandu Creek and the comparative sites, there were more subtle differences in composition, with some sensitive taxa recorded at comparative sites, but not at sites on Meandu Creek upstream of Meandu Creek Dam; however, this was not the case downstream of Meandu Creek Dam.

Macroinvertebrate community structure (based on SIGNAL 2 / family bi-plots) was not indicative of toxic pollution at any site. A higher proportion of sensitive taxa than would be naturally expected for the region was recorded in Meandu Creek downstream of Meandu Creek Dam (particularly within 15 km of the Meandu Creek Dam release point). This

indicates that releases from Meandu Creek Dam are having a positive influence on macroinvertebrate communities downstream of Meandu Creek Dam, which is most likely due to the flow and stable, perennial and diverse habitat created by the constant releases. There was no evidence of acute or chronic toxicity associated with water or sediment quality in Meandu Creek downstream of Meandu Creek Dam.

Taxonomic richness, SIGNAL 2 scores and PET Richness were significantly lower at the Meandu Creek Dam sites than at the comparative sites and downstream of Meandu Creek Dam sites. This is likely to reflect the low habitat diversity of the dam (which is typical of impoundments) as well as the low water levels at the time of the March 2017 survey (and the resulting lack of aquatic habitat at the survey sites). There were no correlations between water or sediment quality and macroinvertebrate community structure that would suggest that electrical conductivity levels or the concentrations of metals in water and sediment were negatively influencing macroinvertebrates within Meandu Creek Dam (or in Meandu Creek upstream and downstream of the dam).

8.1.2.3 FISH AND OTHER AQUATIC VERTEBRATES

Species richness and abundance of fish was low at sites on Meandu Creek upstream of Meandu Creek Dam (adjacent to Meandu Mine). While it is possible that the high electrical conductivity and high concentration of some dissolved metals is affecting the composition of fish communities here, low species richness and abundance at these sites may also be due to a range of other factors including the upstream location in the catchment and a lack of connectivity with downstream reaches (particularly due to the presence of Meandu Creek Dam), along with poorer habitat quality as a result of the construction of diversions and mine water management. There was no obvious evidence of toxic effects to fish in this reach, such as obvious signs of ill-health (skin lesions etc.), suggesting that some native fish species found in the region (gudgeons and rainbowfish) are resilient to variable and sometimes poor water quality.

In general, the range of fish species recorded in Meandu Creek downstream of Meandu Creek Dam was similar to that recorded at the comparative sites in the region. The presence of a variety of native fish and turtles in the Meandu Creek downstream of Meandu Creek Dam confirms its suitability as habitat for a range of native aquatic fauna species, and provide further evidence that potential AMD-related impacts to water and sediment quality are not having a negative impact on the environmental values of the receiving environment.

8.1.3 SUMMARY

It is possible that AMD is resulting in higher electrical conductivity levels and concentrations of ions (including sulfate), nitrate and some metals (notably cobalt, manganese, nickel and zinc) in the waters discharged from Meandu Mine to Meandu Creek Dam. However, in many cases the impact does not extend to or beyond Meandu Creek Dam, and other factors (such as climatic conditions, catchment-related inputs and operation of the Tarong and Tarong North power stations) also influence concentrations of these parameters in the dam. Long-term trends indicate that concentrations of all water quality parameters are generally below the relevant WQOs in Meandu Creek downstream of Meandu Creek Dam.

It is possible that AMD is resulting in the accumulation of the metals (cobalt, manganese, nickel and zinc) in sediment, mostly within the channel running between Meandu Mine and Meandu Creek Dam, and in Meandu Creek Dam. There are also relatively high concentrations of some metals in sediments close to (within 500 m of) Meandu Creek Dam, in areas where fine sediments settle, though sources from power station operation may also be contributing to this.

However, there is no evidence that impacts to water and sediment quality are resulting in negative impacts to the environmental values of Meandu Creek. Aquatic flora and fauna communities upstream of Meandu Creek Dam generally demonstrate resilience to poor water quality (e.g. high electrical conductivity and concentrations of ions, nitrate and some metals). However, these communities are likely affected by poor connectivity to downstream environments and impacts associated with mine water management (e.g. creation of diversion channels and management of water levels by pumping).

Aquatic flora and fauna communities in Meandu Creek downstream of Meandu Creek Dam are in a similar or better condition than would be expected in the broader catchment. The perennial flow regime of Meandu Creek downstream of

Meandu Creek Dam, as a result of consistent releases from Meandu Creek Dam, allows for stable and diverse aquatic habitats to occur, which in turn are colonised by a diverse range of macroinvertebrates (including some sensitive and very sensitive taxa), along with aquatic plants, fish and turtles where there is suitable habitat. This confirms that the quality of water released from Meandu Creek Dam, and the sediment quality of the Meandu Creek downstream of Meandu Creek Dam, is suitable for protecting the downstream aquatic ecosystem.

Based on this environmental investigation is no evidence of environmental harm to the environmental values of the Meandu Creek receiving environment as a result of AMD from Meandu Mine.

8.2 RESILIENCE OF AQUATIC COMMUNITIES

Resilience is the capacity of a system to experience shocks while retaining the same basic function, structure and feedbacks, and therefore identity (Walker et al. 2004). The resilience of aquatic communities in Meandu Creek was assessed based on the sensitivity of aquatic communities, values and processes within the waterway to tolerate disturbance events (either long-term permanent changes or to short-term, moderate impacts). Communities consisting of more sensitive taxa are generally less resilient than those comprising more tolerant taxa, as they are more susceptible to changes in the conditions of their environment.

8.2.1 GENERAL RESILIENCE OF AQUATIC COMMUNITIES

Aquatic communities in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) and within Meandu Creek Dam are considered to have high general resilience (i.e. as a response to unforeseen disturbance) as:

- communities present have adapted to changes in the catchment, including dams, diversions, mining and power station activities
- macroinvertebrate communities are relatively diverse and include some sensitive taxa, but are generally dominated by tolerant taxa that are able to withstand harsh environmental conditions
- despite a history of disturbance (from dams, diversions, agriculture, mining and power station activities) in the catchment, the aquatic habitat is generally in moderate health, with some sensitive and long-lived species present (fish)
- species in the region tend to be opportunistic (a typical trait of ephemeral systems) and are able to adapt quickly, colonise rapidly and regenerate when conditions are suitable (e.g. local waterholes can 'seed' disturbed areas when conditions are suitable)
- long lived species (e.g. fish) are present, which tend to be more sensitive to bioaccumulation and habitat changes.

Aquatic communities in Meandu Creek downstream of Meandu Creek Dam are considered to have a moderate general resilience (i.e. as a response to unforeseen disturbance) as:

- communities have historically adapted quickly to long-term changes, including the relatively recent change from an ephemeral to perennial system due the continuous releases from Meandu Creek Dam
- communities have colonised the waterway relatively quickly following the long-term change from an ephemeral to perennial system due the continuous releases from Meandu Creek Dam
- macroinvertebrate communities are diverse and include many sensitive taxa (making them more sensitive to changes in their environment than communities dominated by tolerant species)
- despite a history of disturbance (from dams, diversions, agriculture, mining and power station activities) in the catchment, the aquatic habitat is in good health, with many sensitive and long-lived species present (fish and turtles)
- species in the region tend to be opportunistic and are able to adapt quickly, colonise rapidly and regenerate when conditions are suitable (e.g. local waterholes can 'seed' disturbed areas when conditions are suitable)
- a diverse range of long lived species are present (e.g. fish and turtles), which tend to be more sensitive to bioaccumulation and habitat changes.

8.2.2 *SPECIFIC RESILIENCE OF COMMUNITIES TO CURRENT CONDITIONS*

Communities both upstream and downstream of Meandu Creek Dam are resilient to disturbance from the current Meandu Mine and the Tarong and Tarong North power stations activities, with aquatic communities adapted to the ambient water quality, sediment quality and habitat conditions (particularly to high electrical conductivity and high concentrations of some metals in the water and sediment which were recorded in Meandu Creek adjacent to the mine).

Overall, aquatic communities of Meandu Creek downstream of Meandu Creek Dam have a high specific resilience (i.e. as a response to a specific disturbance) to current mining and power station activities as they have previously shown rapid adaption and colonisation following changing conditions and are generally in a similar or better condition than would be expected in the broader catchment.

8.3 FUTURE POTENTIAL IMPACTS TO THE ENVIRONMENTAL VALUES OF MEANDU CREEK

As identified in the grounds of the Notice, the department has determined that investigations are required to determine the potential for AMD-related environmental harm (acute and/or chronic impacts on aquatic ecosystems and other relevant WQOs) that could occur from future (ongoing) activities at Meandu Mine, including potential impacts from:

- build-up of metals in sediment downstream of Meandu Creek Dam
- elevated metal concentrations in Meandu Creek waters
- alteration of the pH of Meandu Creek Dam waters and release of sediment-bound contaminants to the downstream environment
- elevated salinity levels in Meandu Creek waters.

Each of these are discussed in the following sections.

8.3.1 *BUILD-UP OF METALS IN SEDIMENT DOWNSTREAM OF MEANDU CREEK DAM*

The results of the current assessment suggest that the greatest build-up of metals in sediment is occurring within Meandu Creek upstream of Meandu Creek Dam (in the channel between CP3 and the dam) and within Meandu Creek Dam. Currently at site CM2, upstream of the dam, these metals may be bioavailable to aquatic flora and fauna, as indicated by results from the April 2018 survey). This site is in the reach of Meandu Creek that widens into Meandu Creek Dam, it also contains a high abundance of instream Cumbungi rushes. A combination of these factors is likely resulting in the baffling of fine sediments and particles out of the water column and into the creek bed at this site. Further downstream of Meandu Creek Dam, while sediment-bound metals are settling in some areas, this is restricted to reaches close to (i.e. within 500 m of) Meandu Creek Dam, and the results of the April 2018 survey indicated these metals are unlikely to be bioavailable to aquatic flora and fauna. The results of aquatic flora and fauna surveys also demonstrate that this is not resulting in negative impacts to the environmental values of the receiving environment.

The chemistry of the water overlying the sediment plays a large role in determining whether sediment-bound metals are released into the water column; in particular, the pH, electrical conductivity and hardness of water. . Under current water chemistry conditions, there is no evidence of negative impacts to the environmental values of Meandu Creek. Therefore, ongoing monitoring of relevant water quality parameters in line with the Meandu Mine EA (EPML00709113) and Tarong and Tarong North power stations EA (EPPR00971913), including the Meandu Creek REMP, will be sufficient to protect the environmental values of Meandu Creek and no impacts to environmental values are anticipated.

8.3.2 ELEVATED METAL CONCENTRATIONS IN MEANDU CREEK SURFACE WATERS

The concentrations of dissolved metals in the Meandu Creek receiving environment were equal to or below the relevant WQOs during the field assessment, and are therefore unlikely to be toxic to aquatic flora and fauna. The results of aquatic flora and fauna surveys confirm this, with no impacts detected to communities in the receiving environment.

Provided that water quality is monitored into the future, and concentrations of metals and metalloids remain below the relevant WQOs and/or within the historical range, no future impacts from elevated metal concentrations in Meandu Creek surface waters are expected.

8.3.3 CHANGES TO THE PHYSICAL WATER QUALITY IN MEANDU CREEK DAM

The Notice discusses the potential for *alteration of the pH of Meandu Creek Dam waters and release of sediment-bound contaminants to the downstream environment*. Long-term impacts to pH as a result of AMD from Meandu Mine have not been noted as part of this environmental investigation in the surface waters of Meandu Creek upstream of Meandu Creek Dam, or in the dam. This is a result of the current monitoring and management of pH on-site. Further, as release water from Meandu Mine moves downstream, it is diluted with the large volume of water in Meandu Creek Dam. The pH of water downstream of Meandu Creek Dam is thus likely to be mainly influenced by the Tarong and Tarong North power stations.

The very high hardness of water in Meandu Creek (including upstream of, within and downstream of Meandu Creek Dam) is likely having a protective effect on aquatic flora and fauna by reducing the toxicity of some metals. Where the water hardness continues to be monitored and managed to remain within the historical range in Meandu Creek downstream of Meandu Creek Dam, an increase in the toxicity of metals in water is not expected to occur.

Where pH, electrical conductivity and water hardness continue to be monitored and managed to remain within the acceptable range (i.e. EA (EPML00709113) limits / WQO range), the release of sediment-bound contaminants to the water column in Meandu Creek downstream of Meandu Creek Dam is not expected to occur.

8.3.4 ELEVATED SALINITY LEVELS IN MEANDU CREEK SURFACE WATERS

Provided that discharges from Meandu Creek Dam do not cause sudden and drastic increases or decreases to the electrical conductivity in Meandu Creek downstream of Meandu Creek Dam, it is unlikely that the aquatic ecosystem (that has adapted to the current electrical conductivity range) will experience any acute or chronic effects. Electrical conductivity levels in the water released from Meandu Creek Dam are currently monitored and managed through the EA (EPPR00971913) for the Tarong and Tarong North power stations. Gradual increases in the electrical conductivity of water released from Meandu Creek Dam are permitted under EA (EPPR00971913) in response to drought conditions, when the electrical conductivity of water sourced from Wivenhoe and Boondoomba dams is expected to increase. A number of studies and investigations have been completed to confirm that a gradual increase in electrical conductivity levels in the receiving environment downstream of Meandu Creek Dam will not result in environmental harm, and that releases of water with high electrical conductivity under drought conditions are more beneficial to the environmental values of this reach than ceasing releases altogether (IMEMS 2016). Further, increased monitoring is triggered during drought conditions to assess any impacts to environment values of Meandu Creek associated with elevated electrical conductivity levels.

8.4 MEASURES TO PREVENT FUTURE POTENTIAL IMPACTS

The current study is considered sufficient in confirming that AMD is not having a negative impact on the environmental values of Meandu Creek. Long-term, ongoing monitoring of water quality parameters (as such pH, water hardness and electrical conductivity) consistent with the Meandu Mine EA (EPML00709113) and Meandu Creek REMP is recommended, in order to detect potential impacts in future. This includes:

- Ongoing monitoring of key physico-chemical water quality parameters, including pH and electrical conductivity, in the vicinity Meandu Mine, including at the Meandu Creek Dam discharge point and pH, hardness and electrical conductivity in Meandu Creek downstream of Meandu Creek Dam. Frequency and monitoring locations vary for each parameter, but are considered sufficient in detecting any substantial changes to water chemistry that could result in increasing effects of metal concentrations in water quality on aquatic flora and fauna in Meandu Creek downstream of Meandu Creek Dam. Where a potential impact is detected, additional monitoring and response will be triggered.
- Three-yearly monitoring of sediment quality, particularly of metals which are potentially indicative of AMD and were above the SQGV in March 2017 and April 2018 immediately downstream of Meandu Creek Dam. Where a potential impact is detected, additional monitoring and response will be triggered.
- Three-yearly monitoring of macroinvertebrate communities, which act as biological indicators of aquatic ecosystem health. Quantitative sampling at each site allows for more rigorous statistical analyses that can be used to detect any potential adverse impacts in the receiving environment.

As a management action (refer to Section 10), Stanwell will update the REMP to include all key indicators for AMD. To do this, monitoring the concentration of iron and manganese in the water quality and the concentration of cobalt, iron and manganese in the sediment will be incorporated into the Meandu Creek REMP.

Where pH or electrical conductivity change and are outside the WQOs or historical range, and / or water hardness decreases so that it is no longer considered to be moderately hard, an additional investigation procedure will be triggered, as per the requirements in the Meandu Mine EA (EPML00709113) and Meandu Creek REMP.

Meandu Creek upstream of the dam (adjacent to the mine) is managed for the industrial use environmental value, which does not include specific limits for the concentrations of metals and metalloids designed to protect aquatic ecosystem values. This area is also managed to protect the aquatic ecosystem values of Meandu Creek downstream of the dam, which currently shows no evidence of negative impacts to environmental values as a result of AMD. As discussed above, where current water quality conditions (particularly pH, electrical conductivity and hardness) remain the same, future impacts are considered unlikely. However, there is a build-up of metals (particularly nickel and zinc) in sediment in the channel between CP3 and the dam (detected at site CM2), which may be related to AMD. While Meandu Creek upstream of Meandu Creek Dam is not managed to protect aquatic ecosystem values, further lines of evidence to determine the acute or chronic toxicity of sediment at site CM2 could be considered to understand the toxicity at this site. In accordance with the *Revision of the Sediment Quality Guidelines* (Simpson et al. 2013), the following lines of evidence could be assessed:

- Direct toxicity tests (three tests, including one whole sediment test)
- The concentration of metals in local biota tissue to assess bioaccumulation (this has been previously completed at Meandu Creek Dam, however metal concentrations in sediment at site CM2 are higher than those in the dam).

8.5 CONCLUSIONS

There is currently no evidence of negative impacts to the environmental values of Meandu Creek as a result of AMD from Meandu Mine. Overall, aquatic ecological communities in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam. Water quality conditions, including hardness and pH, are likely to be reducing the toxicity of metals in water. Further, metals in sediments in some areas of Meandu Creek downstream of Meandu Creek Dam are likely to be immobilised by the availability of sulfides and are unlikely to cause acute or chronic toxicity to aquatic flora and fauna. Where water quality conditions remain unchanged (i.e. remain within the historical range and / or comply with WQOs where applicable, and are monitored and managed in accordance with the current EA (EPML00709113) and/or Meandu Creek REMP), no further lines of investigation are considered necessary to prevent environmental harm on aquatic environmental values occurring from AMD at Meandu Mine.

Conditions C5 and C6 of the Meandu Mine EA (EPML00709113) include daily monitoring of pH, turbidity and electrical conductivity and outline contaminant limits for the release points. Controlling these parameters in the release water will minimise the potential for environmental harm in the downstream receiving environment. The Meandu Creek REMP has been prepared to satisfy conditions WT14, WT15, WT16 and WT24 of the Tarong and Tarong North power station EA (EPPR00971913). Relevant to Meandu Mine, this REMP monitors water quality (physical parameters, ions, metals and metalloids) at two sites in Meandu Creek downstream of Meandu Creek Dam and three control (or background) sites weekly to yearly (depending on the parameter). Sediment quality (metals and metalloids) is monitored at eight sites in Meandu Creek Dam, seven sites in Meandu Creek downstream of Meandu Creek Dam and six control sites every three years. Macroinvertebrate communities are monitored at three sites in Meandu Creek Dam, seven sites in Meandu Creek downstream of Meandu Creek Dam as well as four control sites every three years. Water quality objectives, sediment quality trigger limits and investigation procedures (based on those outlined in ANZECC (2000) and Simpson (2013) and including toxicity investigations) are designed to protect the environmental values of Meandu Creek downstream of Meandu Creek Dam. The Meandu Creek REMP is considered sufficient to protect environmental values in Meandu Creek downstream of Meandu Creek Dam. However, key AMD indicators (including concentrations of cobalt, nickel, iron, manganese and zinc) in the water and sediment will be included in the Meandu Creek REMP (refer to Section 10). Overall, given there is currently no evidence of negative impacts to environmental values of Meandu Creek, current monitoring in compliance with the Meandu Mine and Tarong and Tarong North power stations EAs are considered sufficient for ongoing protection of environmental values.

Upstream of Meandu Creek Dam, site CM2 has abundant reeds and fine sediments, and appears to be effectively trapping metals and reducing transportation further downstream. Further monitoring (e.g. toxicity and bioaccumulation) at site CM2 could be implemented to understand the potential impacts at this site.

A summary of investigation outcomes in relation to the relevant surface water quality and aquatic ecology requirements of the Notice are presented in Table 8.1.

Table 8.1 *Summary of surface water quality and aquatic ecology investigation outcomes with respect to Notice requirements*

NOTICE REFERENCE	NOTICE REQUIREMENT	SUMMARY OF INVESTIGATION OUTCOMES
B2 (i) (ii)	The characterise of Meandu Creek must: identify any environmental values (EVs) and water quality objectives (WQOs) scheduled for Meandu Creek under the Environmental Protection (Water) Policy 2009 (EPP Water) if none are identified, propose EVs/WQOs where required for Meandu Creek	There are currently no assigned EVs in Schedule 1 of the EPP (Water) for Meandu Creek. Relevant EVs were assigned from those outlined in Section 6(2) of the policy, with reference to other relevant sources, such as the Burnett Mary WQIP (BMRG 2015), available literature, previous technical reports and field surveys. Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam form part of the water management systems for Meandu Mine and the Tarong and Tarong North power stations, and thus, the industrial use EV was assigned. Current compliance limits outlined in the EAs for Meandu Mine and Tarong and Tarong North power stations are considered appropriate for management of these waters (published WQOs do not apply to this reach). EVs assigned to Meandu Creek downstream of Meandu Creek Dam are: — aquatic ecosystems (moderately disturbed) — irrigation — farm supply — stock watering — human consumption — primary recreation — secondary recreation — industrial use. Published WQOs have been assigned to this reach to manage these EVs. The most stringent WQO (mostly associated with protecting moderately disturbed aquatic ecosystems) was generally assigned.
B2 (iii)	provide a description of the existing qualities, characteristics and resilience of Meandu Creek	Meandu Creek upstream of Meandu Creek Dam, adjacent to Meandu Mine, is an intermittent waterway with several disjointed, non-flowing pools along the channel, and has been diverted in several places. Meandu Creek Dam is a large earth filled constructed dam. Meandu Creek downstream of Meandu Creek Dam exhibits long periods of continual flow from Meandu Creek Dam releases, characteristic of a perennial waterway. Overall, aquatic communities of Meandu Creek downstream of Meandu Creek Dam are highly resilient to current mining and power station activities as they have adapted quickly to changing conditions (ephemeral to perennial waterway) yet contains some sensitive (e.g. macroinvertebrates) and long-lived species such as fish and turtle that are generally sensitive to bioaccumulation or ecosystem changes.

NOTICE REFERENCE	NOTICE REQUIREMENT	SUMMARY OF INVESTIGATION OUTCOMES
(iv)	with reference to items (i) to (iii) above determine the mine-affected water release quality that must be achieved to protect the relevant EVs of Meandu Creek.	There is currently no evidence that mine-affected water is having a negative impact on the environmental values of the receiving environment. Thus, current release conditions within Meandu Mine's EA (EPML00709113) and monitoring requirements outlined in the Meandu Creek REMP are considered sufficient to protect the relevant EVs of Meandu Creek.
B4	Determine whether AMD at Meandu Mine has impacted on or has the potential to impact on the environmental values of surface waters including Meandu Creek. The studies must include:	There is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment. Water quality conditions, including hardness and pH, are likely to be reducing the toxicity of metals in water. Further, metals in sediments in Meandu Creek downstream of Meandu Creek Dam are likely to be immobilised by the availability of sulfide complexes and are unlikely to cause acute or chronic toxicity to aquatic flora and fauna. Where water quality conditions remain unchanged (i.e. remain within the historical range and/or comply with WQOs where applicable, and are monitored and managed in accordance with the current EA (EPML00709113) and/or Meandu Creek REMP), potential AMD impacts on aquatic environmental values are considered unlikely.
(i)	water quality investigations to determine any impacts on environmental values of surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine	The results of historical surface water monitoring completed at Meandu Mine and the Tarong and Tarong North power stations, and of the March 2017 survey, demonstrated that electrical conductivity levels and the concentrations of major ions (including sulfate) and some dissolved metals are higher in Meandu Creek adjacent to and downstream of Meandu Mine than at comparative sites within the region. This may be indicative of an AMD-related impact; however, other factors such as operation of the Tarong and Tarong North power stations and catchment inputs also influence some of these parameters. Regardless of this, based on the information presented in this report, there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment.

NOTICE REFERENCE	NOTICE REQUIREMENT	SUMMARY OF INVESTIGATION OUTCOMES
(ii)	water quality investigations to determine future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine	Future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine are considered unlikely given: — There is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment. — AMD issues at Meandu Mine will be managed through the implementation of changes to the mining and placement of mined materials. This includes initial measures including interim lime-dosing and changes to monitoring and operations. Further changes are potentially required to the way mining, mine waste, mine water, landform design and rehabilitation are managed at Meandu Mine. — Water quality will continue to be managed in line with the Meandu Mine and Tarong and Tarong North power stations EAs, including compliance monitoring and the Meandu Creek REMP.
(iii)	identify short-term and long-term measures including (if relevant) further lines of investigation, monitoring requirements, and operational or mine planning measures that should be developed and/ or implemented to prevent environmental harm occurring from AMD at Meandu Mine.	In addition to long-term and short-term commitment to managing AMD at Meandu Mine, the following measures are recommended: — include key AMD indicators in the Meandu Mine REMP — further assess the toxicity of metals at site CM2 (downstream of release point CP3 and upstream of Meandu Creek Dam) in line with the <i>Revision of the Sediment Quality Guidelines</i>, including further sediment toxicity test and bioavailability testing at site CM2.

9 INTEGRATED WATER MODEL

SECTION OVERVIEW

This section summaries development of and results from the Integrated Water Model (the model) developed by Golder Associates Pty Ltd (Golder) to predict potential AMD impacts from the Meandu Mine. It specifically addresses Requirement B5 of the Notice. Components of the model have been developed as a collaborative process using input from technical specialists as outlined in Table 9.1.

Table 9.1 *Technical specialist input into development of the Integrated Water Model*

NOTICE REQUIREMENT	TECHNICAL INPUT
<i>B5i) a material model (based on geochemical characterisation)</i>	<i>RGS</i>
<i>B5ii) mine water modelling that takes into account surface water, groundwater and in pit and in mine spoil water</i>	<i>JBT Consulting; Stanwell</i>
<i>B5iii) potential contaminant pathways</i>	<i>JBT Consulting; RGS</i>
<i>B5iv) capacity to predictively model acid production at Meandu Mine</i>	<i>RGS</i>
<i>B5v) capacity to predictively model water quality impacts from AMD on groundwater and Meandu Creek</i>	<i>Golder</i>
<i>B5vi) capacity to predictively model the dissolution and transport of metals to the receiving environment from Meandu Mine.</i>	<i>RGS; Stanwell</i>

Full details of the model development, inputs and assumptions, calibration, verification against measured data and baseline results are provided in Appendix H.

The purpose of the model is to:

- Simulate the surface water, groundwater and geochemical components of the Meandu Mine environment to estimate the AMD potential based on the 2017 Life of Mine Plan developed by Xenith Consulting, which depicts mine operations and development from 2016 to a nominal closure date of 2037 (the base case)
- Apply the predictive model as a tool to trial engineering controls and management measures, where required, to mitigate potential AMD impacts (scenario trials).

The model is a representation of the Meandu Mine water management network developed to predict long-term trends. It estimates the quantity and quality of water stored, transferred and discharged, over the life of mine up to and including closure. It also provides a water balance within the model boundary which is the extent of the catchments reporting to the model components along with an indication of changes in water quality (mass balance of key analytes). Being a predictive decision-support tool the model is subject to certain limitations (refer Section 9.1.6). The model will be subject to further verification in response to mine progression and operational changes.

9.1 MODEL OVERVIEW

9.1.1 GOLDSIM SOFTWARE

The Integrated Water Model has been developed in GoldSim (Version 12.0 – GoldSim Technology Group 2018) to predict potential AMD impacts from the Meandu Mine. GoldSim is used globally to simulate dynamic systems, to understand the factors which control the system and to forecast future behaviour.

Model simulations are run generally on daily time-steps over an identified simulation period with one or multiple realisations. A realisation is defined as a single model run under one set of stochastic inputs. The purpose of using multiple realisations is to test the system under multiple rainfall or other input patterns.

9.1.2 *EXTENT OF THE MODEL*

9.1.2.1 *SPATIAL EXTENT*

The spatial extent of the model incorporates all elements of Meandu Mine bounded by: Meandu Creek Dam and CP2 to the north; Meandu Creek to the west; the extent of the mine catchment to the east; and the extent of the Meandu Creek catchment to the south.

Elements represented within the model boundaries include:

- Water reservoirs (dams, tailings storage areas, ash storage areas, operating pits, decommissioned pits, and backfilled pits).
- Inflows (rainfall, catchment runoff, water in tailings, water in ash, pumped water between mine dams, pumped inflows across model boundaries, seepage, groundwater inflow to deep pits, and mine impacted water expressed from backfilled pits).
- Outflows (evaporation, overflows from water storages, seepage, pumped water between mine dams, pumped outflows across model boundaries, truck-fill water use, and mine impacted water expressed from backfilled pits)
- Meandu Creek streamflow.

A high level container view of site features represented in the model is shown in Figure 9.1.

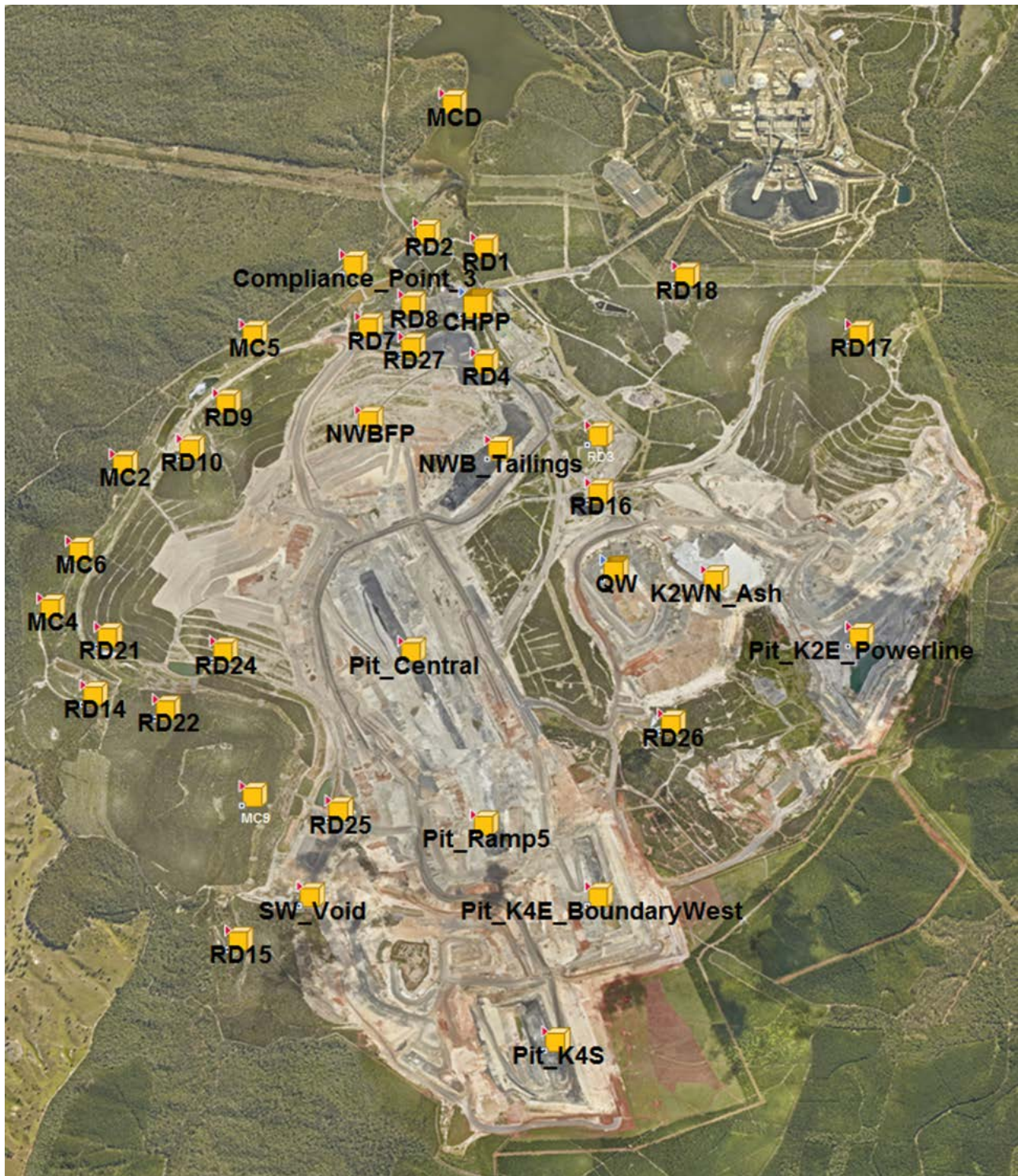
9.1.2.2 *TEMPORAL EXTENT*

The model simulations use a daily time-step for the period 2016 to 2050 (post closure) for three rainfall record scenarios (i.e. a low rainfall data record, a median rainfall data record and a high rainfall data record). Rainfall records are based on SILO data drill 120 year synthetic rainfall data records for the location of Meandu Mine. Rainfall records used for the simulation are described further in Section 9.2.4.1.

Changes in the model components from progression of the mine (such as, changes in material placement and related changes in catchments or rehabilitation) are applied according to the 2017 Life of Mine Plan in a step-wise manner for the years 2016, 2018, 2019, 2020, 2022, 2024, 2027, 2029, 2032, and 2037 (model reference years).

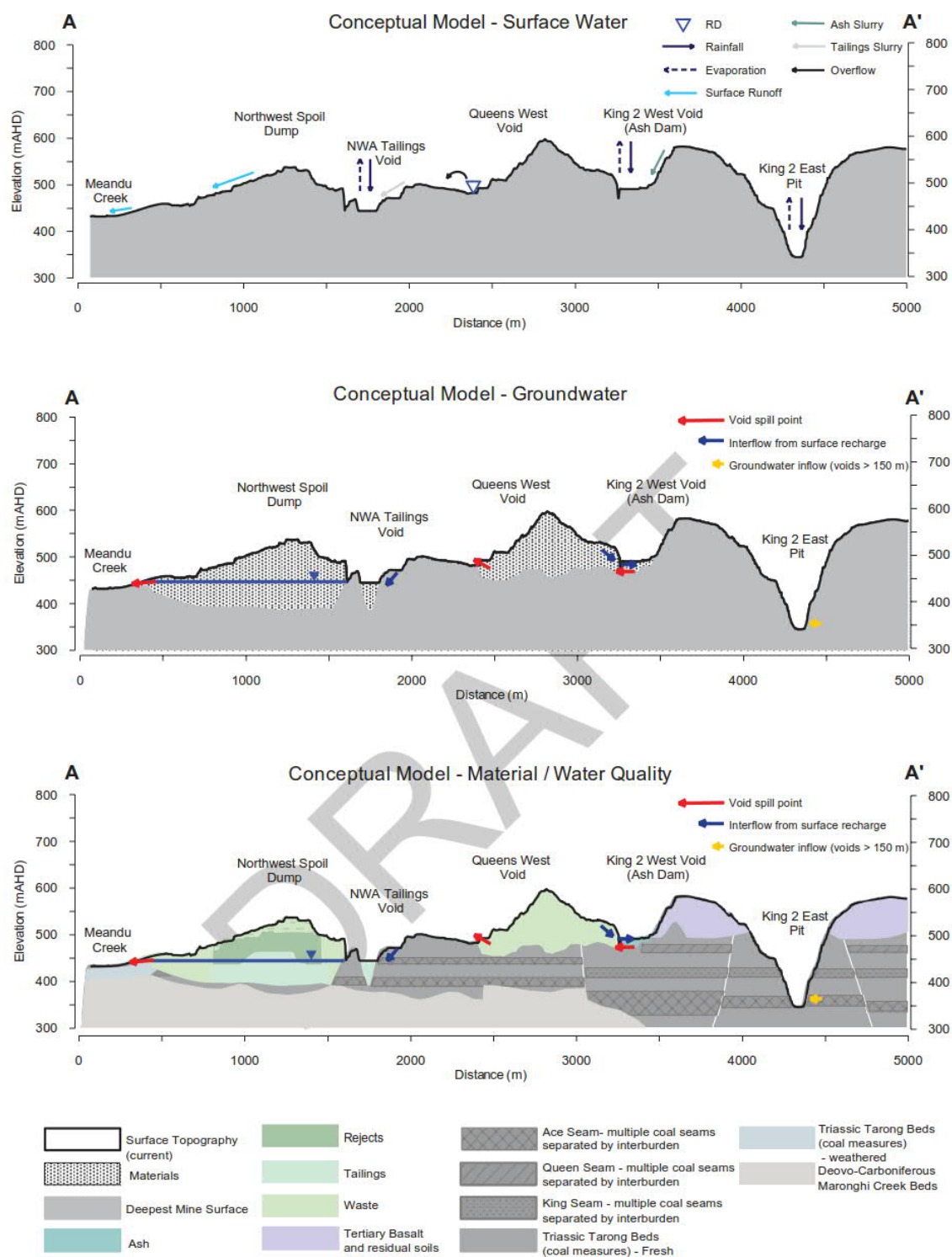
9.1.3 *MODEL DEVELOPMENT*

Prior to development of the Integrated Water Model in GoldSim, three model conceptualisations (representing surface water, groundwater and materials/ water quality) were prepared in collaboration with JBT Consulting, RGS and Stanwell. The conceptual models are shown as arbitrary 2D cross-sections of the modelled 3D network. Schematics of the inflows and outflows represented in each conceptual model are provided in Figure 9.2 with information on each conceptual model provided in the following sections. The integration of the conceptual models provided the framework for subsequent development of the Integrated Water Model.



(Source: Golder 2018) (Appendix H)

Figure 9.1 High-level container view of site features represented in the model



Source: Golder 2018 (Appendix H)

Figure 9.2 Surface water, groundwater and materials/water quality conceptual models

9.1.3.1 SURFACE WATER CONCEPTUAL MODEL

The surface water module developed within the Integrated Water Model represents the surface water features within the model spatial extent. It includes representation of all features that will retain water including water storage dams, raw water dams, retention dams, tailings voids, ash voids, active pits, and inactive voids. Inflows to the surface water model include rainfall and runoff, water retained in tailings and ash, and water expressed at the surface from water retained in below-surface voids.

The surface water conceptual model includes the detail and features found in a mine water balance, using the site layout described in the 2017 Life of Mine Plan. Surface features within the Meandu Mine are dynamic, changing as the mine progresses during operation and closure. Similarly, the model representation of surface water features changes over the life of mine operations and closure.

9.1.3.2 GROUNDWATER CONCEPTUAL MODEL

The groundwater module component of the Integrated Water Model models water contained within, and inflows to and outflows from, the particle void spaces of materials in historical mining voids (mine impacted water). The groundwater module includes representation of historical mine voids as shown in Figure 9.2. Each void has an associated elevation-mine impacted water storage capacity relationship and a spill point from where (when “overflowing”) mine impacted water enters the surface water conceptual model domain as water expressed from below-surface backfilled voids.

Other flows within the groundwater conceptual model include seepage flow into waste deposition areas from surface recharge during rainfall and groundwater inflow to deep mining pits.

9.1.3.3 MATERIALS / WATER QUALITY CONCEPTUAL MODEL

The third module within the Integrated Water Model represents the water quality components. Each of the materials within the below-surface placed materials and the units in the overburden will have different acid and salinity generating potential in the water associated with them. Additionally, over time the acid and salinity generating potential of a material changes.

AMD drainage potential in the materials and overburden have been modelled as vectors of elements attached to each of the materials, overburden and water flows in the surface and groundwater modules. The material and water quality components of the model are detailed in Section 9.2.7.

Water quality has been modelled in the Integrated Water Model using a mass balance mixing model approach, that is, by dilution or concentration of the modelled elements. At any point in time and from any model component (for example, a model component may be the ash void, or overflow from the North-West Backfilled Pit or a retention dam) the mixed solution may be retrieved for further assessment of chemical reactivity.

Material additions occur in a step-wise fashion each month. With each sequential addition of materials an associated step change occurs in quantity and age of materials and the associated water quality.

Material classifications include:

- ash – fly and bottom ash produced at the Tarong and Tarong North power stations through the burning of product coal from Meandu Mine
- rejects – oversized or poor quality material hauled from the CHPP
- tailings – fine fraction washed from the coal in the CHPP that reports to the tailings thickener and is then pumped as a slurry to mined pits (voids) at a solids concentration of 15 to 25%
- waste – side cast waste coal, roof and floor and partings, and over or inter-burden.

9.1.4 MODELLING METHOD AND DEVELOPMENT

Following confirmation of the conceptual models and model specification the Integrated Water Model was developed in GoldSim. Elements representing climate, global parameters and parameters specific to surface water, groundwater and materials/water quality modules have been incorporated, referenced and linked.

Calibration and validation simulations were conducted using measured site data for the period 2016 (calibration) and 2017 (validation). Sensitivity analysis was undertaken for selected results that are influenced by input parameters that are either assumed or uncertain.

The base case model incorporates any control measures that have been implemented by Stanwell prior to 2018 including:

- construction of RD27 and associated infrastructure including lime-dosing from the beginning of 2018
- the change to high density tailings from 2018 removing the tailings slurry flow input into the North-West B TSF and reducing water demand at the CHPP.

Additionally, the base case includes anticipated changes to water infrastructure required during the life of mine to support the 2017 Life of Mine Plan.

9.1.5 GENERAL CAPABILITY AND USE

The model estimates the quantity and quality of water stored, transferred and discharged, over the life of mine up to and including closure. It provides a water balance within the model boundary which is the extent of the catchments reporting to the model components along with an indication of changes in water quality (mass balance of key analytes).

The model has the capacity to forecast:

- water containment in pits and water storages reported in terms of volume and water level
- rates of water transfer and water quantity transferred between storages
- quantity of water released at key discharge locations and compliance points
- quantity of groundwater intercepted by mining pits
- water quality (mass balance of key analytes) of retained water within pits and water storages
- water quality (mass balance of key analytes) at compliance points
- runoff from catchments in response to rainfall and evaporative losses
- changes in flow quantities to the Meandu Mine water infrastructure as a result of operational change and at closure
- the reliability of water supply to the CHPP
- water used at truck fill points.

9.1.6 MODEL LIMITATIONS

The Integrated Water Model is a representation of the Meandu Mine water management network simulated on a daily basis using input data from reference sources and calibrated for a period of time to measured site data. It is designed as a decision-support tool for estimating long-term trends and has the following limitations:

- Operational decisions in mine water management made on a day-to-day basis (such as, turning on/off of pumps to change dewatering supply to retention dams and the CHPP, or emptying and desilting of a retention dam) are not able to be represented in the model.
- Pumped transfers, such as the dewatering of pits and water supply to the CHPP are calibrated to long-term total flow rates and may not represent the day to day variability in supply that occurs due to process operator inputs and scheduled and unscheduled maintenance.
- Water quality is modelled as a mixing model of a group of analytes as they migrate through the system with the flow of water. Chemical reactions between analytes have not been simulated in the model but may be simulated externally to the model for specific locations if required. Further detail about water quality inputs is provided in Section 9.2.7.

9.2 BASELINE MODEL INPUTS AND ASSUMPTIONS

9.2.1 MODEL STRUCTURE AND COMPONENTS

This section provides an overview of the operational processes of the Meandu Mine and mine components represented in the model. The inclusion and connectivity between mine infrastructure will change over time as the mine progresses. As such, two snapshots in time have been provided for components represented in the model – the first being in 2016 at the start of modelling, and the second in 2027 once mining has progressed to the east in accordance with the 2017 Life of Mine Plan. Components of the modelled system for 2016 include:

- Active mining pits - Central, Ramp 5, K4E (Boundary), K4S and K2E
- North-West B TSF
- Ash storage facility (K2W-N)
- Retention dams (RD1, RD2, RD3, RD4, RD7, RD8, RD9, RD10, RD14A, B and C, RD15B, RD16, RD17A and B, RD18, RD21, RD22B, RD24, RD25 and RD26)
- Out of pit dumps (North-West Backfilled Pit and Queen West)
- Meandu Creek ponds (MC2, MC4, MC5, MC6 and MC9)
- Meandu Creek Dam
- Compliance points (CP1, CP2, CP3 and CP4)
- Truck fill locations (Central, K4S, Sparrows and RoM)
- CHPP
- Catchments reporting to pits and retention dams
- South West void
- Pumped and piped or spillway connections between pits and retention dams and between retention dams.

As the mine progresses in accordance with the 2017 Life of Mine Plan, the following changes in infrastructure are anticipated and have been assumed in the model:

- The South-West void and K4S fill point will be decommissioned in 2022. The South-West void will be filled and rehabilitated. Once rehabilitated the drainage flow path to the South-West void will become catchment runoff to Meandu Creek at MC9.
- The recently completed RD27 will be operational from 2018.
- Decommissioning of the North-West B TSF will commence in 2018, corresponding to the commissioning of the solid bowl centrifuge that produces dewatered mixed plant rejects. The void will be filled and capped by 2024.
- Central Pit will no longer be active after 2025 and from 2026 it starts receiving ash from the Tarong and Tarong North power stations. K2W–N will be covered and rehabilitated at this time.
- RD26 will be replaced by a new retention dam when it is consumed by K4E (Boundary) Pit.
- K2E is proposed to be active from 2024 in the 2017 Life of Mine Plan. Before this time K2E will store water that is used to top up RD26 or RD2 as required.
- The central fill point will close around 2024, at which time a new fill point of similar capacity will start from the relocated RD26.

Table 9.2 summarises how each of the key mine components has been represented in the model along with key model inputs and assumptions. Additional details are provided in Appendix H.

Table 9.2 *Model representation, inputs and assumptions for key mine components*

MODEL REPRESENTATION AND INPUTS	
Pits:	Represented as a “reservoir” element in the model with inflow, outflow and geometry modules. Changes in pit shape and size over the life of mine is represented in the model using 2D lookup tables for the model reference years and post closure. The model linearly interpolates elevation-area-storage information for years not included in the 2D lookup tables. Pit water inflows: — catchment runoff including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces that will report to the pit void — direct rainfall (direct to the surface of retained water in the active pit sump or water held in an inactive pit water storage) — surrounds runoff (rainfall that falls within the dynamic area of an active pit) — seepage from waste (spoil and rejects) — pumped transfers in from other pits (for example, water transferred from Ramp 5 Pit sump to Central Pit sump) — groundwater inflow. Pit water outflows: — Evaporation (from the surface of retained water in the active pit sump or water held in an inactive pit water storage) — Seepage (seepage from retained water in the active pit sump or water held in an inactive pit water storage) — Dewatering active pits or pumped transfers from water stored in inactive pits.
Retention Dams:	Represented in the model as a “reservoir” element. The geometry module for retention dams includes capacity, surface area, maximum water level, and water depth. Elevation-storage-area details of each storage have been calculated at 0.5 m increments from the information provided, assuming a standard square pond geometry. Water inflows: — direct rainfall (to the water surface) — surrounds runoff (rainfall to the remaining area of the water storage at the crest of the dam) — catchment runoff including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces — pumped water transfers received by a retention dam — overflow received from other retention dams. Water outflows: — evaporation (directly from the water storage) — seepage (seepage from retained water in the retention dam storage) — truck fill points for water for dust suppression — pumped transfers — overflows.

MODEL REPRESENTATION AND INPUTS	
Meandu Creek Dam:	Elevation-area-storage for Meandu Creek Dam was obtained from bathymetric survey data at 0.1 m elevation increments measured in February 2014. The spillway invert elevation used in the model is RL418.1 mAHD. Water inflows: — direct rainfall (to the water surface) — surrounds runoff (rainfall to the remaining area of the water storage at the crest of the dam) — catchment runoff (to the catchment including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces) — overflow from CP3 (the receiving point for discharge from Meandu Creek and Meandu Mine) — cooling water blowdown inflow from Tarong Power Station (W1) and Tarong North Power Station (W4) (measured data received from Stanwell for the period January 2016 to January 2018) Water outflows: — evaporation (directly from the water storage) — seepage — flow release at location W3 for the period January 2016 to January 2018, with the assumed future flow release being the monthly average of the two years of historical record.
North-West Backfilled Pit:	The North-West Backfilled Pit is represented in the model as a reservoir with an elevation-area-storage relationship assuming a 30% available pore space for water within the deepest mined surface. Further detail on the North-West Backfilled Pit is provided in Section 9.2.1.1.
North-West B tailings:	The North-West B TSF is modelled to receive tailings slurry until 2018 at which stage there is no longer a wet process outflow stream (the solid bowl centrifuge commences operation in 2018). During the process of rehabilitation (up to 2022), a void remains that is subject to rainfall, evaporation and seepage; however, pumping return from the North-West B TSF ceases in 2018. The capacity of the TSF was obtained from bathymetric survey data. It has been assumed that 20% of the total area is available for storage of decant water. Water inflows: — direct rainfall (to the water surface) — surrounds runoff (rainfall to the remaining area of the water storage at the crest of the decant) — catchment runoff (including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces of the catchment that reports to the tailings storage) — supernatant inflow (calculated based on a slurry inflow of 122 tonne/hour (from Plant Information Management System (PIMS) data records), slurry weight percentage of 45% (from CHPP water balance assumptions), and a residue dry density of 0.83 tonnes/m³ (from PIMS data records). Water outflows: — evaporation (from the decant water surface) — pump transfer — seepage to the North-West Backfilled Pit (based on a head-discharge relationship developed in SEEP/W) (refer Section 9.2.1.1).

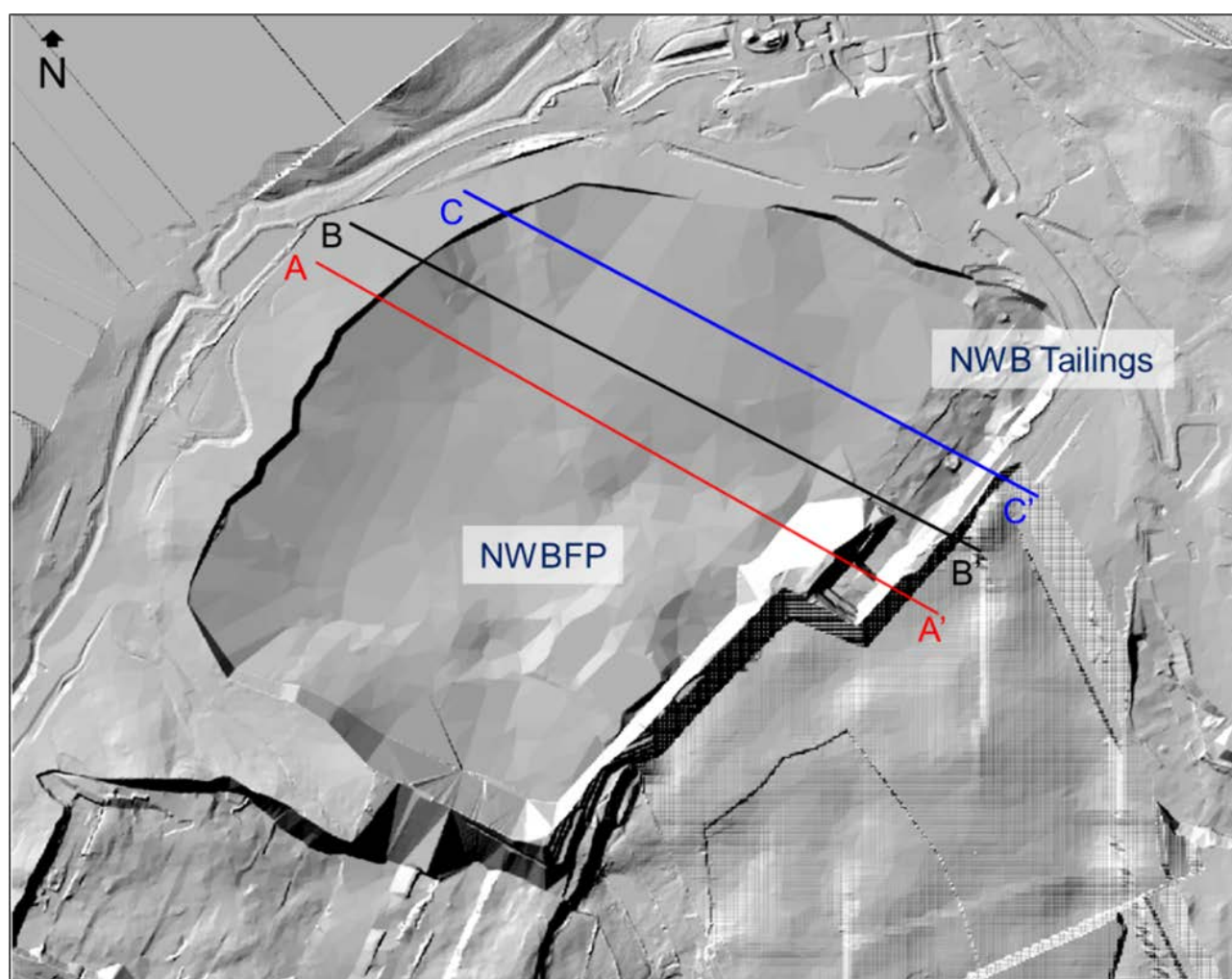
MODEL REPRESENTATION AND INPUTS	
K2W-N Ash Void:	Ash has previously been deposited into the K2W Pit and is currently being deposited into the K2N Pit. The elevation of the ash in both pits meet at approximately RL490 mAHD. The void of the combined pit (designated K2W-N) is represented in the model as a reservoir with an elevation-area-storage relationship. The void receives tailings slurry until 2026 after which, rehabilitation commences. Water inflows: — direct rainfall — surrounds runoff (rainfall to the remaining area of the water storage at the crest of the decant) — supernatant inflow until 2026, calculated based on provided data including slurry inflow rate (typically 120 tonne/hour); slurry weight percentage of 40%; and residue dry density of 0.83 tonnes/m³. — catchment runoff including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces of the catchment that reports to the ash void. From 2026 onwards, catchment runoff to the ash void comprises an assumed 20% of baseflow, with the remainder of baseflow and all surface runoff reporting to RD16. Water outflows: — evaporation — pump transfer to Tarong Power Station — seepage into the basement rock.
Queen West Dump:	Water inflows to the Queen West out of pit dump include: — infiltration (from rainfall) through the waste material — seepage from saturated ash (slurry) deposited in the K2W-N void. Infiltration from rainfall is the baseflow component determined by the rainfall runoff model Australian Water Balance Model (AWBM). The rate of seepage from K2W-N to Queen West during and after the deposition of saturated ash has been provided by groundwater modelling (Golder 2017a). Water outflows: — seepage collected in adjacent sumps and returned to the Tarong Power Station.
Environmental Monitoring Locations (CP3, CP1 and CP2):	CP3 weir receives water from Meandu Creek upstream of Meandu Creek Dam and upstream of Meandu Mine. CP3 weir also receives mine affected water as overflow from RD2 and RD8. There is a pond of 1 ML capacity represented in the model immediately upstream of CP3 weir and water quantity and quality at CP3 is reported from the overflow of this pond. The pond elevation-storage-area curve has been estimated based on a 1 ML pond of 1 m depth. CP1 is within Meandu Creek Dam. In the model water quantity and quality at Meandu Creek Dam is also reported as representative of CP1. CP2 is location at the outflow of RD17. Results are available in this location in the model as required.

9.2.1.1 NORTH-WEST BACKFILLED PIT

The North-West Backfilled Pit is represented in the model as a reservoir with an elevation-area-storage relationship assuming a 30% available pore space for water within the deepest mined surface. Seepage discharge from the North-West Backfilled Pit in the location of Bullgang Corner has been conceptualised as originating from the backfilled pit via the following flow sources:

- infiltration from rainfall on the surface of the North-West Backfilled Pit
- seepage of water stored in the North-West Backfilled Pit
- seepage of water from the North-West B TSF through the North-West Backfilled Pit.

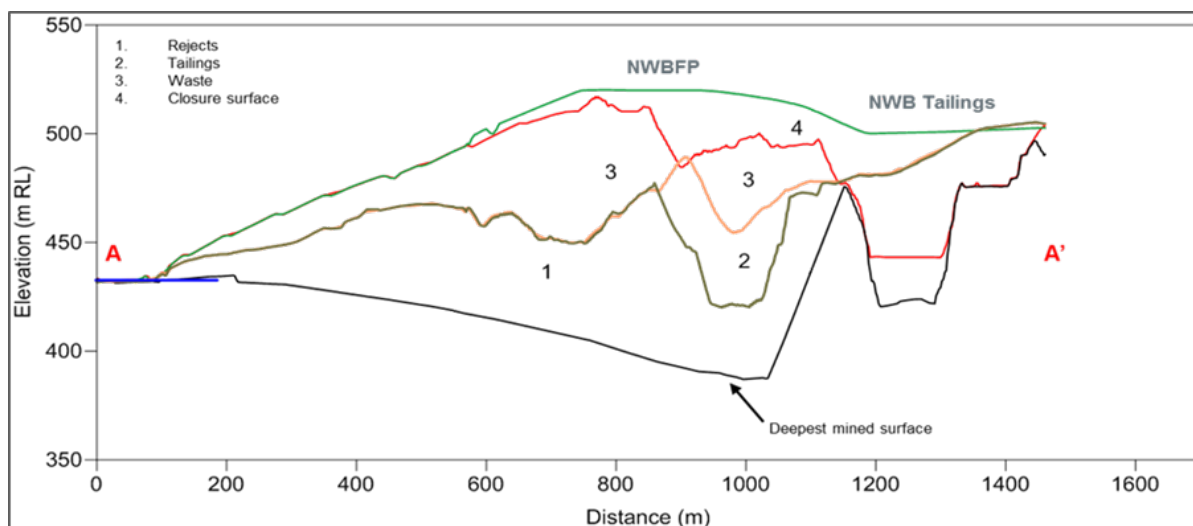
A SEEP/W model was used to estimate the water level – baseflow (seepage) relationship within the North-West Backfilled Pit. SEEP/W is used to analyse groundwater seepage within porous materials such as soil and rock. The groundwater model domain used for the SEEP/W model is based on the deepest mined surface (as shown in Figure 9.3). Cross-sections (2D vertical slices) were generated using historical material deposition data to examine the material distribution within the North-West Backfilled Pit (Figure 9.4).



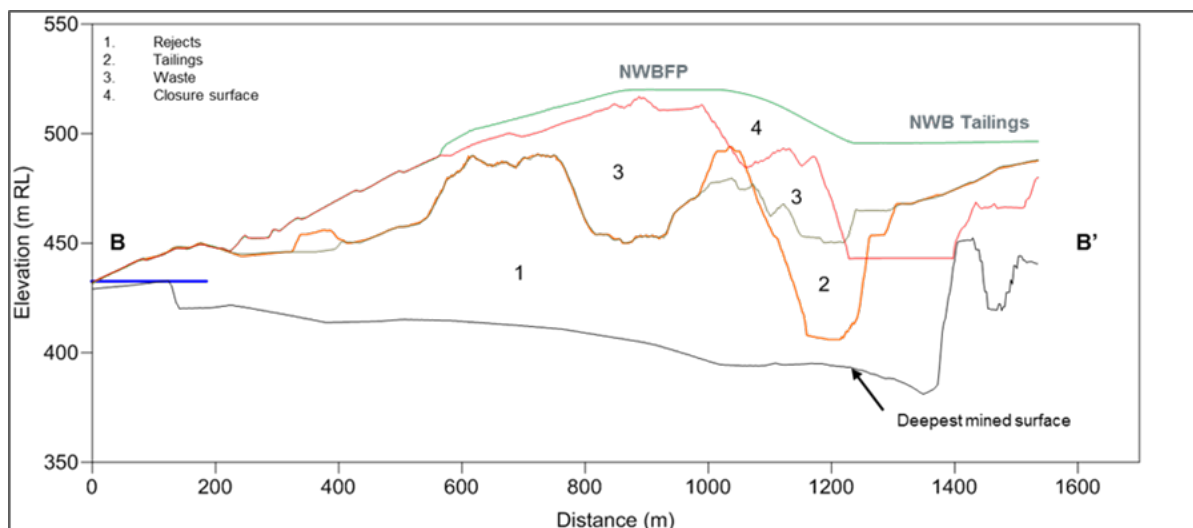
Source: Golder 2018 (Appendix H)

Figure 9.3 Deepest mined surface at North-West Backfilled Pit and North-West B TSF

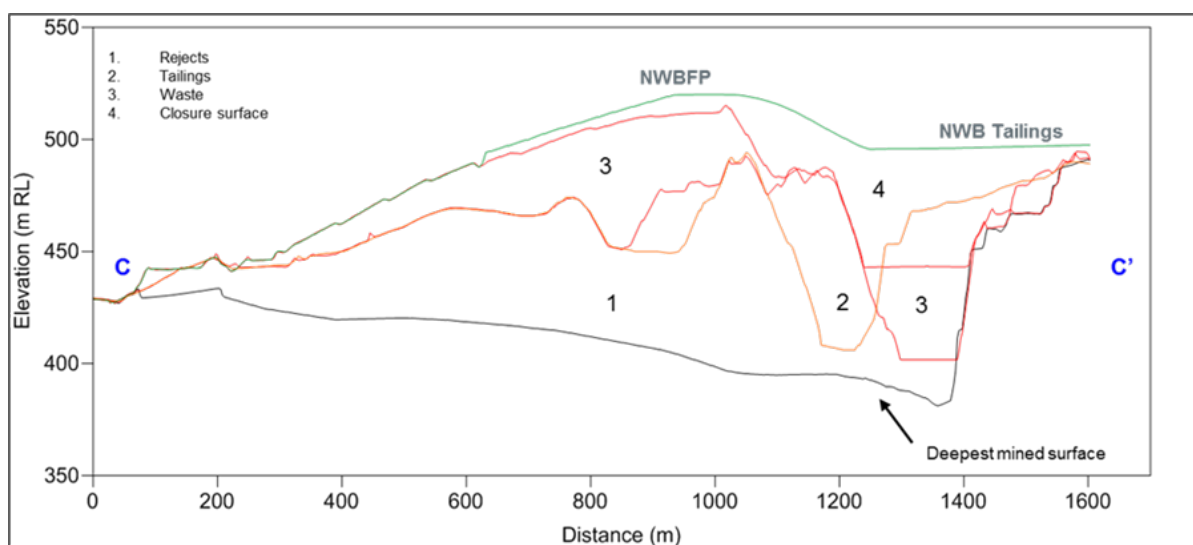
Cross-section AA' shows that the deepest mined surface creates a flow barrier (up to RL475 mAHD) between the North-West Backfilled Pit and the North-West B TSF. Cross-section BB', situated marginally to the north of AA', shows how this barrier reduces in height northwards, until it merges with the deepest mined surface at cross-section CC', allowing potential seepage from the North-West B TSF into the North-West Backfilled Pit.



CROSS-SECTION AA'



CROSS-SECTION BB'



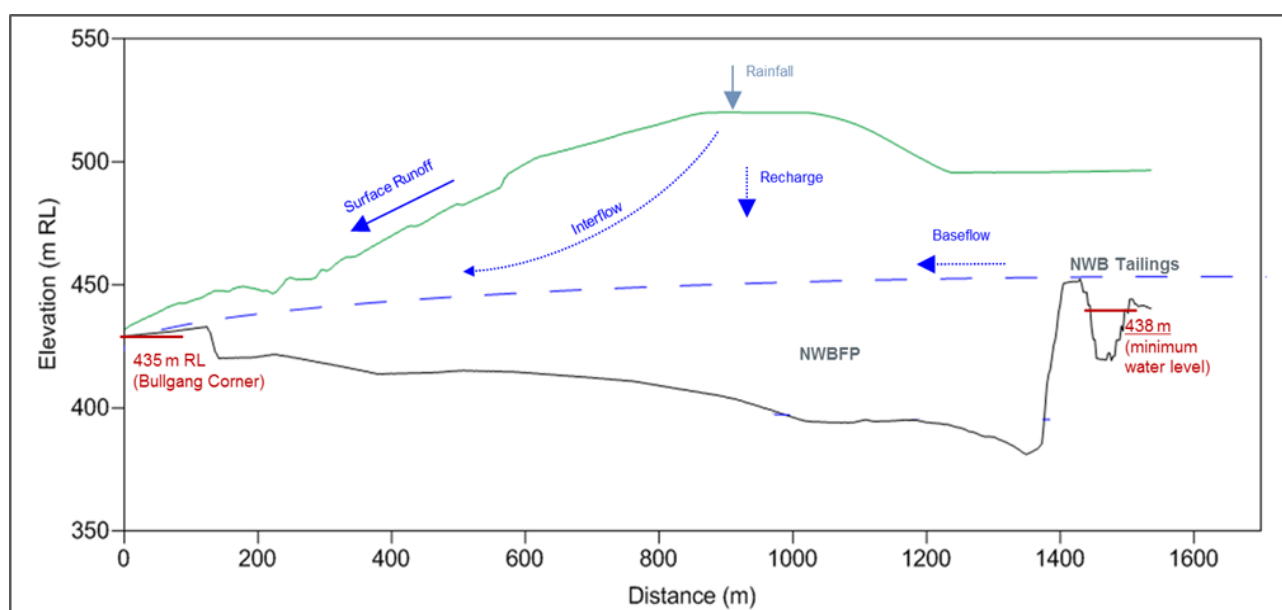
CROSS-SECTION CC'

Source Golder 2018 (Appendix H)

Figure 9.4 North-West Backfilled Pit cross-sections

Conceptualisation of the flow components within the North-West Backfilled Pit that comprise seepage to Bullgang Corner is shown in Figure 9.5 and described as follows:

- The decant water in the North-West B TSF specifies a (groundwater level) boundary condition at that end of the cross-sectional model. The boundary condition prescribes a corresponding “base” water level within the North-West Backfilled Pit which determines a baseflow out of the pit at the tipping point. North-West B TSF is modelled to receive tailings slurry until 2018; and is then in the process of rehabilitation until 2022.
- Additionally, rain falling on the surface of the North-West Backfilled Pit separates into surface runoff, interflow and recharge to the water level within the pit. Recharge to the water level within the North-West Backfilled Pit raises the water level and will therefore increase the base flow component at the tipping point.
- Total seepage flow out of the North-West Backfilled Pit is the sum of interflow and base flow components.



Source: Golder 2018 (Appendix H)

Figure 9.5 North-West Backfilled Pit water flow conceptualisation

The Australian Water Balance Model (AWBM) is used to separate rainfall into surface runoff, interflow and recharge. AWBM separates rainfall into surface runoff and water that infiltrates into the North-West Backfilled Pit. Interflow is then set to be 30% of infiltrated water, with the remainder being recharge to the water level within the North-West Backfilled Pit. The relationship between the water level within the North-West Backfilled Pit and the corresponding base flow component has been estimated by 2D (vertical slice) variably-saturated groundwater flow modelling using cross-section BB' (Figure 9.4) as follows:

- 1 The water level in the North-West B TSF is specified as a constant head boundary condition.
- 2 The corresponding water level in the North-West Backfilled Pit (at the mid-point of the cross-section) was recorded.
- 3 The corresponding rate of seepage at the spill point (or tipping point) at Bullgang Corner was recorded.

The above procedure was repeated using different values for the boundary condition to generate a North-West Backfilled Pit water level – baseflow relationship that could be then used in the water balance model.

9.2.2 CATCHMENT AREAS

Catchment areas (for retention dams, pits, Meandu Creek ponds, CP3 and Meandu Creek Dam) and their sub-catchment land use surfaces (natural, rehabilitated, hardstand, active pit, and waste (spoil and rejects)) have been assessed for stages of the 2017 Life of Mine Plan including the model reference years and post closure.

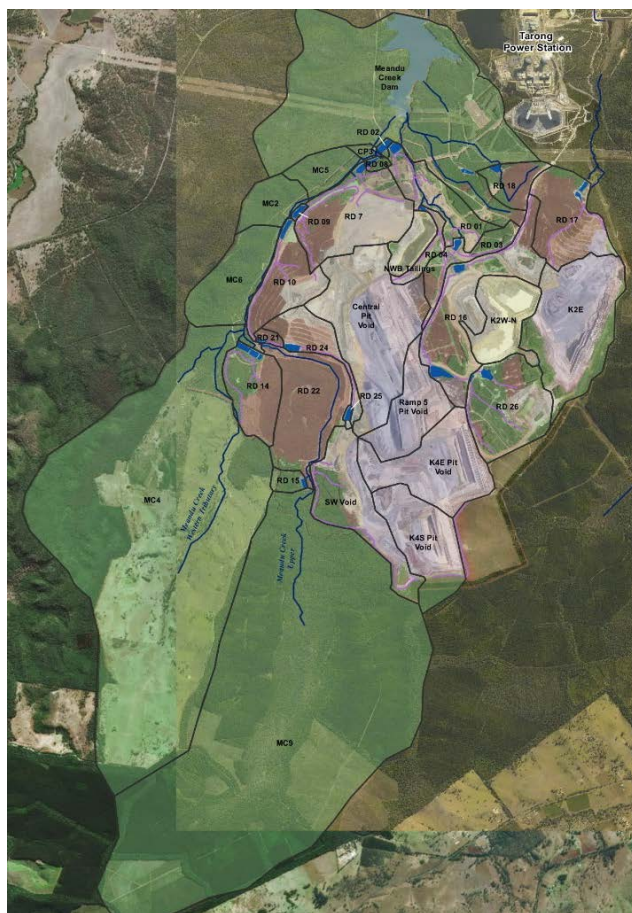
The 2016 catchments and sub-catchments were identified by Stanwell and confirmed using the supplied topographic data and imagery; and with reference to the current Meandu Mine Erosion and Sediment Control Plan (Stanwell 2016). These catchment areas and sub-catchment surfaces were then modified using a spatial mapping and data compilation process in GIS to represent the life of mine. Data used for this assessment included the stage plans, rehabilitation surfaces, and spoil, waste and rejects extent for the life of mine.

In addition, the land use categories for erosion and sediment control planning used by Stanwell were grouped into land use categories with similar runoff characteristics for use in the Integrated Water Model (as shown in Table 9.3).

Table 9.3 *Land use categories*

LAND USE CATEGORY FOR EROSION AND SEDIMENT CONTROL PLANNING	ADOPTED LAND USE CATEGORY FOR RUNOFF CHARACTERISTICS IN THE MODEL
Natural	Natural
Cleared	Natural
Spoil	Waste
Waste	Waste
Rehabilitated	Rehabilitated
Tailings	Tailings
Ash	Ash
Hardstand	Hardstand
Active Pit	Active Pit
Dams	Dams

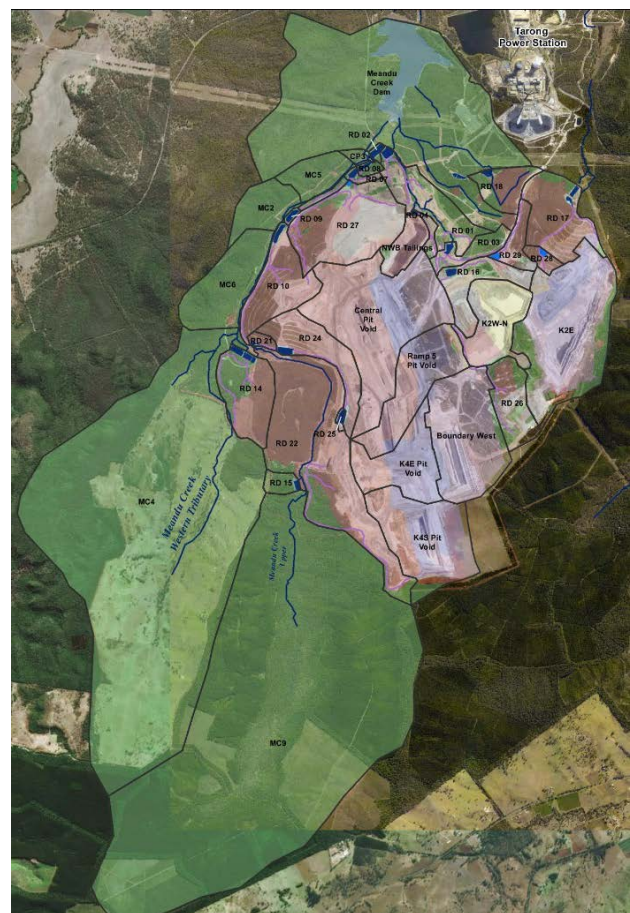
Catchment areas in the model are dynamic and are referenced in a three-dimensional lookup table including catchment, sub-catchment area and year. The catchment areas used for 2016 and 2029 are shown in Figure 9.6. Detailed catchment areas for the life of mine including total of sub-catchment area assigned to each surface land use type is provided in Attachment B of Appendix H.



LAND USE 2016

- ACTIVE PIT
- DAM
- HARDSTAND
- NATURAL
- REHAB
- SPOIL
- TAILINGS
- WASTE

2016



Land Use 2029

- ACTIVE PIT
- DAM
- HARDSTAND
- NATURAL
- REHAB
- SPOIL
- TAILINGS
- WASTE

2029

Source: Golder 2018 (Appendix H)

Figure 9.6 Catchments and sub-catchments (land use) 2016 and 2029

9.2.3 MATERIAL BALANCE

Scheduled annual quantities, AMD classification and dump location of waste, rejects and ash were supplied by Xenith for the 2017 Life of Mine Plan (to 2037). The process of allocating material quantities for the life of mine and the rules applied to the material balance calculations is detailed in Appendix D. The quantity of materials placed in each catchment area was assigned in the model on a monthly basis. Material type and quantity were then used in the assessment of water quality from waste, rejects and ash. The method for assigning water quality parameters to each material type is described in Section 9.2.7.

9.2.4 WATER INFLOWS

Key water inflows include rainfall, catchment runoff and groundwater inflow into pits. The following sections outline how these inflow components have been incorporated into the model.

9.2.4.1 RAINFALL

SILO DATA DRILL

SILO Data Drill (SILO) accesses grids of data interpolated from point observations by the BoM. It relies on measured data from BoM rain gauges to use for interpolation to a specified grid location, such as the Meandu Mine. SILO data is generally preferred for modelling purposes as it provides a site specific continuous and long data record.

SILO data was obtained for the Meandu Mine location. The model user has the option to run the historical data series using a dry climate time series, a wet climate time series for the period 1900 to 2017 (Queensland Government, 2018), a median climate time series or using the 2016, 2017 calibration data record (BoM Station 040199 Tarong).

The SILO rainfall data series are outlined in Table 9.4. Each data series is 34 years in length (that is the period of simulation).

Table 9.4 *SILO rainfall data series*

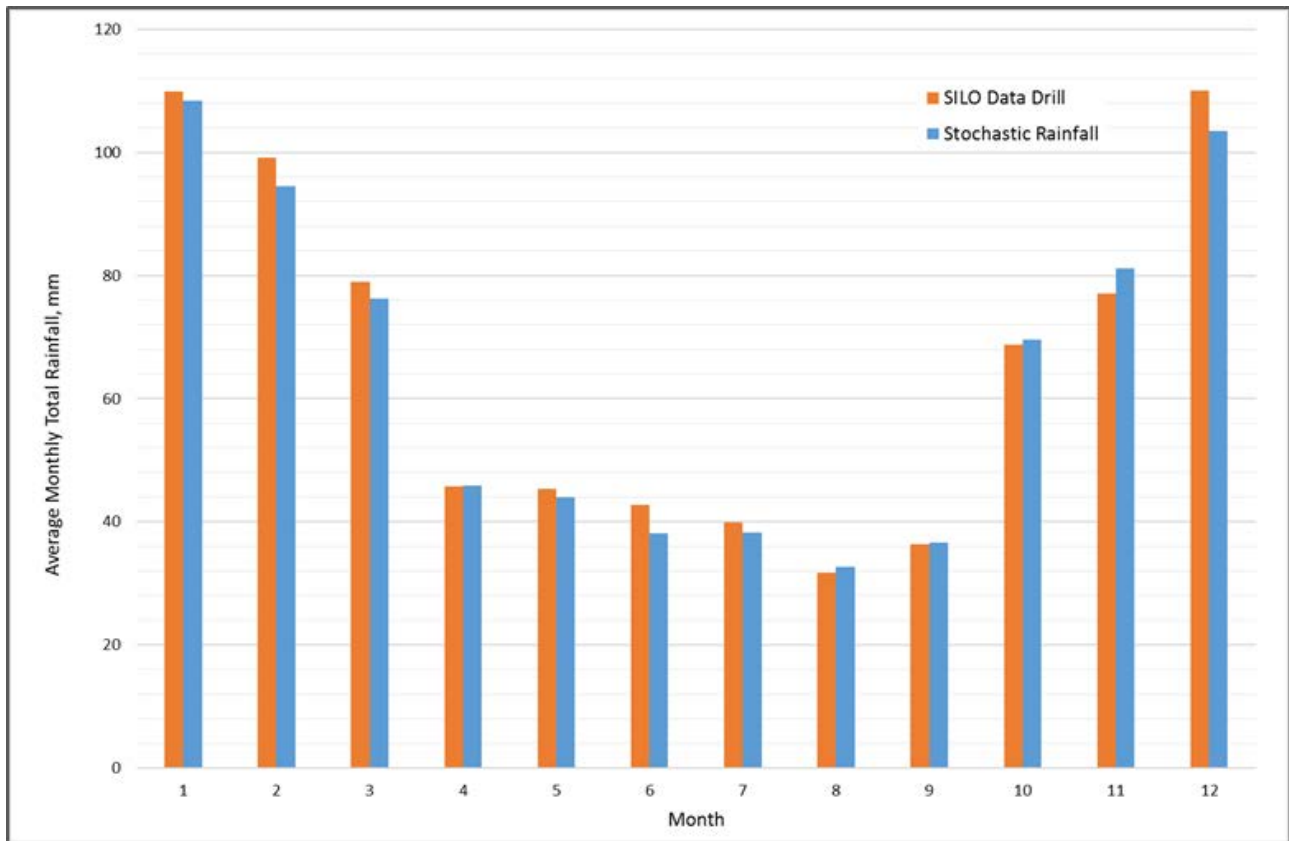
CLIMATE SERIES	REPRESENTS OVER PERIOD OF 34 YEARS	START YEAR OF RECORD	AVERAGE ANNUAL RAINFALL OF DATA SERIES (mm)
Dry	5 th percentile rainfall total	2014	740
Median	50 th percentile rainfall total	1914	777
Wet	95 th percentile rainfall total	1940	832

The SILO data has been incorporated into the model as a time series. Time shifting of the data has been enabled which means that the record is entered as the historical data series; but the model is run according to the calendar year set in the simulation settings. Once the simulation reaches the end of the historical record (2017) it will loop back to the start (1900).

STOCHASTIC RAINFALL DATA

Stochastic rainfall generators are necessary for probabilistic modelling of hydrologic systems beyond limits of the historical record. Stochastic generators attempt to reproduce the statistical characteristics of the historical records in synthetic sequences of arbitrary length (Srikanthan & Zhou 2003). Golder has programmed a stochastic climate generator module for use in GoldSim which is based on the Transition Probability Matrix (TPM) method developed by Srikanthan and McMahon (2000). Additional details on how the stochastic daily rainfall records were generated is provided in Section 4.3.1.2 of Appendix H.

A comparison of the monthly average rainfall from the SILO Data Drill record and a 500 year stochastic generated record is provided in Figure 9.7. From analysis of the different rainfall records available, SILO Data Drill records used to generate 500 years of stochastic daily rainfall records provided a good representation of rainfall at the Meandu Mine site for use in the water balance model.



Source: Golder 2018 (Appendix H)

Figure 9.7 Comparison of stochastic rainfall and SILO Data Drill rainfall

9.2.4.2 CATCHMENT RUNOFF

The model uses the AWBM to simulate catchment runoff and streamflow response to rainfall. The AWBM takes into account catchment characteristics and preceding climatic conditions. A concurrent data series of rainfall and runoff for a period is used to calibrate the model for a specific catchment. Once calibrated, AWBM is used to predict runoff from much longer rainfall records used in predictive modelling.

The AWBM has been calibrated for a catchment to the west of the Meandu Creek catchment by JBT Consulting (2014). The Barker Creek catchment Brooklands Gauge (136203A) was used for the assessment based on the availability of long continuous stream flow records, proximity to the mine site and size relative to the Meandu Creek catchment area (JBT Consulting, 2014). Additionally, the catchment comprises predominantly natural and grazing land uses, consistent with the catchment of upper Meandu Creek (JBT Consulting, 2014). Calibration parameters are discussed in Section 4.3.2 of Appendix H.

9.2.4.3 GROUNDWATER INFLOW TO PITS

Groundwater inflows are based on estimates made for the annual reporting on associated water take for the water year 2016/2017 (Golder 2017b) and from anecdotal information from Stanwell site personnel regarding groundwater encountered in pits at Meandu Mine. Based on anecdotal observations (Stanwell), the Queen coal seam is the wettest coal seam and as such the K4E and K2E pits have a higher inflow of groundwater than other pits. The K4S Pit has in the past received higher rates of groundwater inflow due to localised faults acting as flow conduits to the pit. Central Pit receives more significant quantities of water from spoil on the western side of the pit than other pits.

The range of potential groundwater inflow to pits was calculated based on the method described in Marinelli and Niccoli (2000). Groundwater inflow is entered in the model in terms of L/s/ha of pit area. Calibration of groundwater inflow to pits is discussed in Section 5.1.3 of Appendix H.

9.2.5 WATER OUTFLOWS

Key water outflows include evaporation, water inputs to the CHPP, truck-fill water use and seepage losses and overflows from retention dams. The following sections summarise how these water outflows have been incorporated into the model.

9.2.5.1 EVAPORATION

SILO DATA DRILL

Evaporation data has been obtained from the SILO data drill for the period 1900 to 2017 (Queensland Government 2018). Two data series are used in the model:

- Moreton's shallow lake evaporation is used for evaporation from retention dams and pit sumps
- Moreton's actual evapotranspiration is used in AWBM.

The evaporation record corresponding to the relevant rainfall record is applied when selecting low, median and high rainfall data scenarios. For stochastic simulations, an average evaporation record (January to December in all years) from the SILO Moreton's shallow lake evaporation and Moreton's actual evapotranspiration is applied to daily data series.

9.2.5.2 COAL HANDLING PREPARATION PLANT WATER USE

A water balance for the CHPP was provided by Stanwell for reference water use. The balance was completed on 1800 tonne per hour feed, then converted to L/ROM tonne.

Water inputs into the CHPP include water in feed coal; raw water addition and retention dam water addition (RD2, RD8). Water outputs from the CHPP include water in product coal; water in coarse rejects and water in tailings.

The assumptions used in this assessment are:

- Feed total moisture = 4.2% (value obtained from 2014 large diameter bore core laboratory data)
- Total product moisture = 10.6% (average of analytical laboratory samples from 2013 – 2015)
- Total rejects moisture = 13.3% (QCC LIMN model, and design specification)
- Tailings solids weight percent = 32% (recent solid bowl centrifuge trial)
- The balance assumes washing 100% of the time, that is no dry bypass.

By calculating the water in the feed coal and the water out on product and reject streams, the remainder is the required water input from raw water addition and retention dam water addition. The calculated water demand of the CHPP from raw and retention dam sources supplied by Stanwell is provided in Table 9.5. An estimate of the demand once solid bowl centrifuges are installed in the CHPP (from 2018) has also been provided by Stanwell.

Table 9.5 CHPP water balance

PRODUCT QUALITY	CURRENT OPERATIONS AT 1800 tph (m ³ /hr)	CURRENT OPERATIONS L/ROM tonne	SOLID BOWL CENTRIFUGE INSTALLED AT 1800 tph (m ³ /hr)	SOLID BOWL CENTRIFUGE INSTALLED L/ROM tonne
Low yield coal	362	201.1	217	120.6
High yield coal	224	124.4	165	91.7
Medium yield	269	149.4	181	100.6

The range of water demand has been entered in the model as a stochastic element with a triangular distribution resampled on a daily basis. This form of data input allows the model user to represent uncertainty in an input parameter (when future coal yield data on a day to day basis is not available). GoldSim uses the Monte Carlo method to sample stochastic elements to introduce variability within an anticipated range of values with the greatest proportion of sampling occurring in the centre of the range. Calibration of the input data to the cumulative total water use is discussed in Section 5.1.5 of Appendix H.

9.2.5.3 TRUCK-FILL WATER USE

The water outflow from assigned retention dams for haul road dust suppression is applied in the model as a fixed daily rate of use and is based on site water data records as shown in Table 9.6.

Table 9.6 *Truck fill water use*

LOCATION	YEARS	SOURCE RETENTION DAM	HOURS (PER DAY)	PUMP RATE (L/s)	SUPPLY (ML/day)	COMMENT
Central	2016, 2017	RD10	2.2	60	0.47	
Central	2018 - 2037	RD27; RD10	6.6	60	0.47	Assume 30% of requirement is sourced from RD27, remainder from RD10.
K4	2016 - 2023	RD25	1.4	90	0.44	Moved to the east when mining starts in K2E in 2024.
K4	2024 - 2037	RD26	1.4	90	0.44	RD26 is re-located (that is replaced by a new RD26) when current RD26 is lost to proposed K4E Pit progression.
Sparrows	2016 - 2037	RD26	0.5	50	0.50	RD26 becomes nominally RD28 when RD26 is lost to proposed K4E Pit progression.
ROM	2016, 2017	RD2	fixed day rate		0.67	
ROM	2018 - 2037	RD27; RD2	fixed day rate		0.67	Assume 30% of requirement is sourced from RD27, remainder from RD2.

9.2.5.4 RETENTION DAMS

SEEPAGE

All retention dams have an allowance for seepage losses that depends on an assumed hydraulic conductivity of the base materials:

- 1.00E-06 m/s for Meandu Creek ponds
- 1.00E-07 m/s for constructed retention dams
- 1.00E-08 m/s for Meandu Creek Dam.

Seepage is calculated at each time-step using the following method:

$$\text{Seepage loss} = (\text{water depth} / \text{maximum depth}) * \text{hydraulic conductivity} * \text{storage area}.$$

OVERFLOW

All retention dams have a spill elevation defined within the geometry data at which elevation the reservoir will overflow. Overflows are linked and contribute to the inflows of the linked dam allocated on a daily time-step.

9.2.6 WATER TRANSFERS

9.2.6.1 PUMPS AND PIPES

The transfer of water between pits and retention dams or between retention dams using pumps has an assigned pump efficiency and date range. All pumped flows are potential flow demands. The reservoir element in GoldSim will only supply water if the quantity of water demand is available in the reservoir on a particular time-step.

Dewatering of pits has been calibrated to site dewatering records by adjusting the pump efficiency inputs.

9.2.7 WATER QUALITY

9.2.7.1 ANALYTES

Water quality analytes are included in the model as a vector of species elements that follow water flow paths in water transfers and mixed in mixing cells. The volume of the mixing cell is either the quantity of water in a flow pathway or reservoir. This mass balance approach provides a time history of the concentration of the group of species at each location described in the model; including pits, retention dams and compliance points.

Each input water quantity component has a water quality value assigned. Two forms of water quality input data are used in the model:

- 1 A fixed concentration for a particular flow based on the average of historical laboratory analysis at representative locations (for example, natural catchment runoff).
- 2 A decay equation based on kinetic leach column (KLC) testing is applied as a species load per mass of material per month for deposited materials including waste, rejects and ash.

These are discussed in the following sections. Analytes tracked throughout the model are outlined in Table 9.7.

Table 9.7 Water quality analytes

CATIONS, ANIONS	METALS	ACIDITY
Calcium	Aluminium	Hydrogen ions
Potassium	Iron	
Magnesium	Manganese	
Sodium	Zinc	
Chloride	Copper	
Fluoride	Nickel	
Sulphate		

9.2.7.2 WATER QUALITY PARAMETERS

FIXED WATER QUALITY INPUTS

The model contains water quality parameters attached to inflows from identified sources. Analyte concentrations were provided by RGS; with the exception of the groundwater input parameter provided by JBT Consulting and blowdown water quality provided by Stanwell.

Values are based on the average of measured water quality at the assigned location and are considered to be representative of the inflow path used in the model. Water quality parameters assigned to each inflow path are provided in Table 12 of Appendix H.

Aqueous phase inputs to the Integrated Water Model were derived by RGS and Golder from average measured water quality data. For example, the average water quality data from the samples collected from Ramp 7 and Bullgang Corner were used as the numerical input in the Integrated Water Model for AMD entering the system at this location. In addition to the aqueous inputs, geochemical source terms were derived using KLC data.

RGS provided Golder with recommendations for the water source terms that could be used for the mass balance model and were integrated with the geomaterial source terms.

9.2.7.3 MATERIAL DECAY EQUATIONS

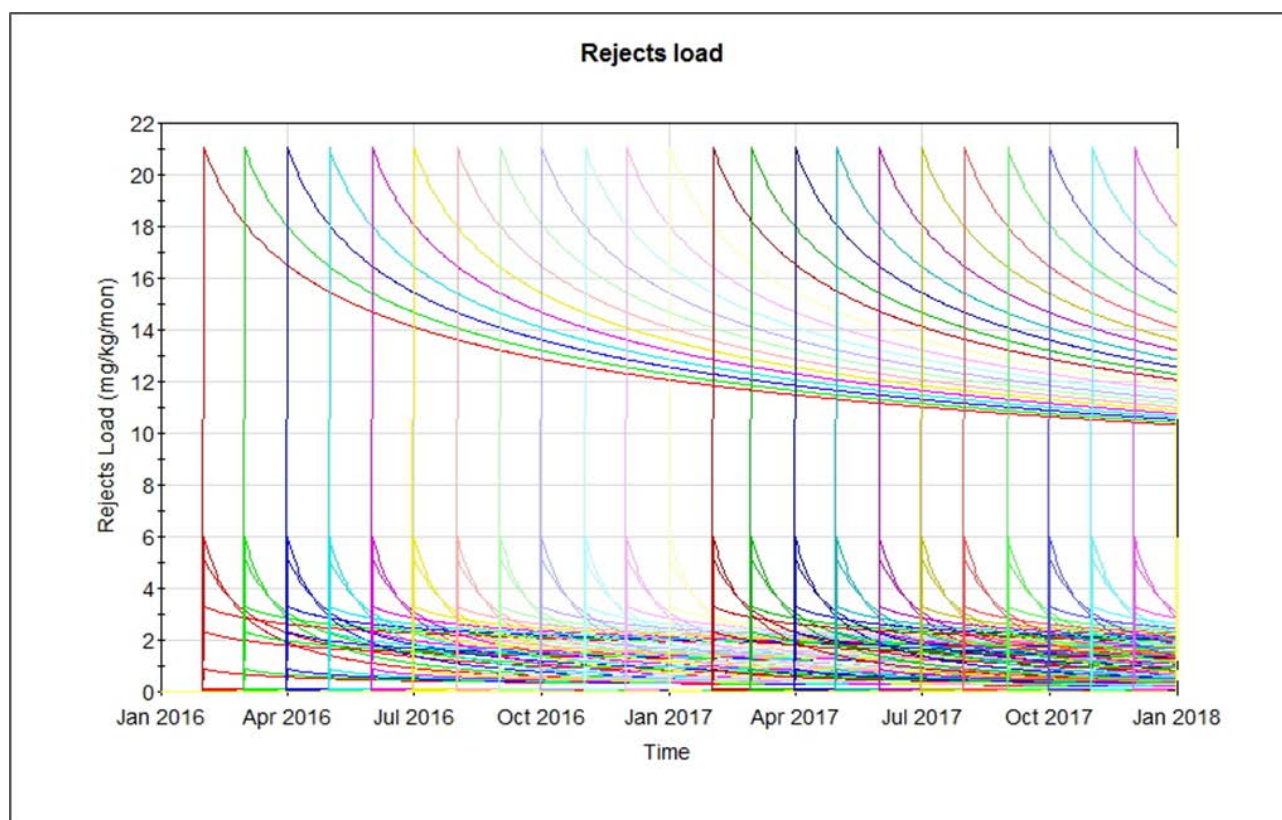
Materials (rejects, PAF waste, NAF waste and ash) are assigned to a pit, tailings or ash catchment. A quantity of materials is assigned on a monthly basis conceptually as a new block of materials stacked on top of the previous month's materials. The available analytes per unit mass of material have been assigned as a decay function (provided by RGS) with an independent variable of month, that is in the form of:

$$\text{Load (mg/kg/month)} = \text{coefficient} * (\text{month} \wedge \text{exponent})$$

Decay curves are assigned to each new load of material as shown in Figure 9.8. The colour denotes a new load of material being deposited for each model run and shows each analyte with a different decay curve.

The load/kg waste/ month is then multiplied out by the applicable material mass to give a load of each analyte. The load is then totalled for each time-step to total the crest of a curve along with tails from previous month load deposition. A 1% contact factor is applied to represent the contact made between available load and infiltrated water.

The decay curves assigned to each analyte (as provided in Table 9.7) and each material type (rejects, PAF waste, NAF waste and ash) are calculated from KLC tests and were provided by RGS.



Source Golder 2018 (Appendix H)

Figure 9.8 Decay curves are assigned to each new load of deposited material

9.2.7.4 INITIAL WATER QUALITY VALUES

Initial water quality values for each pit, retention dam, Meandu Creek Dam, North-West B TSF, K2W-N ash storage and ponds within Meandu Creek (i.e. MC2, MC4, MC5, MC6 and MC9) use measured values from the Meandu Mine water quality data base provided by Stanwell, with sample dates as close as possible to the simulation start date of 1 January 2016. Where measured values are not available for a particular location an alternative representative location has been used.

9.2.7.5 LIME-DOSING SYSTEM

Lime treatment of AMD occurred during 2016 and 2017 in RD7 and subsequently from 2018 in RD27. The lime-dosing system at RD7 required manual periodic replenishment of lime. The new system in RD27 is a continuous application of lime dose at the low flow inlets from Bullgang Corner and Ramp 7.

The rate of flow of the low flow inlets to RD27 is limited to 19 L/s from Bullgang Corner and 11 L/s from Ramp 7. Flow in excess of the capacity of the low flow inlets is directed to RD7.

Lime treated resurgent seepage water quality is applied to flow from Bullgang Corner and a low flow component of Ramp 7 discharge (equivalent to 4.7 L/s representing the diffuse seepage from North-West Backfilled Pit). Subsequent to 2018, any flow in excess of the low flow capacity of the Bullgang Corner inlet to RD27 carries the water quality of North-West Backfilled Pit resurgent seepage (without treatment) to RD7. Flow from Ramp 7 mixes in the Ramp 7 channel (with applied relevant water qualities) and the excess is directed to RD27.

9.2.7.6 ELECTRICAL CONDUCTIVITY CONVERSION FACTOR

A Total Dissolved Solids (TDS) to electrical conductivity conversion factor has been defined for Meandu Mine based on laboratory analysis of over 1,350 samples collected at sampling point W1 over the period 1985 to 2013.

The correlation between electrical conductivity and TDS is expressed as:

$$\text{TDS} = \text{F} * \text{EC}$$

Where:

- TDS is the sum of the concentration of the ions sodium, potassium, calcium magnesium, fluoride, chloride, phosphate, bromide, nitrate, sulfate and carbonate expressed in mg/L.
- F is the site specific (Meandu Mine) correlation factor of 0.5346
- EC is electrical conductivity expressed as $\mu\text{S}/\text{cm}$.

9.3 CALIBRATION AND VERIFICATION

9.3.1 MODEL CALIBRATION

All calibration simulations use measured climate data including the Tarong (BoM Station 040199) rainfall record for the period 1 January 2016 to 31 December 2017 and SILO Moreton's evaporation and actual evapotranspiration records for the same period. The model structure and inputs and assumptions for the various inflows and outflows are used as reference start parameters for inputs to the calibration process.

Quantity parameters calibrated included:

- water flow rate at CP3
- water level in Meandu Creek Dam
- pit water level
- AWMB parameters
- CHPP water use (i.e. water demand identified in the CHPP)

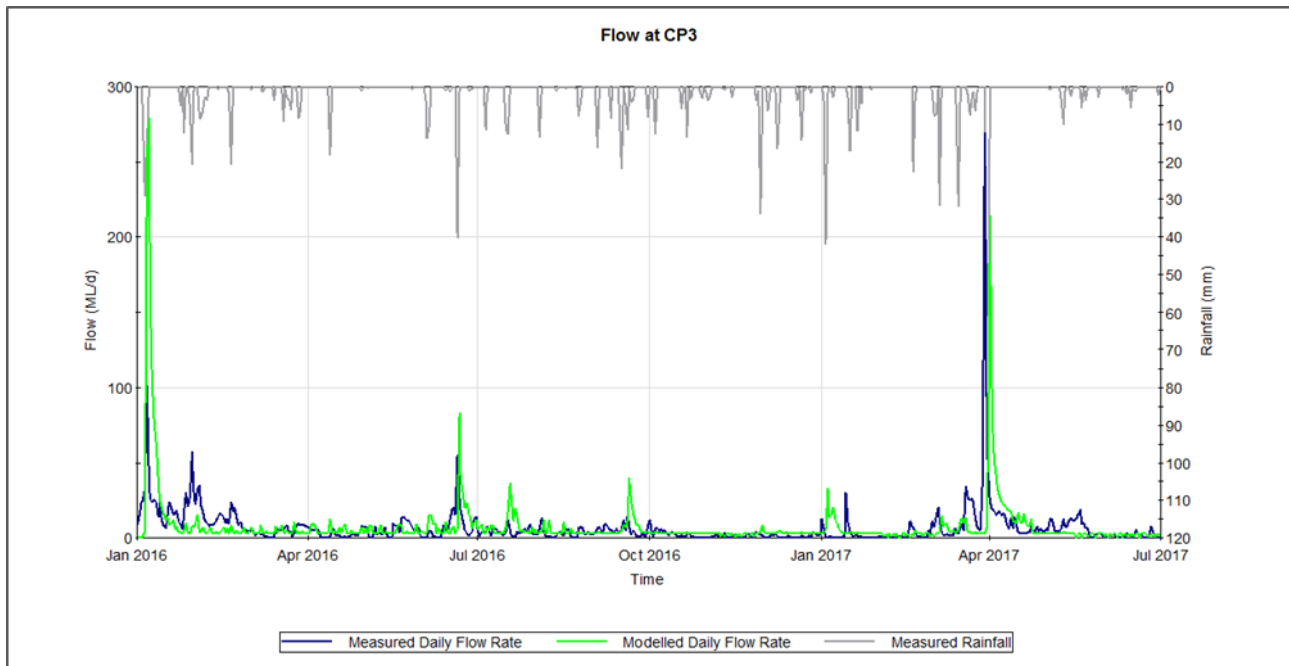
- CHPP water demand (i.e. based on introduction of solid bowl centrifuge)
- seepage at Ramp 7 and Bullgang Corner
- pump efficiency of return water from the decant pond on the North-West B TSF and K2W-N ash dam.

A summary of the Integrated Water Model calibration results is provided in Table 9.8, with supporting detail available in Section 5 of Appendix H. Quality inputs and assumptions were supplied by RGS and have not been calibrated in the model.

Table 9.8 *Summary of Integrated Water Model calibration results*

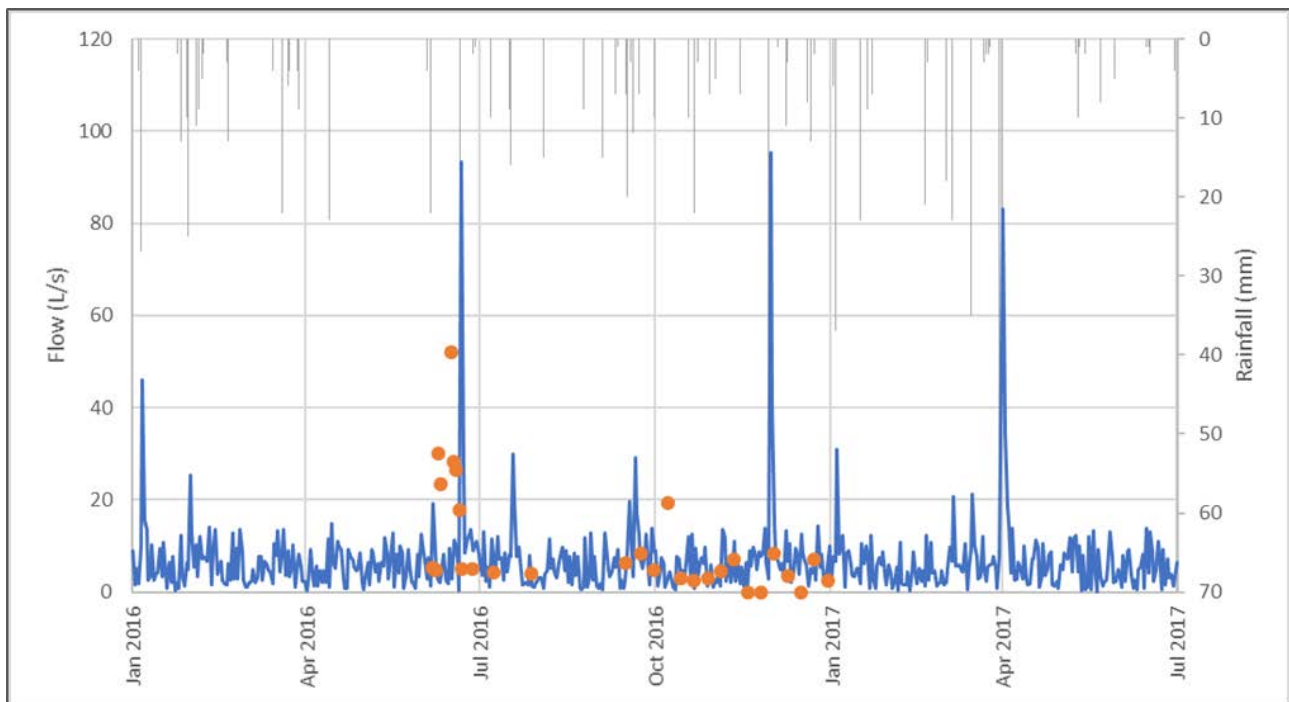
PARAMETER	CALIBRATION AND RESULTS
Water flow rate at CP3	Main contribution to the flow at CP3 is catchment runoff from the various surfaces at the mine and the natural catchment of Meandu Creek as well as water from dewatering of runoff and groundwater that enters the pits and is not utilised at the CHPP. Calibrated by adjusting the parameters of the AWBM and in conjunction with calibration to the measured dewatering from pits. Fair alignment in the rainfall runoff response for modelled results of flow through the CP3 weir when compared to measured flow rates during peak and low flow periods (refer Figure 9.9).
Water level in Meandu Creek Dam	Meandu Creek Dam is the ultimate reservoir of total flow from Meandu Creek upstream of Meandu Creek Dam and Meandu Mine. Fair alignment between modelled and measured water level in the dam. The peak flow event early in January 2016 is slightly overestimated with flow through the spillway (at elevation RL418.1 mAHD) and non-retention of flow subsequent to this event. For the remainder of 2016 and early 2017 there is good alignment in fluctuations in water level response. In response to a short-term increase in blow down water discharge to the dam in May – June of 2017, there is a gradual rise in water level consistent with the measured record. There was no rainfall during this period.
Pit water levels	Measured data is available for: — quarterly total dewatering volumes for each pit — quarterly water level in pit that currently store water (i.e. K4S and K2E pits). Adjustable parameters include: — groundwater inflow — pump efficiency (fraction of pump capacity) — AWBM parameters that determine runoff (surface flow and infiltration from waste (spoil and rejects). Good alignment (at K4S Pit) and fair alignment (at K2E Pit) achieved between modelled and measured cumulative dewatering. The measured and modelled in pit water level for both K4S and K2E pits shows fair alignment over a period of time though poor representation of the day to day operational water use. The differences between measured and modelled levels may be due to inaccuracies in pit geometry in the location of the stored water. The model will assume a level water layer stored across the base of the pit at low water levels which is likely not the case in an empty pit. Increasing inflows to correct the water level representation will over compensate an inaccurate representation of dewatering flow volumes.
Calibrated AWBM parameters	AWBM parameters have been optimised during the calibration process at pits and the ultimate flow and retention locations of CP3 and Meandu Creek Dam. The parameters identified in calibration of the AWBM to the natural catchment of Barker Creek at Brooklands have been used to represent natural land use runoff response. Other land use surfaces have been parameterised manually by calibration of the model and understanding of the components of the AWBM model.

PARAMETER	CALIBRATION AND RESULTS
CHPP water use	CHPP water use is based on the water demand identified in the CHPP water balance assessment undertaken by Stanwell. The range of variability is set using the potential variability identified in the water balance for low, medium and high yielding coal, that is 201.1, 149.4 and 124.4 L/tonne respectively. The water use identified at the CHPP is the total of water from RD8 and RD2 along with raw water used in processing. Measured CHPP water use for the period 2016 and 2017 was supplied from PIMS measured values at pumps 18 and 19. The water use for both 2016 and 2017 are at the lower end of the potential range as determined by the CHPP water balance. Good alignment between measured and modelled cumulative total water use. Modelled values exhibit less variability as they are based on a daily demand resampled from a potential and more narrow range of yields.
CHPP water demand	The solid bowl centrifuge has recently been installed and as such there are no measured values of record for water demand given the change in water use anticipated at the CHPP. The CHPP water model estimated solid bowl centrifuge water demand has been revised down by the same ratio as the calibrated CHPP water demand. The calibration assumes that all forms of coal yield were processed during 2016/ 2017.
Ramp 7 and Bullgang Corner	Flow rate (seepage rate) data was recorded at the Ramp 7 culvert and at Bullgang Corner between June and December 2016. Modelled flow values match measured values well, with similar ranges of values and behaviour. Modelled values appear to be more responsive to rainfall events (refer Figure 9.10).
North-West B TSF	The pump efficiency of the return water from the decant pond on the North-West B TSF was calibrated to quarterly measured values. Using the calibrated modelled pump efficiency resulted in a good alignment to measured values.
K2W-N ash dam	The pump efficiency of the return water from the decant pond on the K2W-N ash dam was calibrated to quarterly measured values Using the calibrated modelled pump efficiency resulted in a good alignment to measured values.



Source: Golder 2018 (Appendix H)

Figure 9.9 Flow calibration at CP3



Source: Golder 2018 (Appendix H)

Figure 9.10 Comparison of modelled and measured flow rates at Ramp 7 culvert

9.3.2 MODEL VERIFICATION

9.3.2.1 QUANTITY

Where available 2016/2017 measured data has been used for the calibration process. Minimal flow data is available at AMD seepage locations, Bullgang Corner and Ramp 7. Flow monitoring equipment is to be installed at the low flow inlets to the new RD27 and continuous flow monitoring data will be available for both Bullgang Corner and Ramp 7 once the equipment is operational.

Once this data is available the model results for seepage at Bullgang Corner and Ramp 7 will be verified against measured data to provide confidence in the assumptions.

9.3.2.2 WATER QUALITY

Verification between modelled and measured water quality parameters at CP3, Meandu Creek Dam (CP1) and retention dams RD7, RD2 and RD8 was undertaken. The results from this verification are summarised in Table 9.9. Additional information is provided in Section 6 of Appendix H.

Table 9.9 *Summary of results from Integrated Water Model quality verification at CP3, CP1, RD7, RD2 and RD8*

PARAMETER	RESULTS
CP3	
Electrical conductivity	— Generally, modelled values are in the range of those measured at CP3. — A dilution response is more evident in the modelled data following rainfall events. — Peak electrical conductivity in the modelled record is 2644 $\mu\text{S}/\text{cm}$ and occurs during an extended dry period.
pH	— Modelled values occur across the range of measured data, but there is poor variability in the modelled data when compared to measured data in early 2018. — The greater variability in measured data may be due to current lime-dosing processes occurring for approximately 12 hours per day. The model assumes dosing is occurring 24 hours a day. Further verification may be obtained when continuous data becomes available from the dosing system installed in RD27.
Sulfate	— Modelled sulfate concentrations are in the range of those measured. — There are limited measured data points available. CP3 receives mine impacted flow from RD8 (Ramp 7 – Bullgang – RD7 – RD8 flow path), as well as from the eastern side of the mine from RD2. RD8 is preferentially pumped to the CHPP and is programmed to do so in the model. Sulfate verification at RD8 and RD2 are provided below.
Manganese	— Measured concentrations of manganese at CP3 were higher than modelled. — The lower estimates of manganese concentration in the model may be from the model simulating daily time-steps and therefore assuming continuous lime dose treatment. The manganese concentration in seepage from the North-West Backfilled Pit without lime dose treatment used for modelling is 32.2 mg/L, and with lime dose treatment is 4.63 mg/L. — Other inflows to CP3 that influence the mixed solution at this location have a manganese concentration of < 1 mg/L.
Nickel and zinc	— Modelled estimates of nickel and zinc concentrations at the CP3 weir are generally lower than the measured values. — Lower modelled estimates of nickel and zinc may also be due to the assumption of continuous lime dose treatment in the daily time-step model. Input concentrations of nickel are 0.512 mg/L and 0.039 mg/L in resurgent seepage and in lime treated water respectively. — Input concentrations of zinc are 4.27 mg/L and 0.003 mg/L respectively.
MEANDU CREEK DAM (CP1)	
Electrical conductivity	— Good alignment between measured and modelled data at this location. — There is less variability in electrical conductivity results as expected in a large water storage. — The lower values in the model in the early months of 2016 correspond to the high estimation of a rainfall event at the start of the simulation, with a longer period of overflow from the dam than in the measured data.

PARAMETER	RESULTS
pH	— The model estimation of pH shows less variability in the modelled record when compared to measured data.
RD7, RD2 AND RD8	
Electrical conductivity	— RD7 – representative of available measured data — RD8 – representative of available measured data — RD2 – less well represented but in the order of the electrical conductivity of the available measured data
Sulfate	— RD7 – reasonably well aligned to available measured records — RD8 – reasonably well aligned to available measured records — RD2 – reasonably well aligned to available measured records

9.4 MODEL OUTPUTS (BASE CASE SIMULATIONS)

The base case scenario incorporates control measures that have been implemented at the Meandu Mine prior to 2018 including:

- construction of RD27 with continuous lime-dosing of low flow inflows to RD27
- the change to high density tailings, removing the tailings slurry flow input to North-West B TSF and reducing water demand at the CHPP.

Additionally, the base case includes anticipated changes to water infrastructure required during the life of mine to support the 2017 Life of Mine Plan.

The base case simulations (summarised in the following sections) were run on daily time-steps for the period 2016 to 2050, using three climate scenarios based on low, medium and high rainfall data records.

9.4.1 WATER QUANTITY

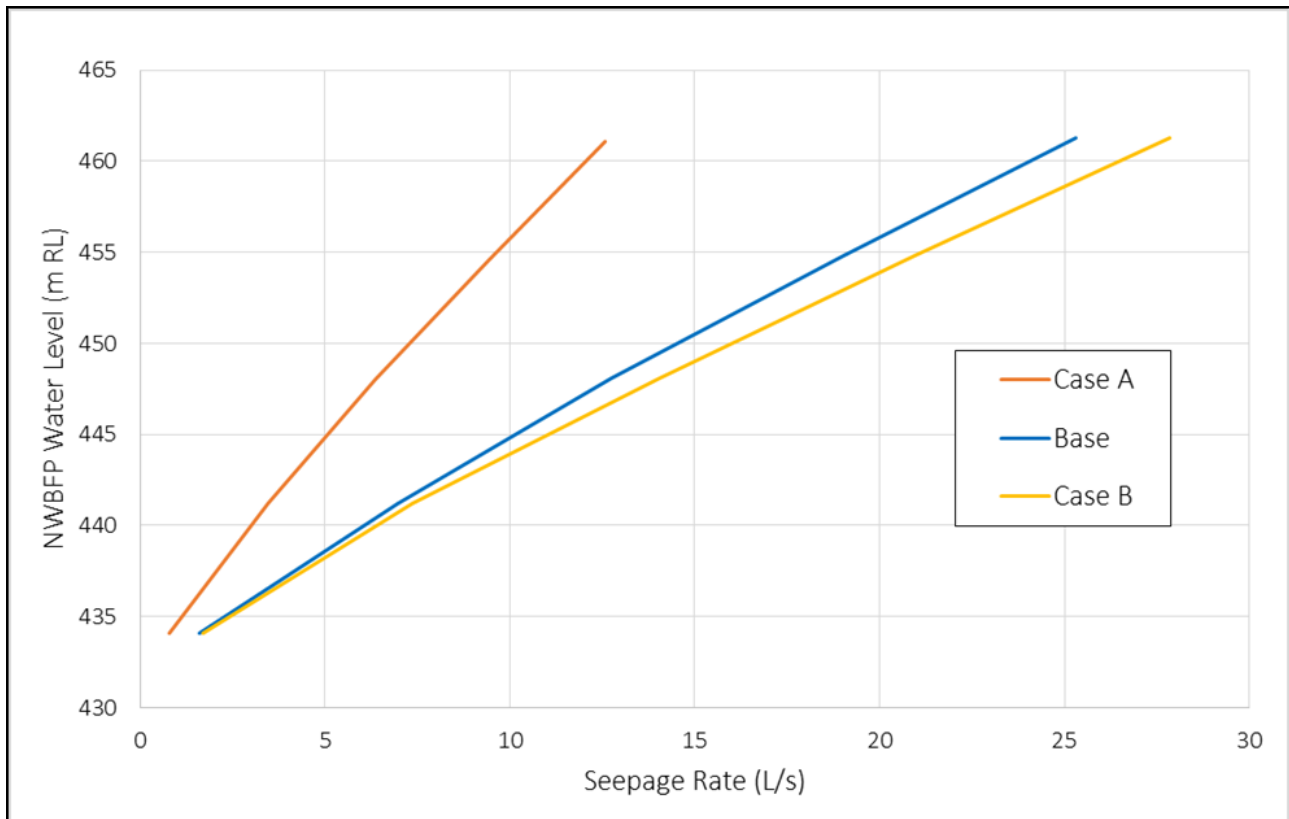
9.4.1.1 NORTH-WEST BACKFILLED PIT – BULLGANG CORNER AND RAMP 7 SEEPAGE

Baseline simulations of seepage at Bullgang Corner under the three climate conditions (low, median and high rainfall periods) were conducted. In addition to the base case, two sensitivity cases were defined (using the parameter values specified in Table 9.10) to generate sensitivity curves for the North-West Backfilled Pit water level – seepage rate relationship (Figure 9.11). Case A has lower hydraulic conductivity values for spoil and rejects (other parameter values remain unchanged from the base case). Case B has a higher hydraulic conductivity value for tailings (other parameter values remain unchanged from the base case).

Table 9.10 North-West Backfilled Pit hydraulic conductivity sensitivity cases

CASE	UNIT	SPOIL	TAILINGS	REJECTS	HARD ROCK
Base	m/s	2.00E-06	2.0E-09	2.0E-05	5.0E-10
Case A	m/s	1.00E-06	(same as base)	1.0E-05	(same as base)
Case B	m/s	(same as base)	5.0E-07	(same as base)	(same as base)

Source: Golder 2018 (Appendix H)

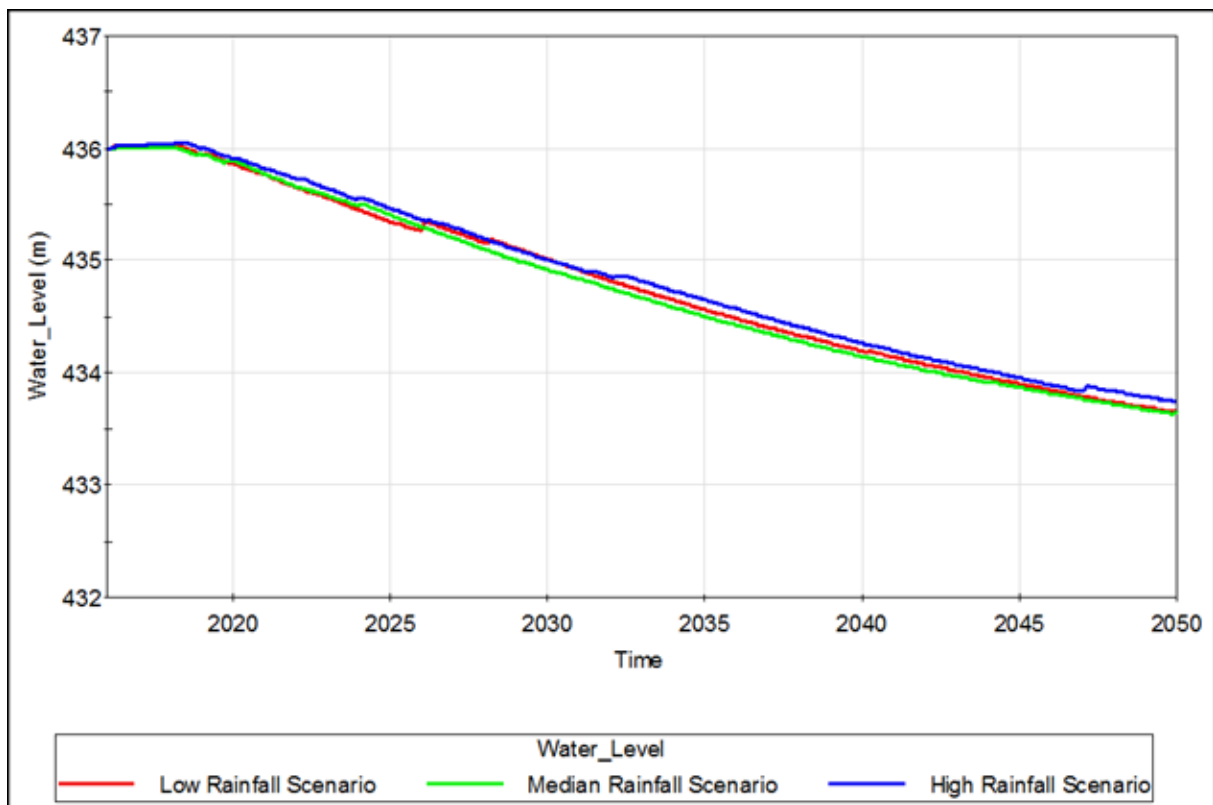


Source: Golder 2018 (Appendix H)

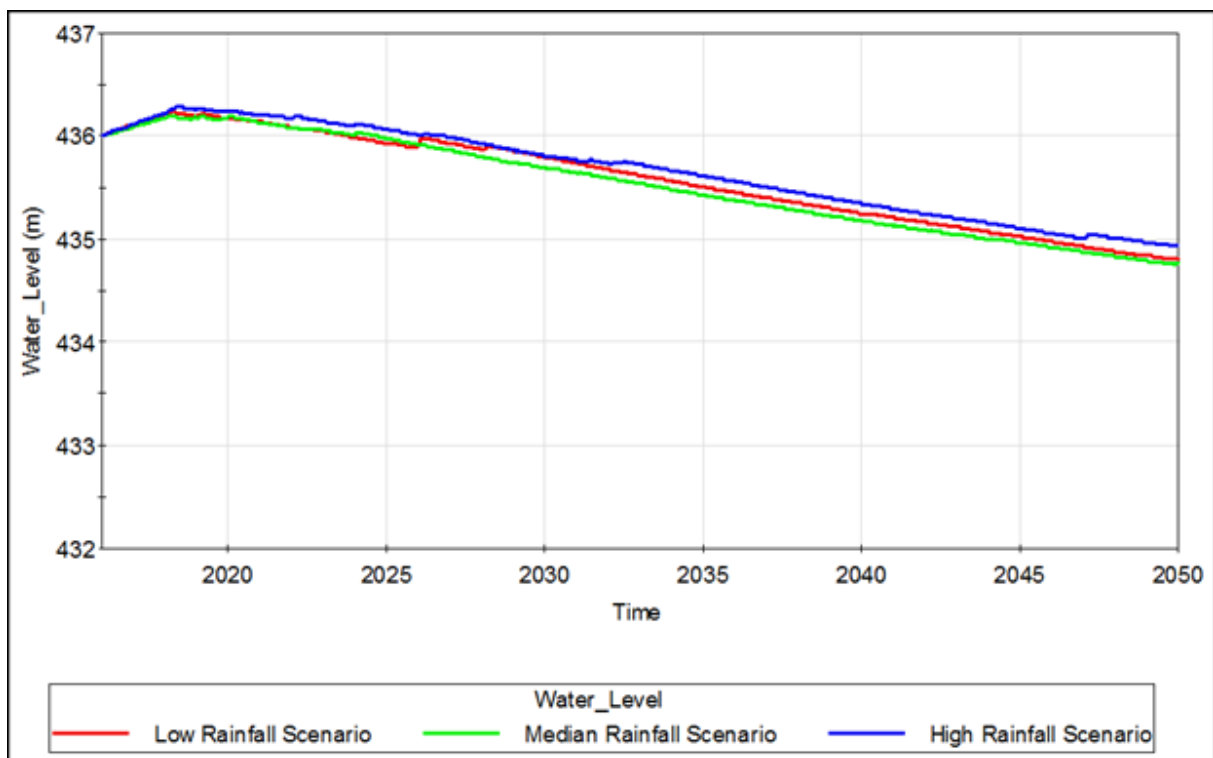
Figure 9.11 Sensitivity results for the North-West Backfilled Pit water level - baseflow relationship

Water level in the North-West Backfilled Pit using the base, Case A and Case B water level - baseflow relationships are shown in Figure 9.12.

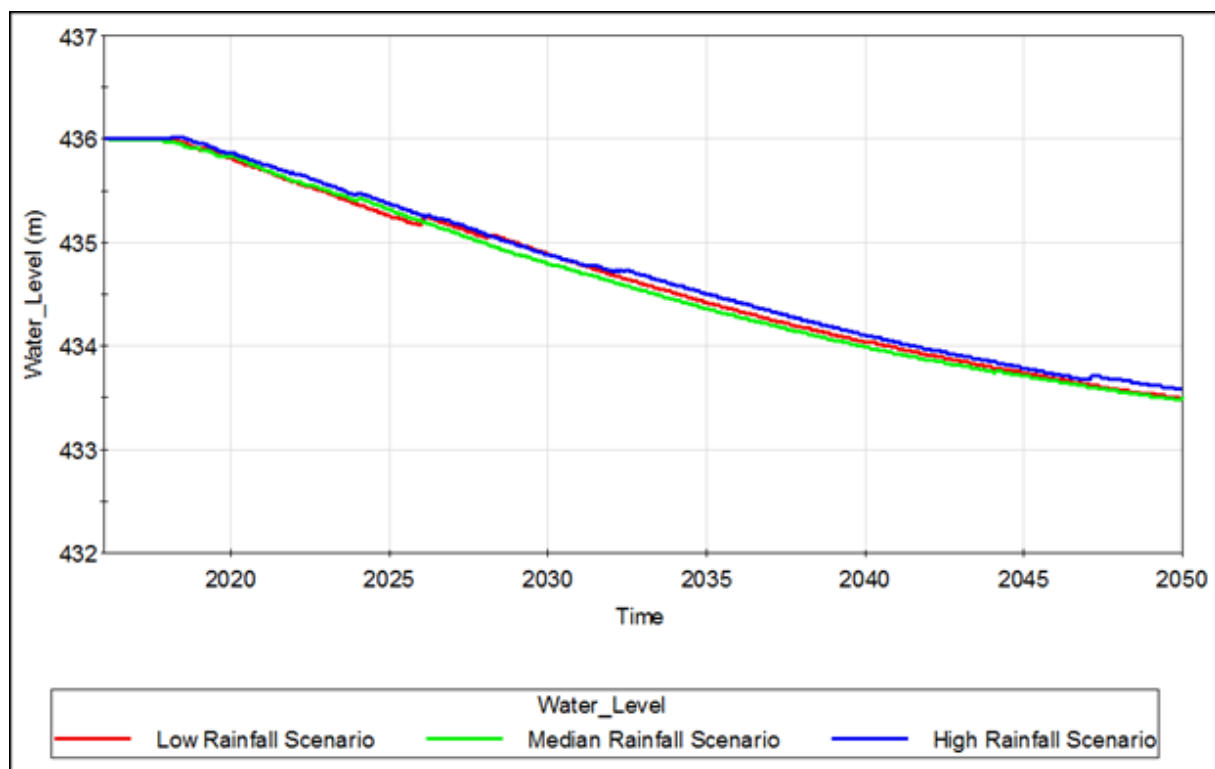
Case A has the lowest water level - baseflow relationship resulting in lower seepage rates and a slower decline in the North-West Backfilled Pit water level. Case B has the highest water level – baseflow relationship, resulting in increased seepage and a more rapid decline in the North-West Backfilled Pit water level.



BASE CASE



CASE A



CASE B

Source: Golder 2018 (Appendix H)

Figure 9.12 Water levels in North-West Backfilled Pit – base case, Case A and Case B

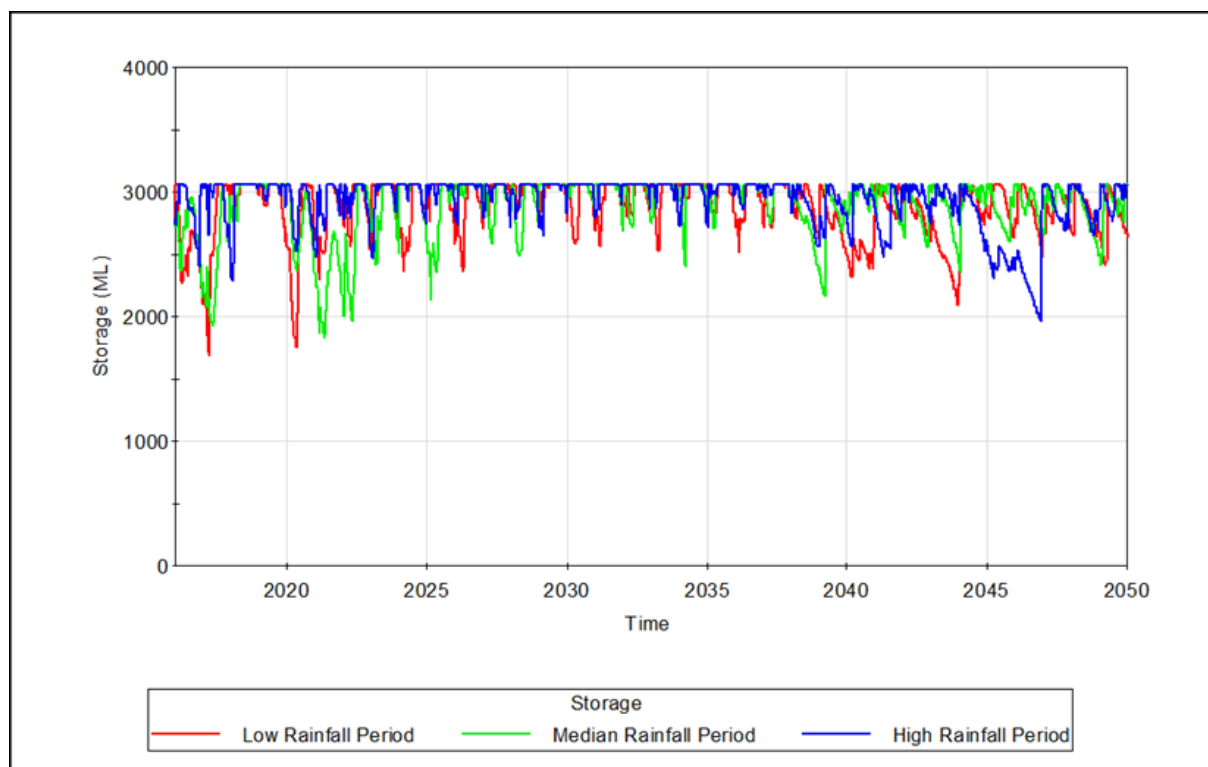
9.4.1.2 FLOW AT CP3

Daily flow at CP3 simulated using the three climate scenarios showed periodic high and low flows in both operational and closure periods in all scenarios as well as periods of no flow. Periods of low flow are more frequent during mining operations. An assessment of exceedance probability supports these observations. There is a 50% probability that flow will exceed 3.87 ML/day during operations and 0.04 ML/day post closure respectively.

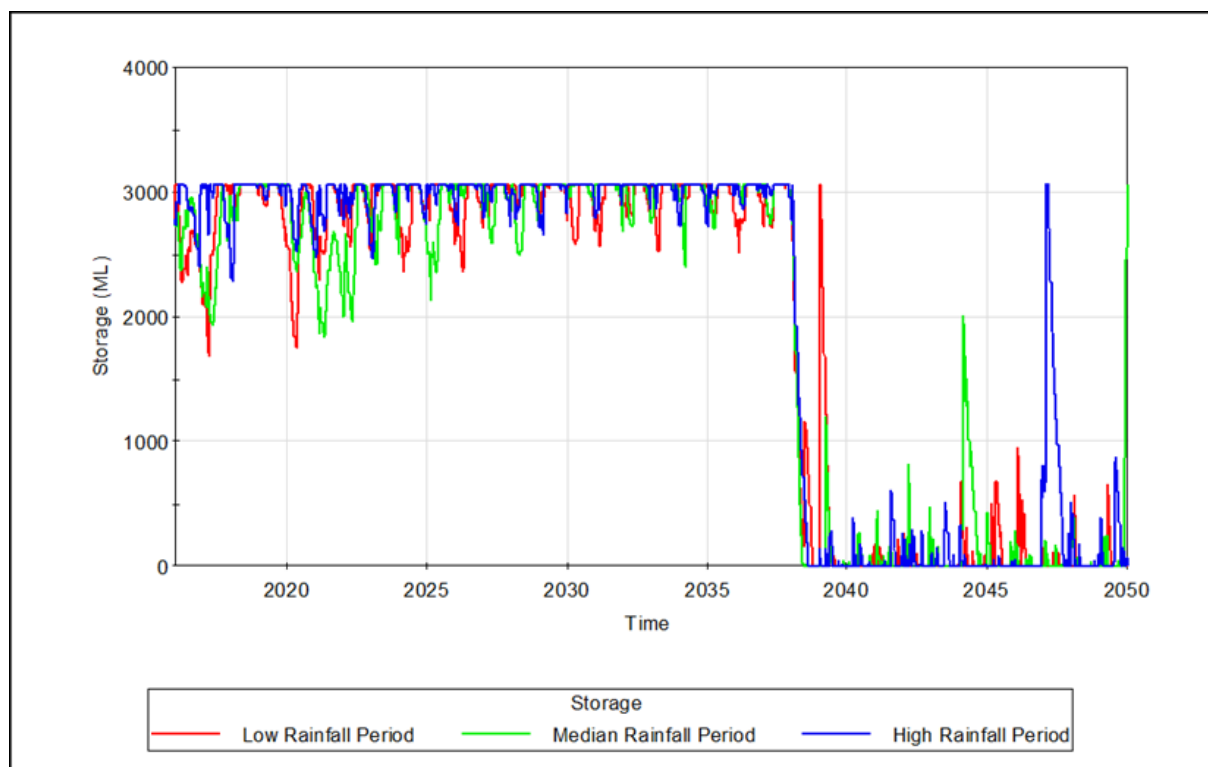
9.4.1.3 MEANDU CREEK DAM WATER LEVEL

Two scenarios were simulated for the operational and post closure period at Meandu Creek Dam. The first, shown in Figure 9.13, is the storage volume in low, median and high rainfall scenarios with power station blowdown water inflow and low flow releases discontinued after 2037. In this scenario, Meandu Creek Dam is at or close to capacity throughout the operational and post closure period. There is a period of 2 years between 2021 and 2023 where the dam is less than capacity and no overflows occur in low and median rainfall scenarios. This is a period of high production and water demand at the CHPP; when less water is available from dewatering (Ramp 5 Pit is closed and mining in K2E Pit is about to recommence); and at a time corresponding to a low rainfall period in both low and median records.

In the second scenario (Figure 9.13) power station blowdown water inflow ceases after 2037 and low flow discharges from Meandu Creek Dam are continued after closure; the low flow demand is the current average monthly discharge. In this scenario there is a rapid decline in water stored at closure.



WITHOUT LOW FLOW RELEASE POST CLOSURE



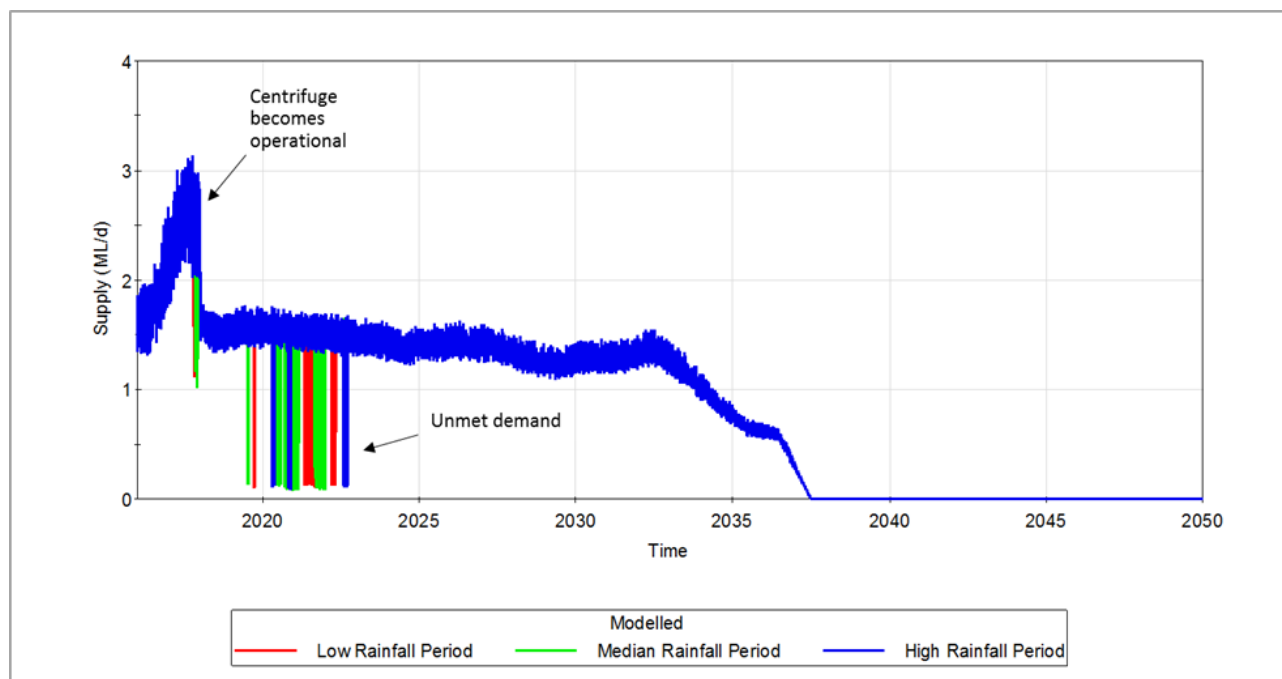
WITH LOW FLOW RELEASE POST CLOSURE

Source: Golder 2018 (Appendix H)

Figure 9.13 Meandu Creek Dam storage without and with low flow release post closure (base case)

9.4.1.4 WATER SUPPLY – CHPP

Water supply to the CHPP is higher at the start of the simulation (2016 / 2017) prior to the implementation of the solid bowl centrifuge, which became operational in December 2017 (as shown in Figure 9.14). The modelling shows there may be a period when supply from RD8 and RD2 does not meet demand on some days during 2020 – 2023. In the simulation this period occurs when relatively high production and corresponding water demand at the CHPP coincides with less water being available from dewatering at Ramp 5 Pit which is closed and mining in K2E Pit is about to recommence. Changes to water management may be required during that period to ensure sufficient water to the CHPP. Stanwell will monitor water requirements and availability prior to that time.



Source: Golder 2018 (Appendix H)

Figure 9.14 Water supply to the CHPP (base case)

9.4.1.5 HIGH FLOW BYPASS OF RD27

Treatment in RD27 is applied to water that enters RD27. However, when flows in excess of the capacity of the RD27 inlet occur these will bypass treatment and flow to RD7 and if not utilised in the CHPP will be discharged at CP3. Some of this high flow will carry with it impacted water from Bullgang Corner and Ramp 7.

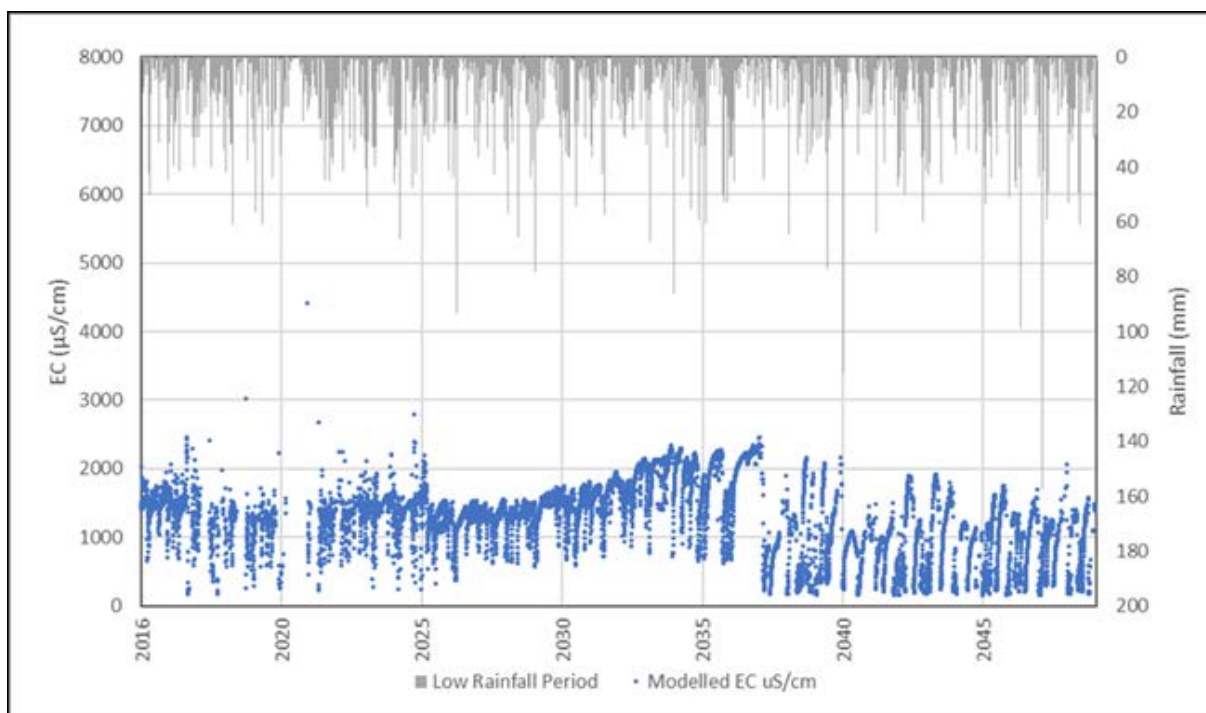
Simulations have been run in all climate scenarios to gain an understanding of the occurrence of high flow bypass, to quantify the cumulative water directed to RD27 and RD7 from Bullgang Corner and the water collected in Ramp 7 (including catchment runoff). In all cases total treated flow exceeds the high flow bypass.

9.4.2 WATER QUALITY

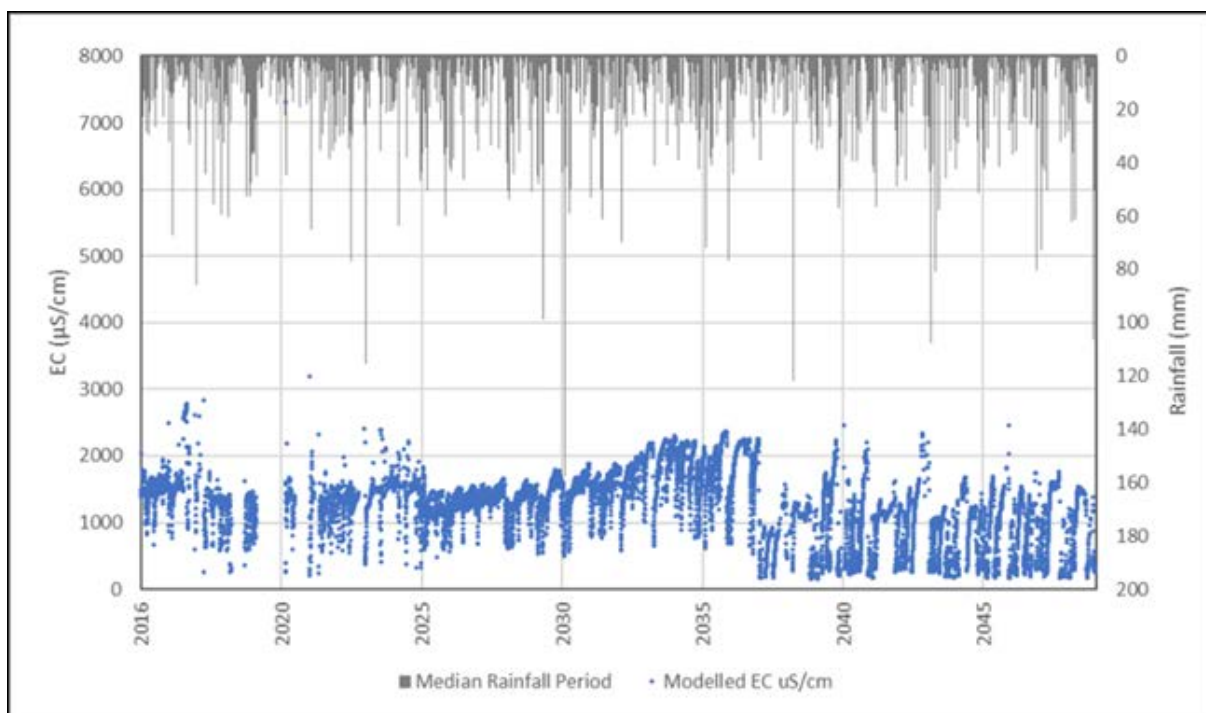
9.4.2.1 CP3

ELECTRICAL CONDUCTIVITY

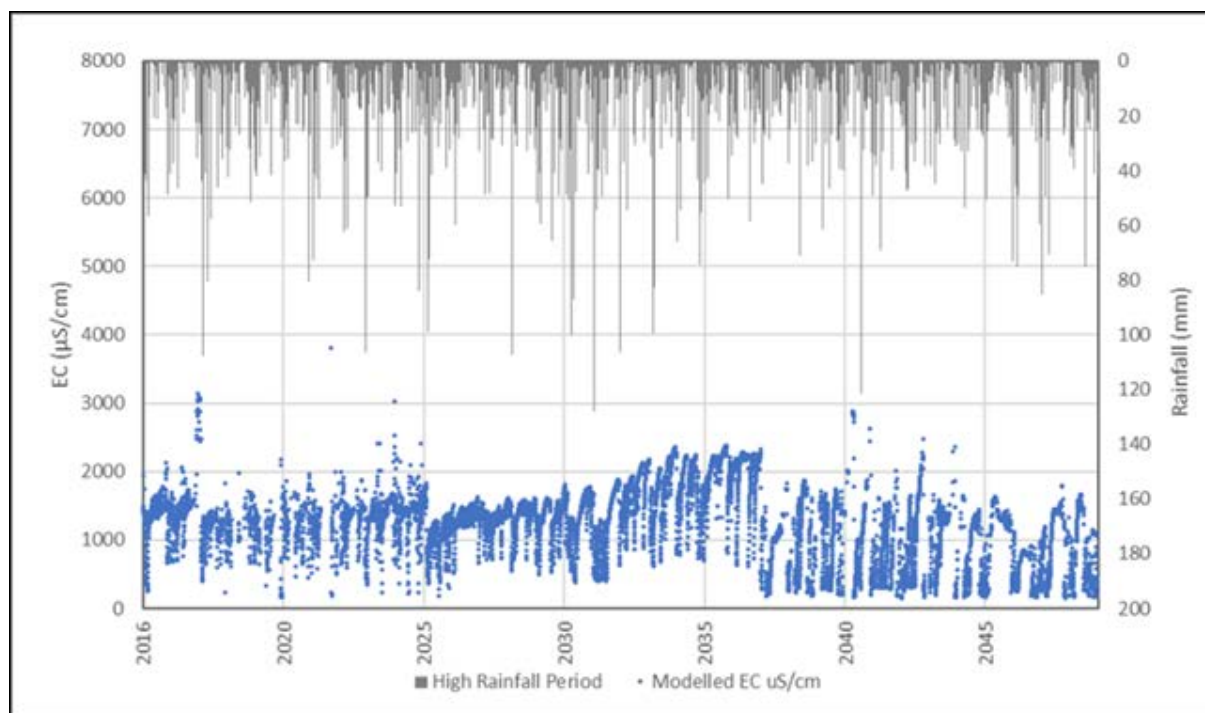
Electrical conductivity results at CP3 for low, median and high rainfall scenarios is shown in Figure 9.15. In all scenarios for the period 2020 – 2025 there are some instances of modelled electrical conductivity values exceeding 2,500 $\mu\text{S}/\text{cm}$. During operations, up until closure there is a very gradual increase in electrical conductivity that finishes at the end of operations and remains below reportable electrical conductivity concentrations. In the post closure period there are some instances where electrical conductivity exceeds 2500 $\mu\text{S}/\text{cm}$ particularly in the median and high rainfall simulations.



LOW RAINFALL



MEDIAN RAINFALL



HIGH RAINFALL

Source: Golder 2018 (Appendix H)

Figure 9.15 Electrical conductivity at CP3 – low, medium and high flow scenarios (base case)

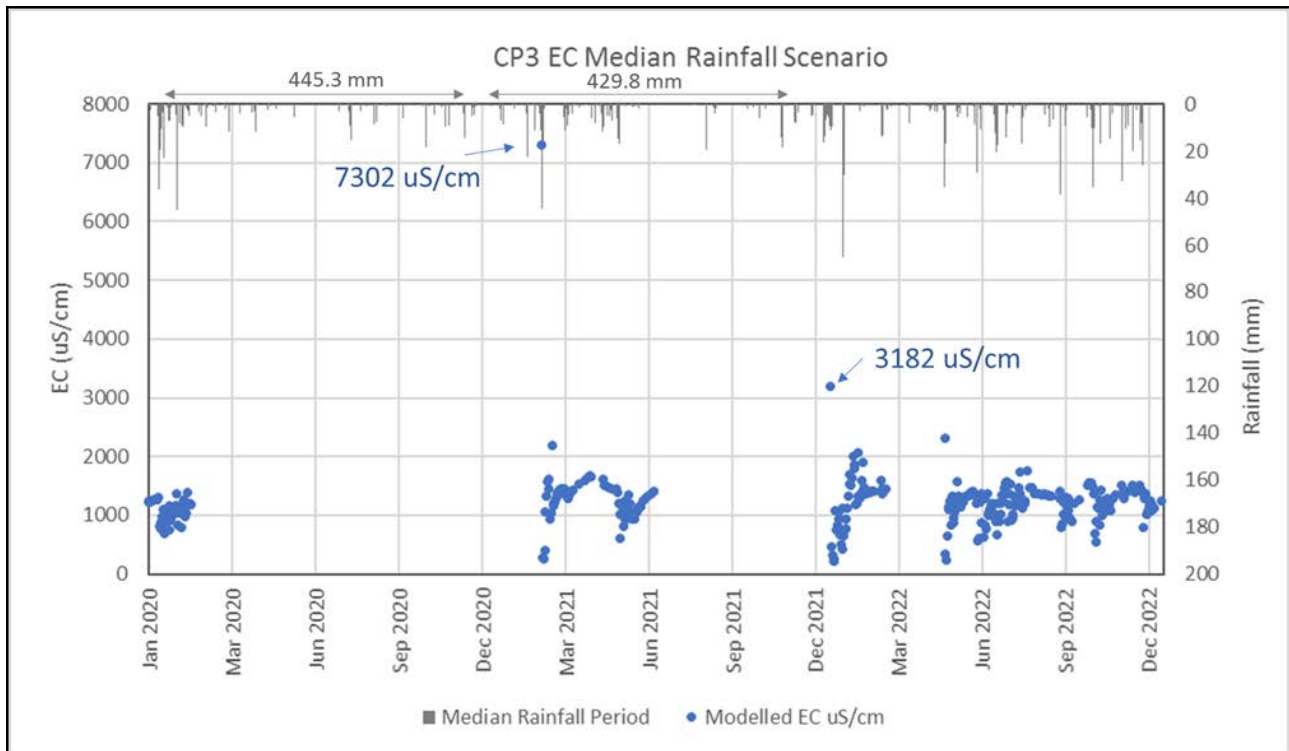
A summary of the results for all scenarios is provided in Table 9.11.

Table 9.11 Summary electrical conductivity results all simulations at CP3

CP3 EC RESULTS	LOW RAINFALL SIMULATION	MEDIAN RAINFALL SIMULATION	HIGH RAINFALL SIMULATION
Maximum electrical conductivity (µS/cm)	4402	7302	3795
Number of instances >2 500 µS/cm (34 years)	4	33	39

As discussed previously, between 2020 and 2025 each rainfall scenario uses a different rainfall record, the rainfall records for the median scenario has two consecutive years with annual rainfall totals of less than 450 mm. This is also a period of relatively high production and water demand at the CHPP and when less water is available from dewatering (Ramp 5 Pit is closed and mining in K2E Pit is about to recommence). Peak values in electrical conductivity occur immediately after an extended dry period (as shown in Figure 9.16)

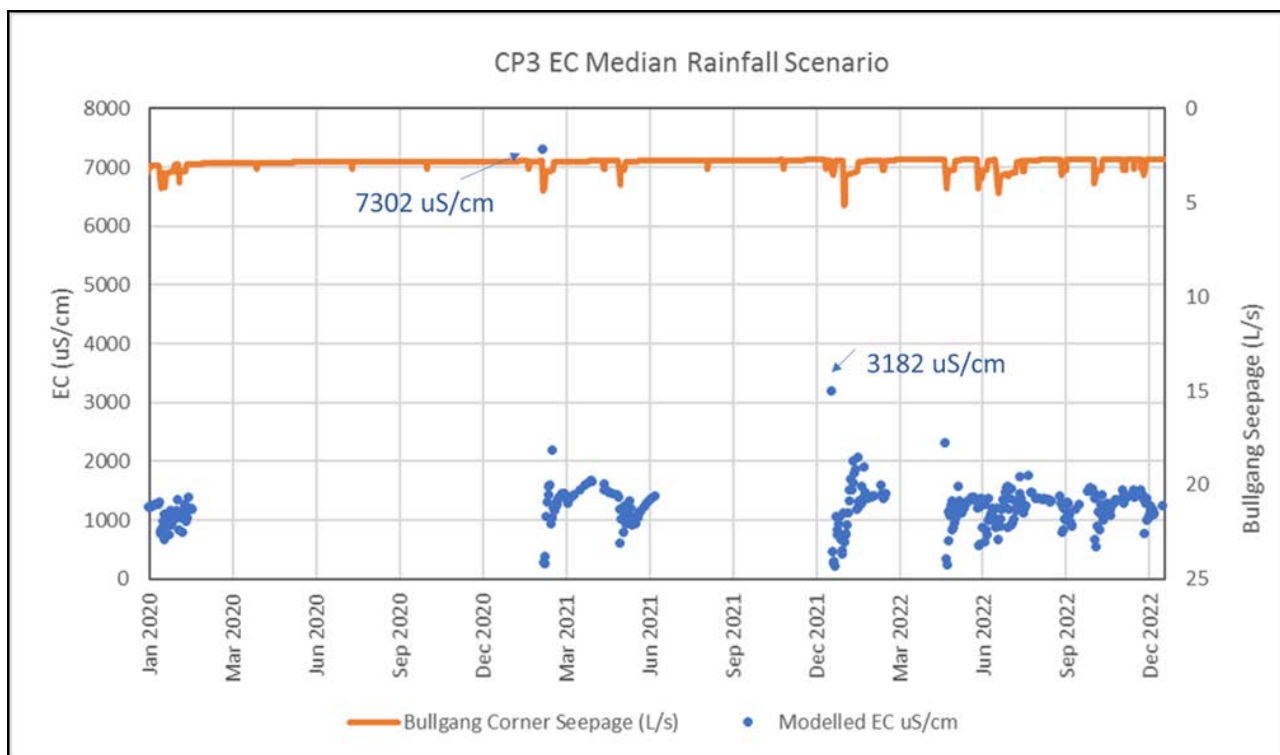
Each of the modelled exceedances (i.e. electrical conductivity values exceeding 2,500 µS/cm) including those in the post closure period occur with the first flush of runoff through the weir following a dry period.



Source: Golder 2018 (Appendix H)

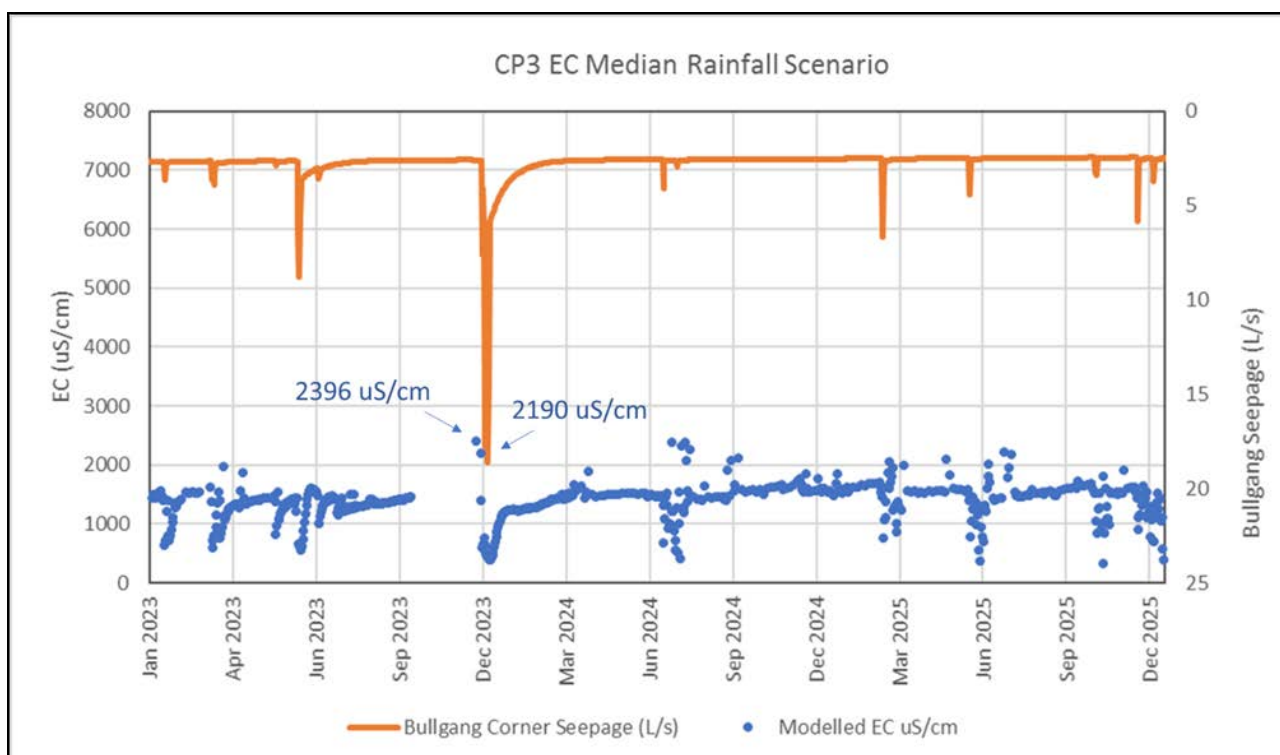
Figure 9.16 High electrical conductivity events at CP3 compared to the modelled rainfall record for the period 2020–2022

During the same period there is very little change in seepage from Bullgang Corner. There are small peaks in flow at around the same time as the peaks in electrical conductivity occur as shown in Figure 9.17. Conversely during a period of high flow from Bullgang Corner during 2023 – 2025 there is a small if any response in change in electrical conductivity (as shown in Figure 9.18).



Source: Golder 2018 (Appendix H)

Figure 9.17 High electrical conductivity events at CP3 compared to modelled Bullgang Corner seepage for the period 2020–2022

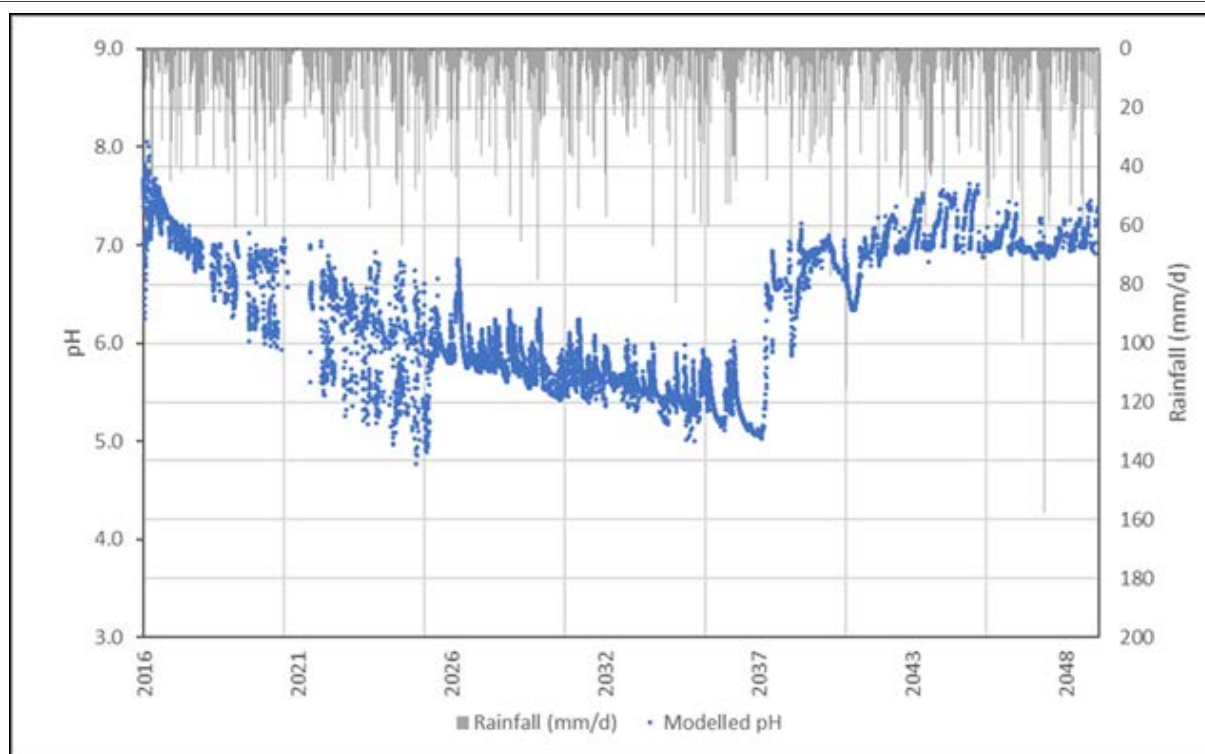


Source: Golder 2018 (Appendix H)

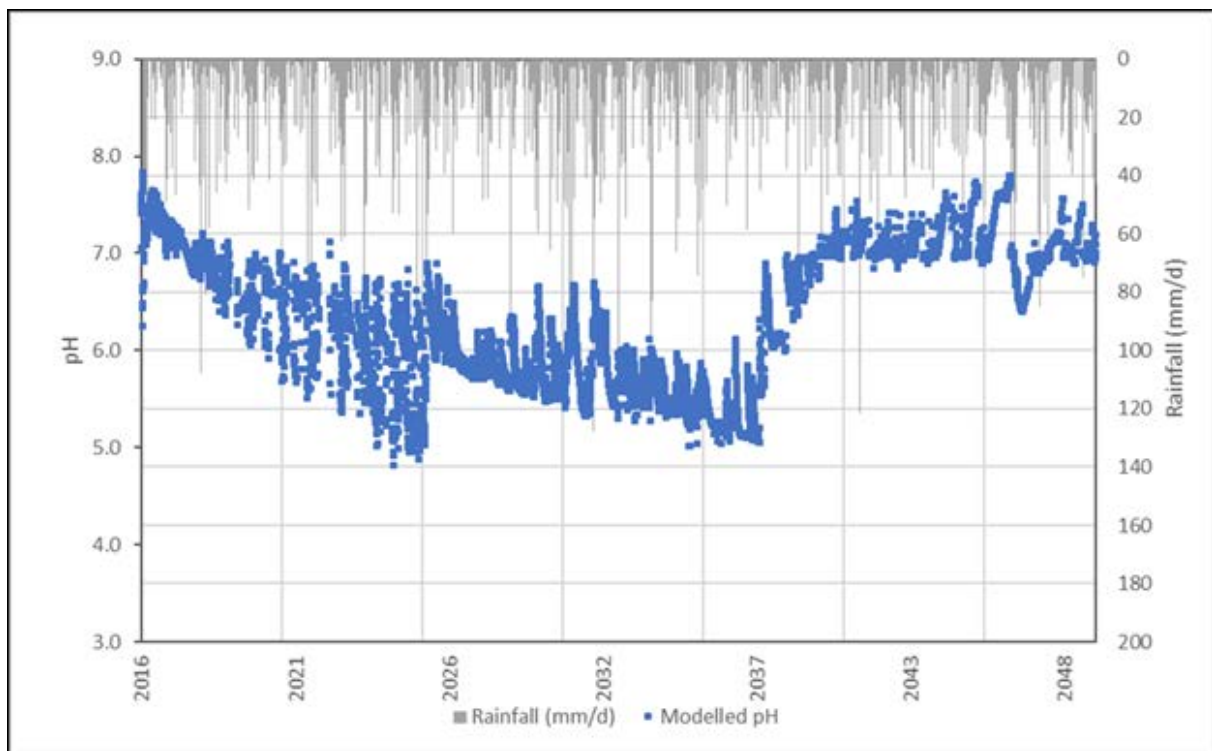
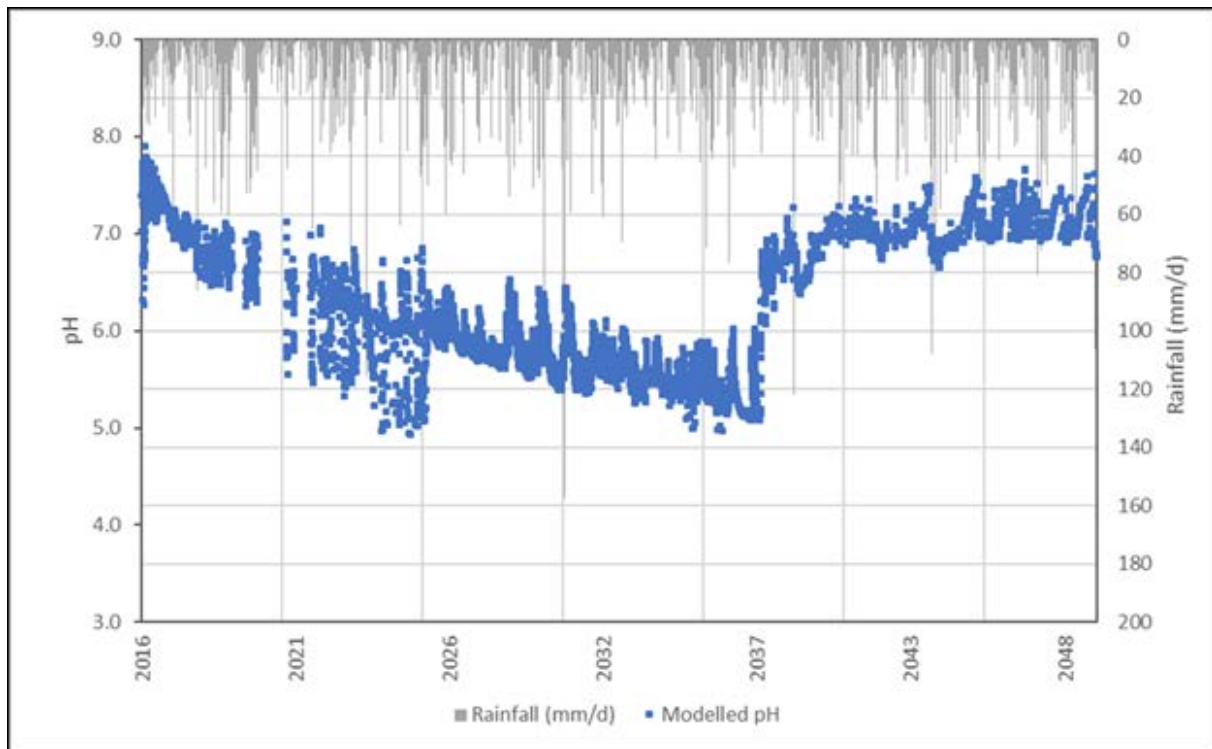
Figure 9.18 High seepage event at Bullgang Corner compared to electrical conductivity at CP3 during the period 2023–2025

PH

Long-term pH results at CP3 are provided in Figure 9.19. Results are very similar in all climate scenarios. The lowest pH occurs in all scenarios in 2025 (range of 4.82 – 4.93) and declines also occur towards the end of operations. Once dewatering of all pits ceases in 2037 the pH returns to near neutral conditions. There was less confidence in the verification of the model for pH and there are limited data records available for in-pit samples; pH is established based on the concentration of hydrogen ions only and may need revision to incorporate hydroxide component. Regular in-pit pH sampling is recommended to assist in further verification of the model.



LOW RAINFALL

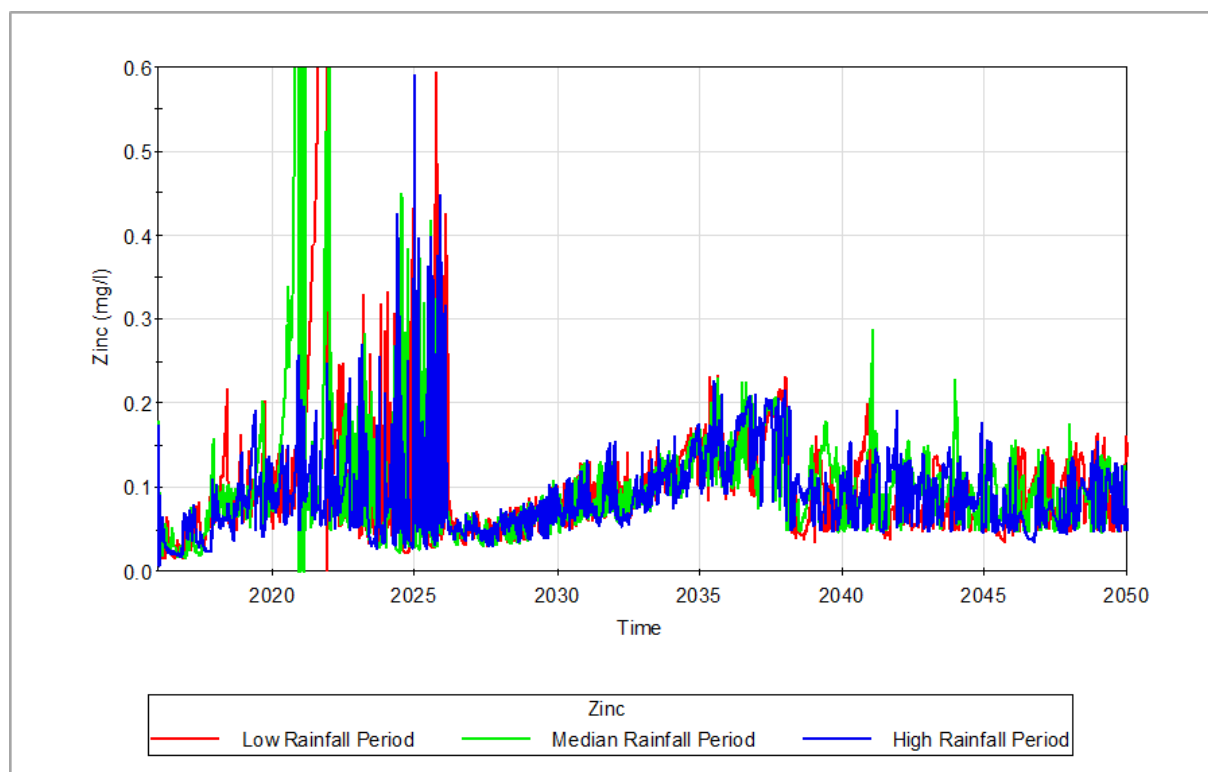


Source: Golder 2018 (Appendix H)

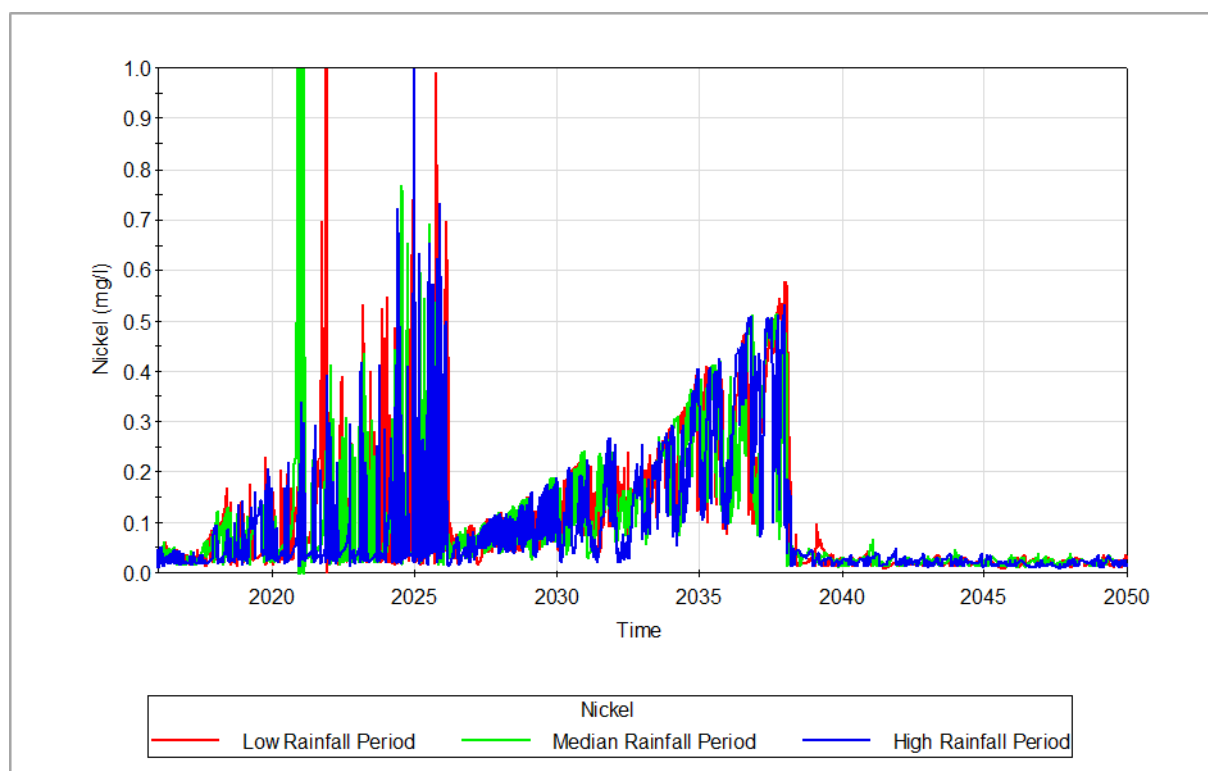
Figure 9.19 pH at CP3 – low, medium and high rainfall scenarios (base case)

METALS

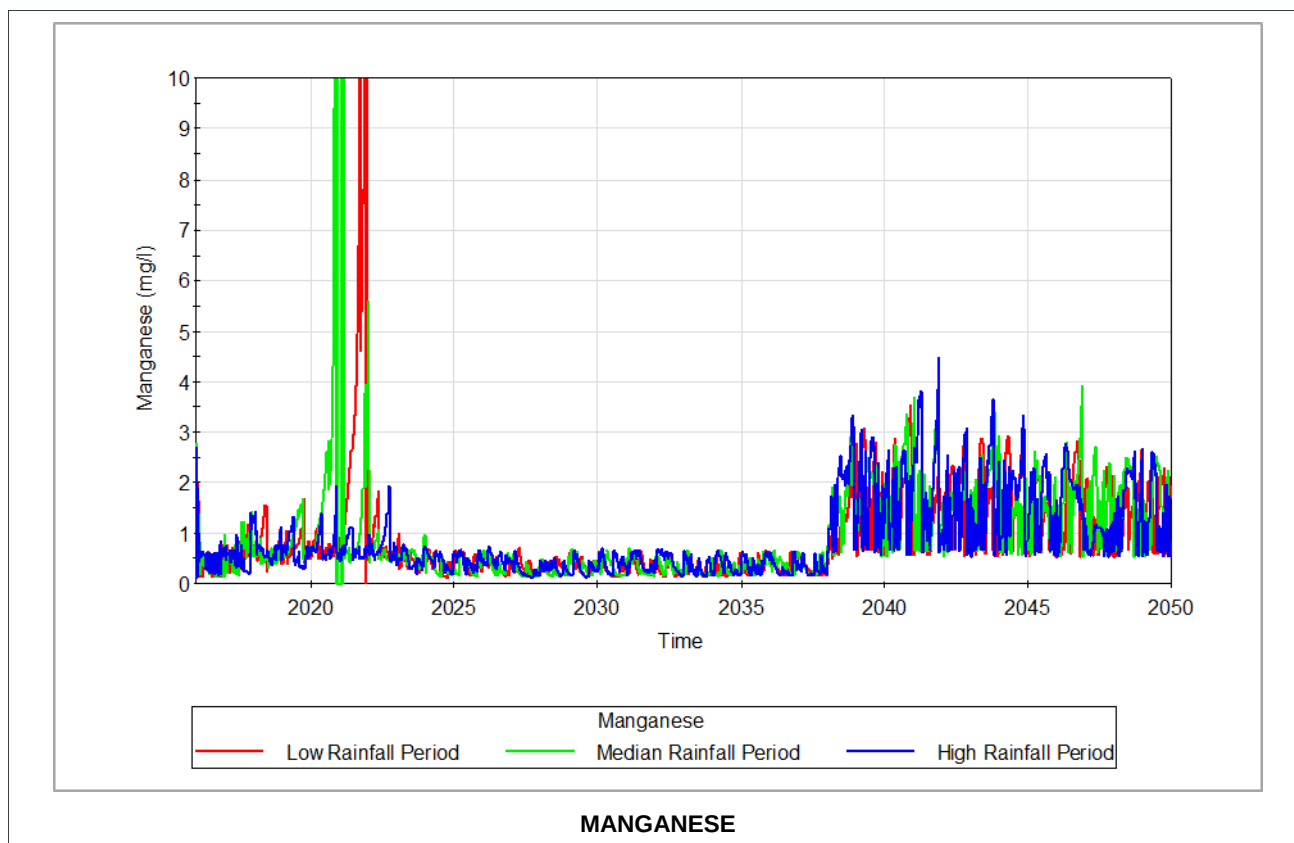
Figure 9.20 shows zinc, nickel and manganese concentrations (respectively) at CP3 for the base case under all climate scenarios. Post closure, zinc concentrations are typically less than 0.14 mg/l, nickel concentrations are typically less than 0.035 mg/l and manganese concentrations are typically less than 0.25 mg/l.



ZINC



NICKEL



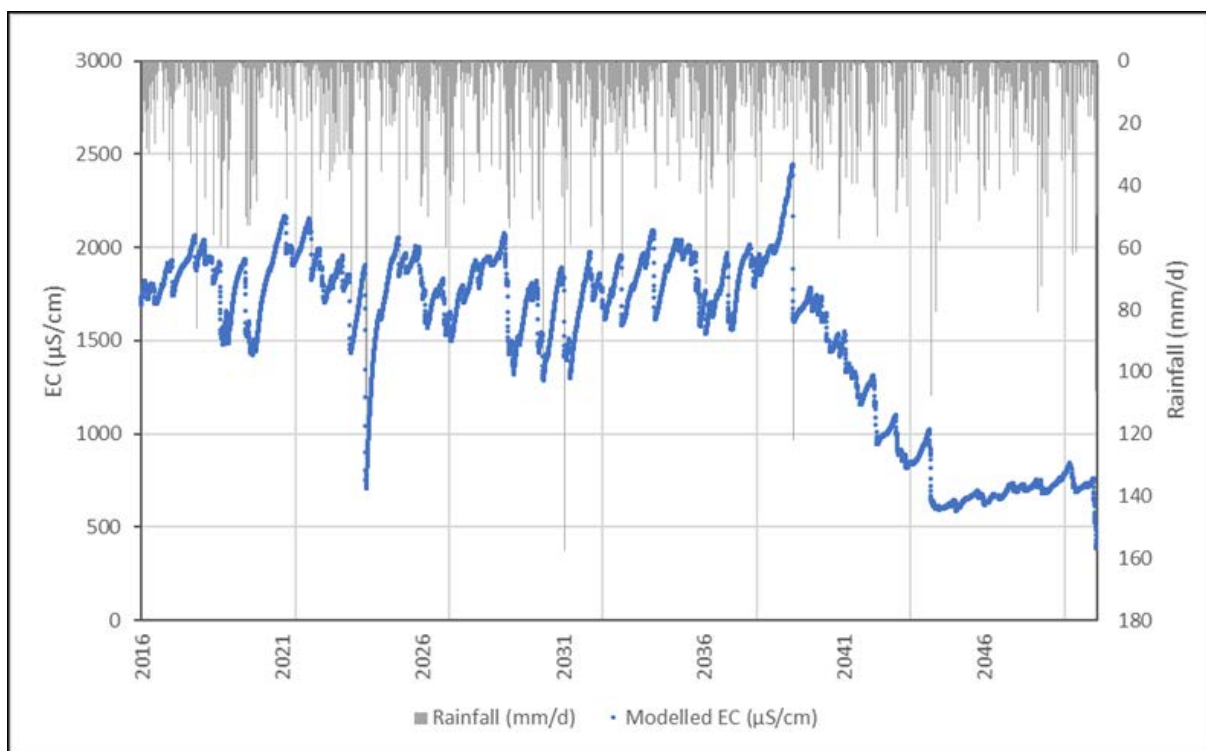
Source: Golder 2018 (Appendix H)

Figure 9.20 Metal concentrations at CP3 (without low flow discharge) for all climate scenarios (base case)

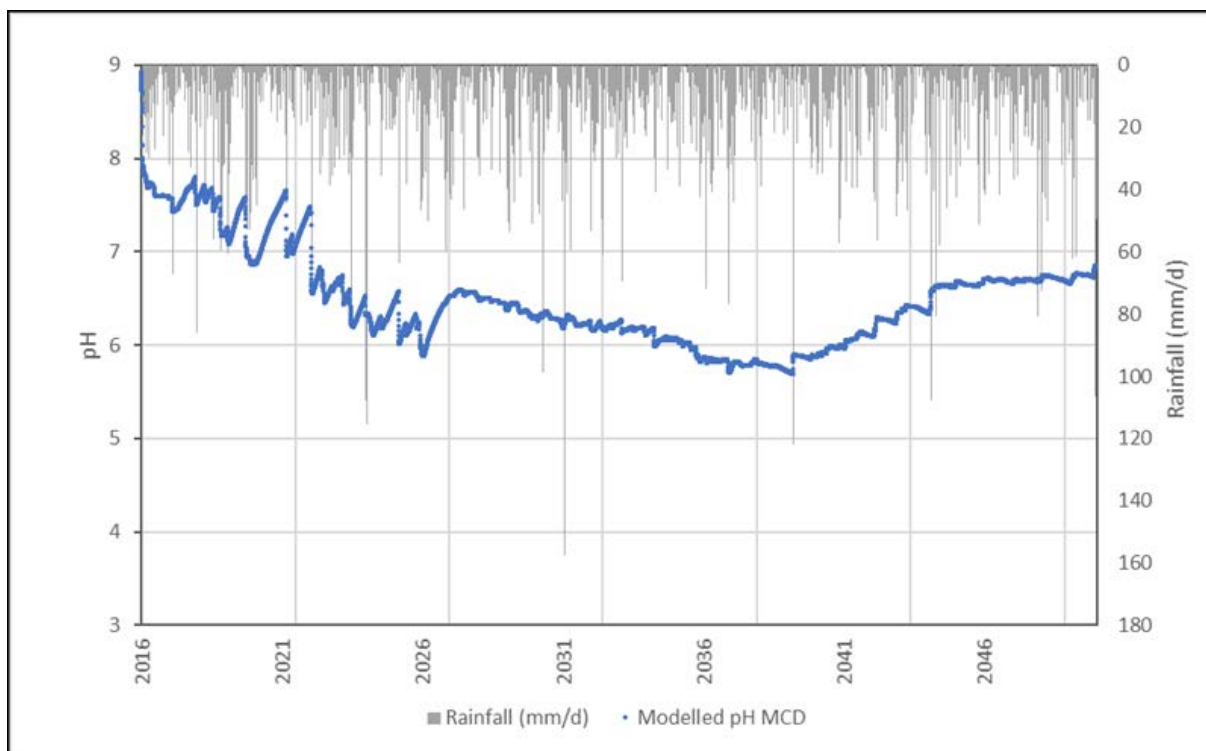
9.4.2.2 MEANDU CREEK DAM

Electrical conductivity at Meandu Creek Dam is shown in Figure 9.21 for the median rainfall scenario. This is the case where in the modelled system the low flow outlet is switched off when operations cease. Meandu Creek Dam remains near to capacity during operations and closure. The electrical conductivity is generally in the order of 1,500 $\mu\text{S}/\text{cm}$ to 2,000 $\mu\text{S}/\text{cm}$ during operations. At closure electrical conductivity reduces to around 500 $\mu\text{S}/\text{cm}$.

pH at Meandu Creek Dam is shown in Figure 9.21. The pH is influenced by inflow pH from CP3 and is in the range of 5.7 to 8.5; increasing after closure to 6.5 to 7.0. As discussed in Section 9.3.2.1 there is uncertainty in the verification of the model representation of pH at CP3.



ELECTRICAL CONDUCTIVITY



pH

Source: Golder 2018 (Appendix H)

Figure 9.21 Electrical conductivity and pH at Meandu Creek Dam (median rainfall scenario) (base case)

9.5 MODEL OUTPUTS (SCENARIOS)

Two engineering controls were identified for further assessment using the model:

- Scenario 1: Dewatering of the North-West Backfilled Pit using 1 bore (at 6 L/s) or 2 bores (at 12 L/s).
- Scenario 2: Improving (thickening) the rehabilitation cover to an area of 1 m – 3 m cover on the north-east surface and embankment of the North-West Backfilled Pit referred to as RSA1.

The modelled results from these scenarios are discussed in the following sections.

9.5.1 SCENARIO 1: DEWATERING OF NORTH-WEST BACKFILLED PIT

An option under consideration for control of resurgent seepage at Bullgang Corner and the diffuse seepage at Ramp 7 is the controlled dewatering of the North-West Backfilled Pit. Two pumping rates have been considered for the full duration of simulations:

- The installation of one bore with the capacity to dewater the North-West Backfilled Pit at a rate of 6 L/s (Scenario 1A)
- The installation of two bores with the combined capacity to dewater the North-West Backfilled Pit at a rate of 12 L/s (Scenario 1B).

Due to some changes in water quality identified in the modelled system for the closure period using Scenario 1A and 1B (refer Section 9.5.1.2), two additional scenarios have also been considered. That is, Scenario 1C and 1D, where pumping is discontinued in 2037 at the end of mining.

The options for pump rate and pumping duration tested using the modelled system are shown in Table 9.12.

In the modelled scenarios, water extracted during dewatering of the North-West Backfilled Pit was added to the Bullgang Corner seepage flow directed to RD27.

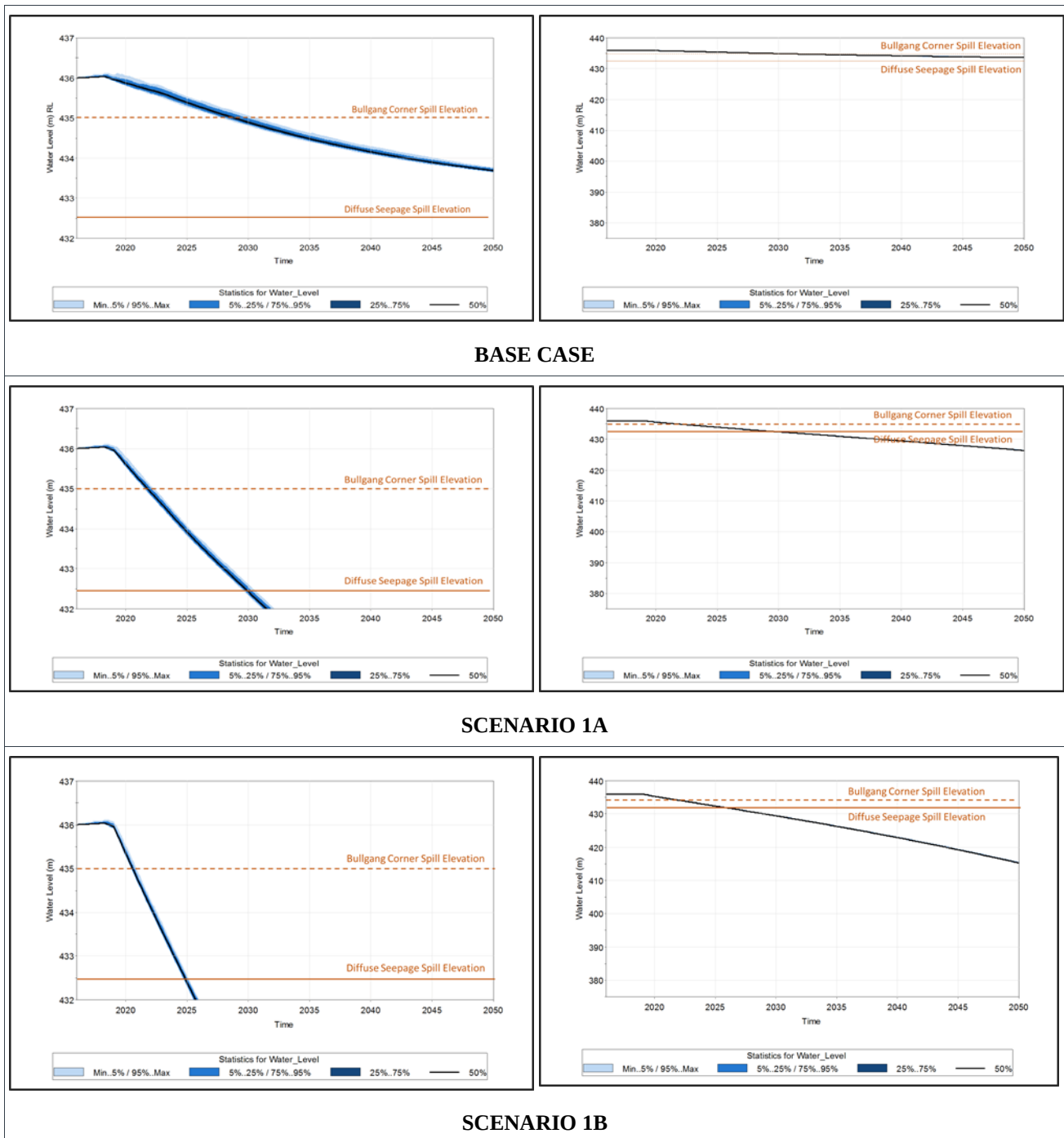
Table 9.12 *Dewatering scenarios*

SCENARIO	PUMP RATE (L/S)	PUMP START (YEAR)	PUMP END (YEAR)
1A	6	2019	2050
1B	12	2019	2050
1C	6	2019	2037
1D	12	2019	2037

The results considered the dewatering performance (drawdown potential) of the bores and water quantity and quality implications to RD27 and at the downstream compliance point CP3.

9.5.1.1 WATER LEVEL IN NORTH-WEST BACKFILLED PIT

The water level in the North-West Backfilled Pit, simulated using 100 model realisations (stochastically generated rainfall), for the base case, Scenario 1A and Scenario 1B are provided in Figure 9.22. Two different scales of the water level axis are provided in each case; the first showing the water level relative to the spill elevation to Ramp 7 (RL432 mAHD) (diffuse seepage spill elevation) and the second showing the water level relative to the base of fill in the North-West Backfilled Pit (RL375.0 mAHD).



Source: Golder 2018 (Appendix H)

Figure 9.22 Water level in North-West Backfilled Pit – Base case, Scenario 1A and Scenario 1B (100 realisations)

Table 9.13 provides the estimated date of effective dewatering of the North-West Backfilled Pit for Scenario 1A and 1B compared to the without dewatering (the base case). Without dewatering the water level gradually declines to below the spill elevation for resurgent seepage at Bullgang Corner by May 2028 (median of 100 model realisations); but remains above the diffuse seepage to Ramp 7 spill elevation at closure, indicating that resurgent seepage will continue to occur to Ramp 7 beyond closure.

With dewatering at 6 L/s (Scenario 1A) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by August 2021 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by July 2029 (median of 100 model realisations). With dewatering at 12 L/s (Scenario 1B) the water level

declines to below the spill elevation for resurgent seepage at Bullgang Corner by June 2020 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by September 2024 (median of 100 model realisations).

Table 9.13 *Date of effective dewatering below spill elevations at Bullgang Corner and Ramp 7 (100 model realisations)*

SPILL POINT	DATE RANGE	BASE CASE	SCENARIO 1A	SCENARIO 1B
Bullgang Corner (RL435 mAHD)	Earliest	April 2027	May 2021	May 2020
	Median	May 2028	August 2021	June 2020
	Latest	February 2030	February 2022	October 2020
Diffuse seep to Ramp 7 (RL432 mAHD)	Earliest	#	March 2029	July 2024
	Median	#	July 2029	September 2024
	Latest	#	March 2030	January 2025

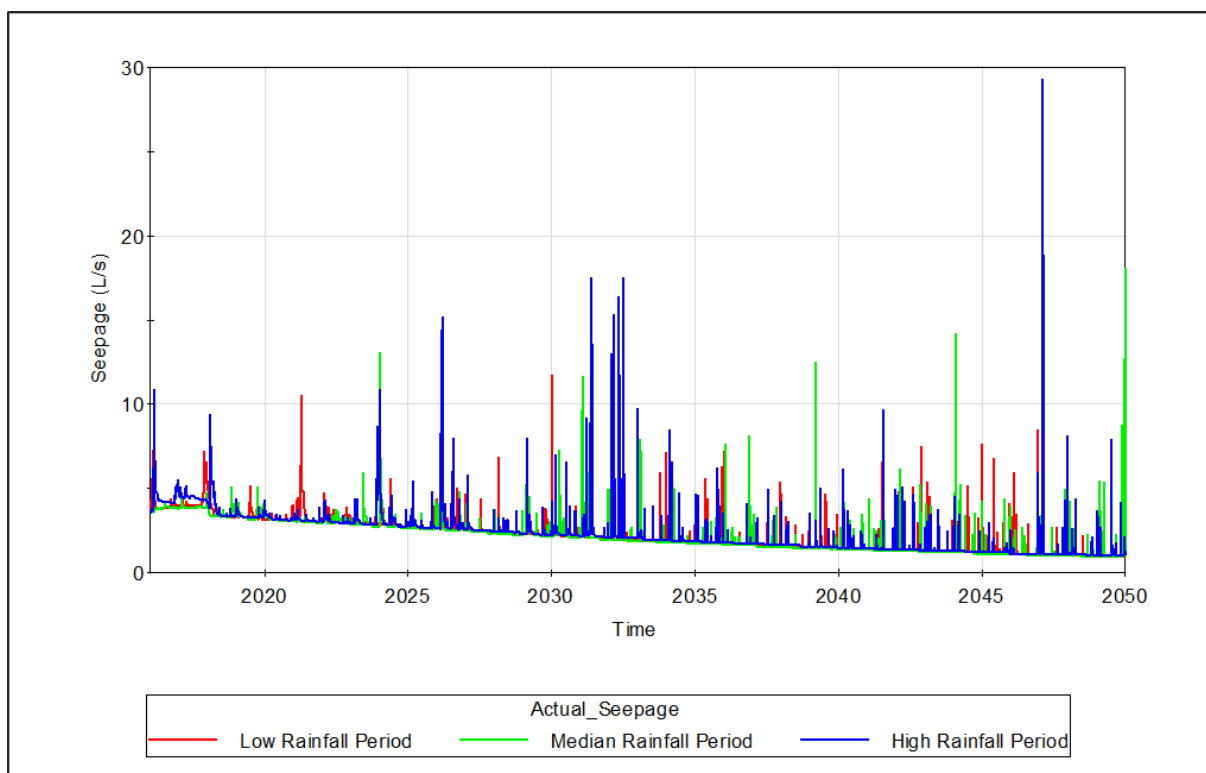
indicates water level does not go below spill elevation during the simulation period

The water elevation in the North-West Backfilled Pit at the end of mining and at the end of the closure period simulated is provided in Table 9.14. The greater the rate of dewatering the greater the reduction in water surface elevation in the North-West Backfilled Pit. There is a slight rise in water elevation in Scenarios 1C and 1D after dewatering ceases at the end of mining (of less than 0.5 m by 2050 for Scenario 1C and less than 1 m by 2050 for Scenario 1D) as the model assumes that there is no outflow through the floor of the pit.

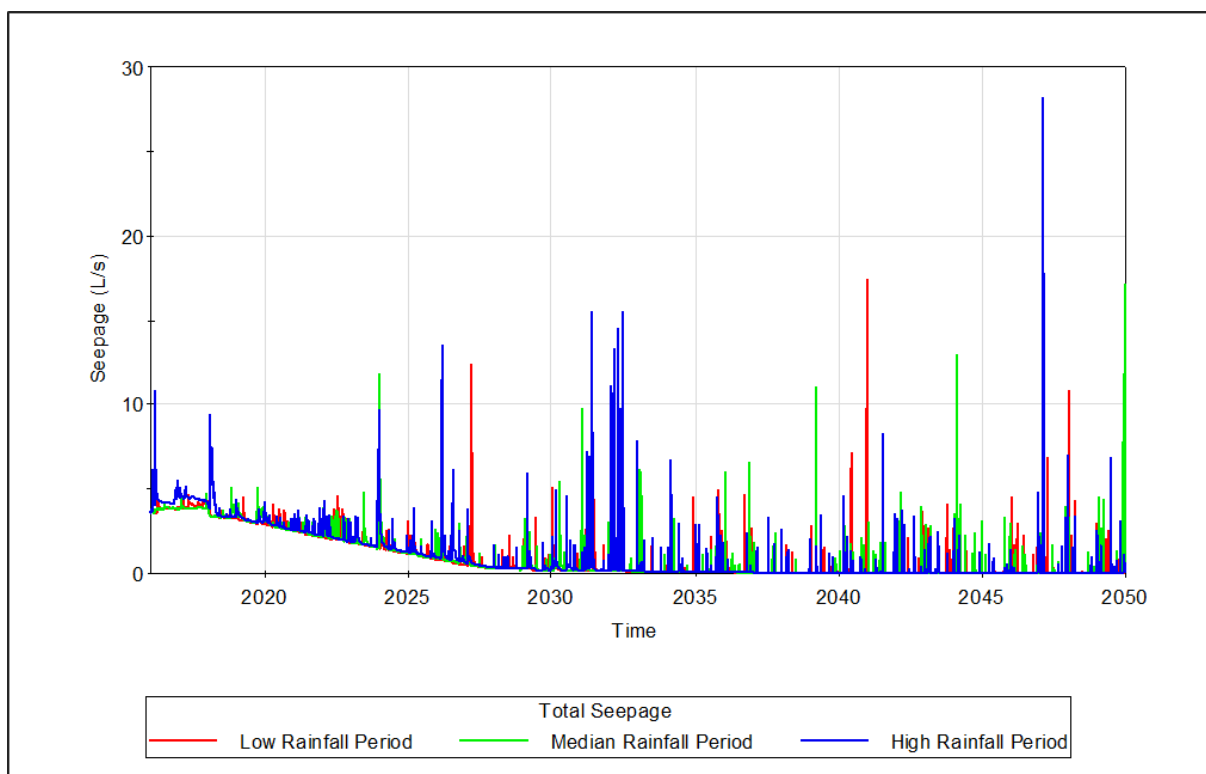
Table 9.14 *North-West Backfilled Pit water elevation (RL m) (median of 100 realisation)*

SCENARIO	END OF MINING 2037 (RL mAHD)	AT 2050 (RL mAHD)
Base Case	434.3	433.7
Scenario 1A	430.1	426.4
Scenario 1B	424.3	415.3
Scenario 1C	430.1	430.5
Scenario 1D	424.3	425.1

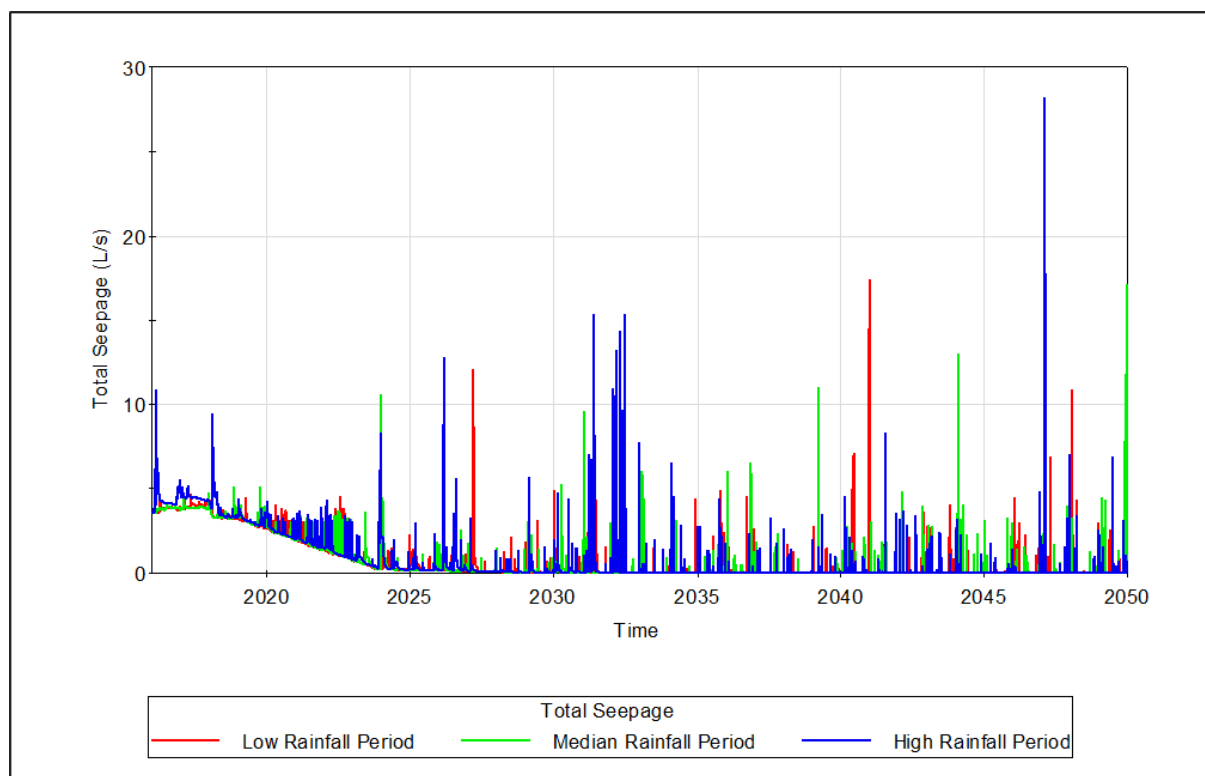
Seepage from the North-West Backfilled Pit reporting to Bullgang Corner and diffuse seepage at Ramp 7 is comprised of resurgent seepage as well as interflow (as shown in Figure 9.5). The resurgent seepage is the constant low flow component. Interflow occurs in response to rainfall. The total seepage flow for base case, Scenario 1A and Scenario 1B is shown in Figure 9.23 for low, median and high rainfall periods. As can be seen from these figures the low flow component of the seepage ceases to occur with dewatering, however, discharge from the North-West Backfilled Pit area will continue due to infiltration and interflow in response to rainfall events.



BASE CASE



SCENARIO 1A



SCENARIO 1B

Source: Golder 2018 (Appendix H)

Figure 9.23 Total seepage (Bullgang Corner and Ramp 7) – Base case, Scenario 1A and Scenario 1B (low, medium and high rainfall periods)

Table 9.15 provides the annual average resurgent seepage and interflow. As the water level in the North-West Backfilled Pit is drawn down the resurgent seepage rate declines. The faster the drawdown the lower the resurgent seepage rate.

Table 9.15 Annual average resurgent seepage and interflow (median rainfall simulation)

YEAR	BASE CASE (L/S)	SCENARIO 1A (L/S)	SCENARIO 1B (L/S)
2018	4.49	4.49	4.49
2019	4.53	4.45	4.37
2020	3.40	3.02	2.63
2021	3.35	2.74	2.11
2022	3.99	3.31	2.61
2023 - 2037	3.06	1.37	1.04
2038 - 2050	2.24	1.07	1.07

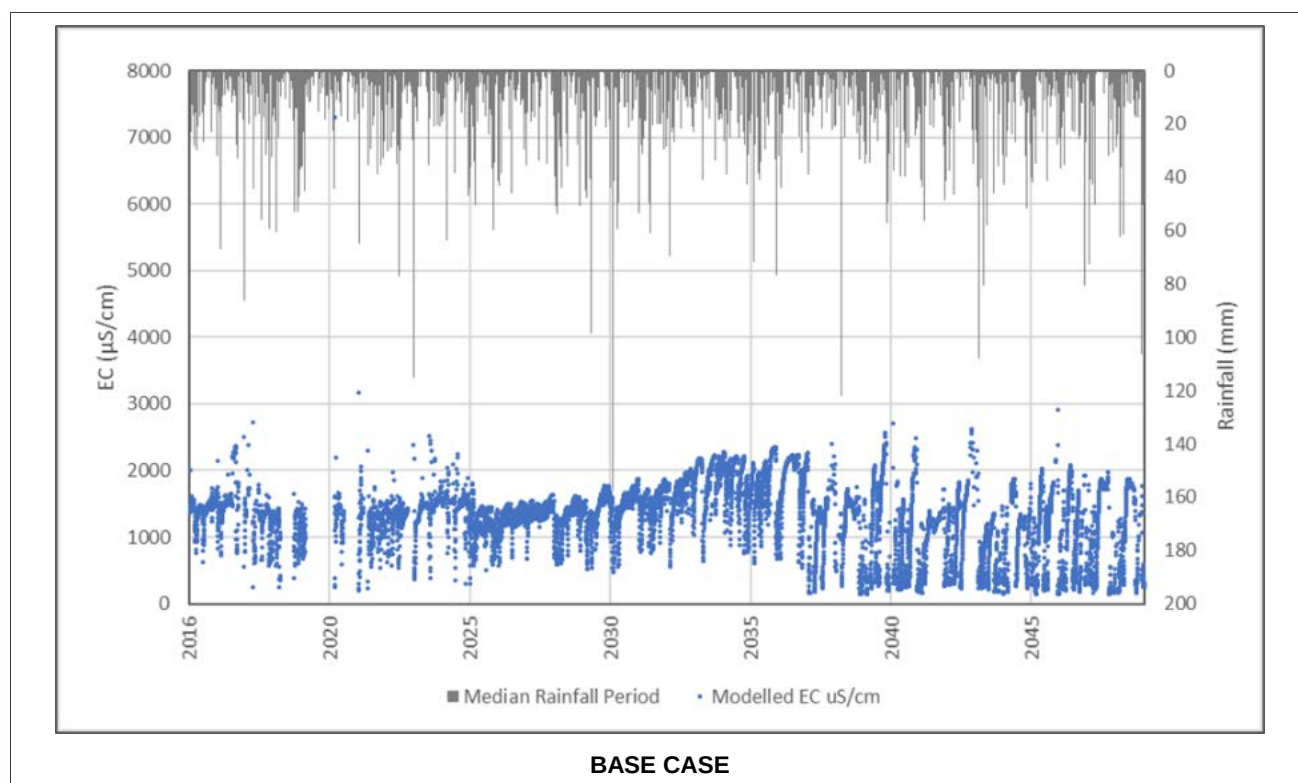
The low flow inflow to RD27 inclusive of dewatering from the North-West Backfilled Pit and Ramp 7 flow (diffuse seepage and RD27 catchment runoff) is shown in Table 9.16. Water in excess of the low flow inlets to RD27 is sent via a high flow bypass to RD7. The average annual high flow bypass flow rate is provided in Table 9.16. There is no difference between the scenarios in the quantity of water in excess of what is able to enter RD27 via the low flow inlets.

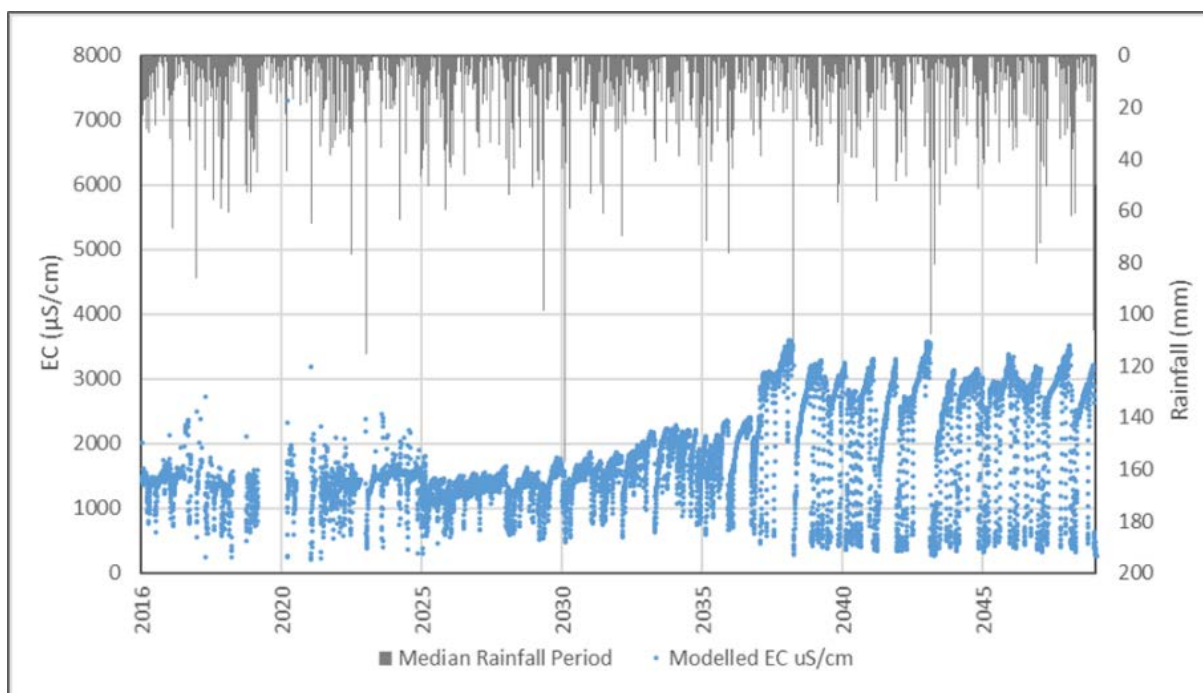
Table 9.16 Annual average inflow to RD27 and quantity of water in high flow bypass (median rainfall period)

YEAR	INFLOW TO RD27			HIGH FLOW BYPASS		
	BASE CASE (L/S)	SCENARIO 1A (L/S)	SCENARIO 1B (L/S)	BASE CASE (L/S)	SCENARIO 1A (L/S)	SCENARIO 1B (L/S)
2018	4.49	4.49	4.49	3.00	3.00	3.00
2019	4.53	10.45	16.37	4.56	4.56	4.56
2020	3.40	9.02	14.63	0.50	0.50	0.50
2021	3.35	8.74	14.11	0.54	0.54	0.54
2022	3.99	9.31	14.61	2.14	2.14	2.14
2023 - 2037	3.06	7.37	13.04	1.94	1.92	1.92
2038 - 2050	2.24	7.07	13.07	1.63	1.61	1.61

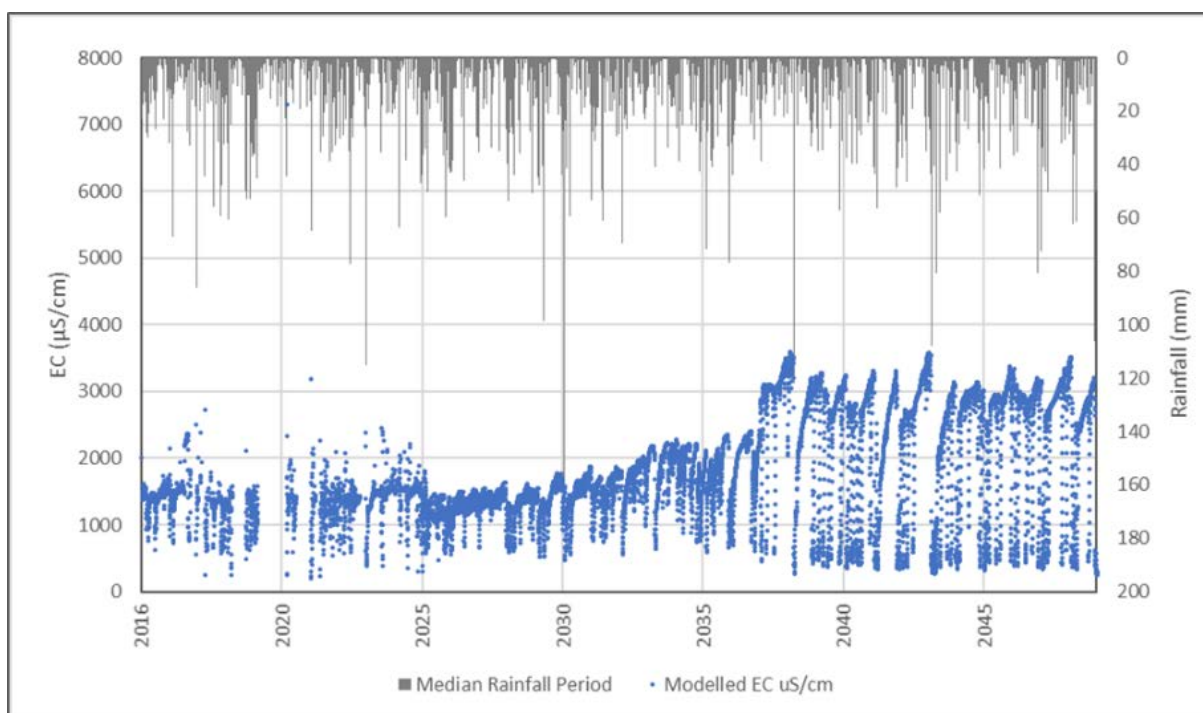
9.5.1.2 WATER QUALITY

Electrical conductivity at CP3 for the base case, Scenario 1A and Scenario 1B is shown in Figure 9.26. In both Scenario 1A and Scenario 1B during the post closure period (2038 – 2050) there is a marked increase in electrical conductivity as seen in Figure 9.24. The reason for this increase in the modelled system is that at closure, due to the cessation of use of treated water at fill points and for transfer to RD26 the pond continuously overflows. The primary inflow to RD27 during this period is low flow seepage from the North-West Backfilled Pit that, when treated, has a modelled electrical conductivity of 3700 $\mu\text{S}/\text{cm}$. The overflow from RD27 is routed via RD7 and RD8 to CP3. Also, with the cessation of pit dewatering at closure there is reduced flow through the eastern retention dam system routing water via RD2 to CP3. As a result, the water quality at CP3 is impacted directly by the water quality of the overflow from RD27.





SCENARIO 1A

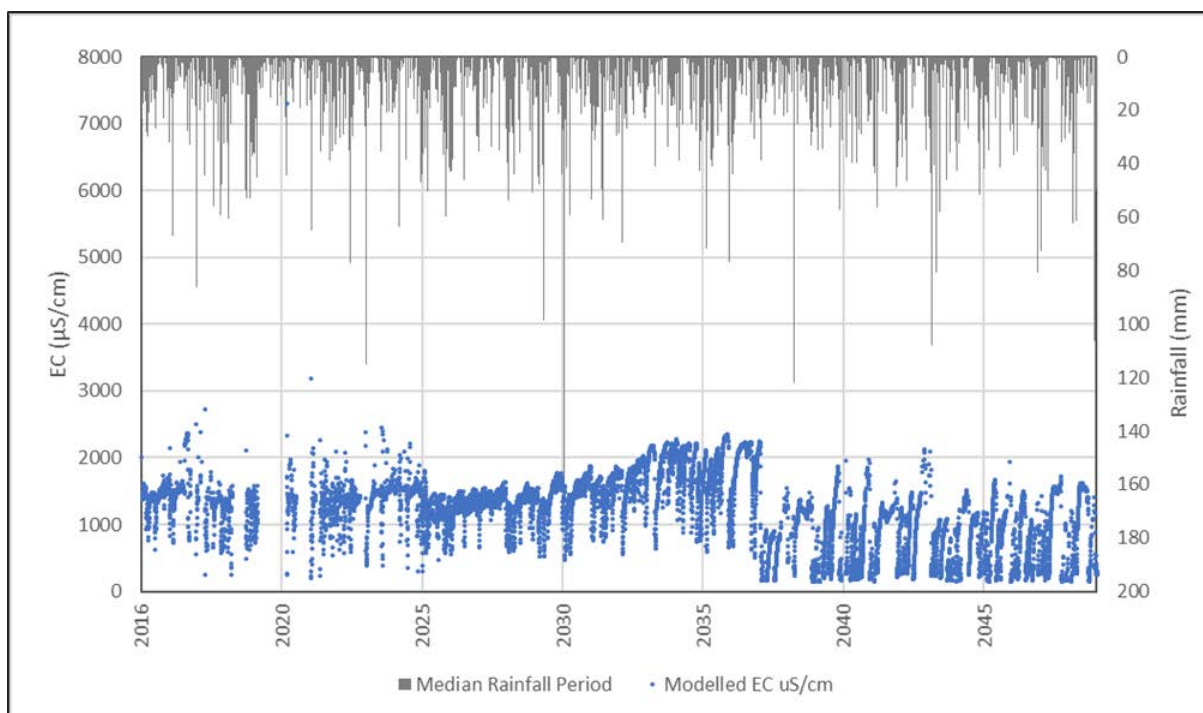


SCENARIO 1B

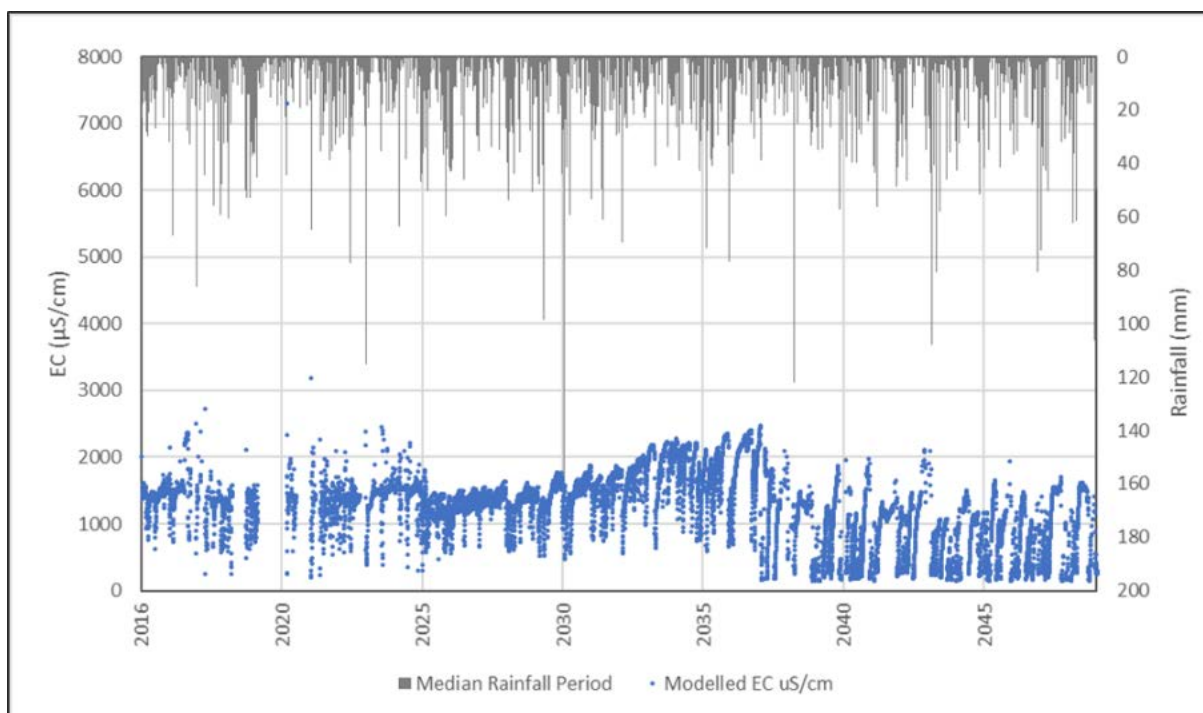
Source: Golder 2018 (Appendix H)

Figure 9.24 Simulated electrical conductivity at CP3 – Base case, Scenario 1A and Scenario 1B (median rainfall simulation)

Alternative scenarios (Scenario 1C and Scenario 1D) were simulated where the dewatering pumps were turned off at the end of mining operations in 2037. The resultant electrical conductivity at CP3 is shown in Figure 9.25. If water requiring treatment from dewatering is stopped at the start of the closure period, the electrical conductivity remains below 2,100 $\mu\text{S/cm}$.



SCENARIO 1C



SCENARIO 1D

Source: Golder 2018 (Appendix H)

Figure 9.25 Simulated electrical conductivity at CP – Scenario 1C and Scenario 1D (median rainfall simulation)

9.5.2 SCENARIO 2: IMPROVED COVER TO RSA 1

A second engineering control has been simulated using the model, that is, application of an improved cover system to the RSA1. The existing cover (1 m on the western embankment of the North-West Backfilled Pit, termed RSA1a in the model; and 3 m on the western surface of the North-West Backfilled Pit, termed RSA1b in the model); is of a reduced thickness compared to the nominal 6 m depth of cover used since 2016 above PAF Material and particularly coarse

rejects at Meandu Mine. Surface runoff and baseflow from RSA1a reports directly to the Ramp 7 haul road drain. Surface runoff from RSA1b reports to the Ramp 7 haul road drain and baseflow reports as recharge to the North-West Backfilled Pit. Due to the reduced thickness of the existing soil cover in the location of RSA1a and RSA1b; in the base case, these areas have been modelled as having the same surface runoff and baseflow characteristics as waste.

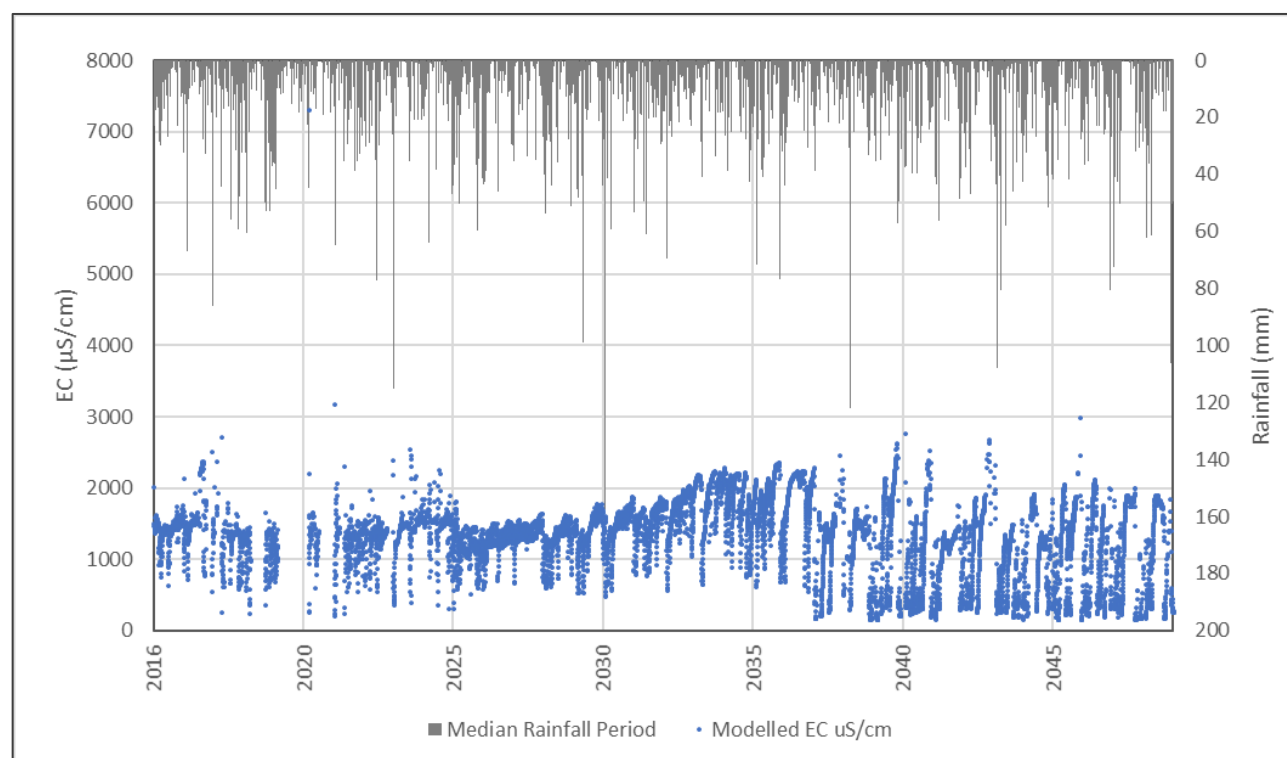
The purpose of this simulation trial (Scenario 2) is to determine the impact of the change in cover thickness of RSA1a and RSA1b on the quantity of recharge to the North-West Backfilled Pit and quality of water at downstream compliance points in the modelled system. For the Scenario 2 simulation, the relevant areas have been modified from the base case to have the runoff/recharge properties of rehabilitated land.

On average, there is a 13% reduction in infiltration (as shown in Table 9.17), however, this change is insufficient to make a significant change to the water surface elevation in the North-West Backfilled Pit. Output from the Integrated Water Model determined therefore that improved cover thickness alone is insufficient to make a significant change to water surface elevation in the North-West Backfill Pit domain.

Table 9.17 Change in surface cover results – quantity (median rainfall simulation)

	AVERAGE CHANGE IN INFILTRATION FROM BASE CASE (2018 – 2026)	WATER SURFACE ELEVATION 2037 (RL m)	WATER SURFACE ELEVATION 2050 (RL m)
Base case	0%	434.3	433.7
Scenario 2	13% reduction	434.3	433.7

There is also minimal change from base case in the modelled electrical conductivity at CP3 for the duration of the simulation as shown in Figure 9.26.



Source: Golder 2018 (Appendix H)

Figure 9.26 CP3 electrical conductivity Scenario 2 (median rainfall simulation)

9.6 DISCUSSION

9.6.1 BASE CASE

The base case has been modelled with the AMD and mine water controls implemented from 2016 (refer Section 2.6). The modelled network has components that represent each of the mine water management elements at Meandu Mine, including surface water quantity, groundwater quantity and water quality.

The sensitivity of modelled seepage at Bullgang Corner to North-West Backfilled Pit hydraulic parameters was examined by varying the hydraulic conductivity values of the materials in the groundwater (SEEP/W) model. Discharge from the North-West Backfilled Pit continues to be released, in all cases trialled, without further controls in place, for the duration of the simulation period that includes operations and post closure period.

Flow at CP3 was simulated using three climate scenarios. There are periodic high and low flows in both operational and closure periods in all scenarios, as well as periods of no flow. Periods of no flow are more frequent during mining operations, but there is also an increase in background low flow during operations when compared to the post closure period.

Two scenarios were simulated for the operational and post closure period at Meandu Creek Dam.

- The first, stops continuous low flow discharge when operations cease, and Meandu Creek Dam remained close to capacity during operations and the post closure period.
- The second, allowed a continuation of low flow discharge at current rates which resulted in a marked decline in storage volume.

As simulated in the 2017 Life of Mine Plan, once the K2E Pit is dewatered, in preparation for mining that pit, the model indicates there may be periods of insufficient water supply available to the CHPP; particularly during extreme dry periods. Stanwell would monitor water requirements and availability in the lead up to this period and adjust water management practices. Note that Meandu Mine is currently using the predictive model to inform a water conservation/harvesting initiative.

In all climate scenarios simulated there are frequent high flow bypasses of inflow to RD27. In total, approximately half of the catchment and other flow to RD27 will bypass RD27 and go to RD7. This occurs during high flow events and does not appear to impact on water quality at CP3.

There is good confidence in the representation of electrical conductivity at CP3 in the modelled system. Electrical conductivity values exceeding 2,500 $\mu\text{S}/\text{cm}$ occurred in the modelled system at periods of low flow. There was only a small, if any, change in electrical conductivity at CP3 in response to high flows of resurgent seepage from Bullgang Corner and Ramp 7 haul road drain.

Post-closure, modelling indicates that metal concentrations typically remain between stable upper and lower limits, though may exhibit sharp and temporary increases when water volumes are very low (that is, during extremely dry conditions). Electrical conductivity behaviour post-closure typically remains below reportable concentrations, with some electrical conductivity values exceeding 2,500 $\mu\text{S}/\text{cm}$ occurring in some simulations (during dry conditions).

There is less confidence in the representation of pH at CP3 and subsequently at Meandu Creek Dam (CP1) in the modelled system. Low pH events in the modelling appear to be related to pit dewatering activities. Once pumping from pits ceases at closure, the pH as modelled returns to neutral conditions. pH is represented in the model based on the concentration of hydrogen ions only and may need revision to incorporate a hydroxide component. Undertaking more frequent in-pit pH sampling is recommended to assist in further verification of the model.

9.6.2 ENGINEERING CONTROLS

Dewatering of the North-West Backfilled Pit was applied in the model for four scenarios:

- Scenario 1A – dewatering in place for entire period of simulation (2019 to 2050) at a rate of 6 L/s
- Scenario 1B – dewatering in place for entire period of simulation (2019 – 2050) at a rate of 12 L/s
- Scenario 1C – dewatering in place up for the period of mining up until 2037 at a rate of 6 L/s and then discontinued for the closure period
- Scenario 1D – dewatering in place up for the period of mining up until 2037 at a rate of 12 L/s and then discontinued for the closure period.

Without dewatering (the base case) the water level gradually declines to below the spill elevation for resurgent seepage at Bullgang Corner (RL435 mAHD) by May 2028 (median of 100 model realisations); but remains above the diffuse seepage to Ramp 7 spill elevation (RL432 mAHD) at closure, indicating that resurgent seepage will continue to occur to Ramp 7 up until and beyond closure. With dewatering at 6 L/s (Scenario 1A) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by August 2021 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by July 2029 (median of 100 model realisations). With dewatering at 12 L/s (Scenario 1B) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by June 2020 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by September 2024 (median of 100 model realisations). The water level may be reduced to RL424.3 mAHD, that is approximately 8 m below the diffuse seepage spill point by 2037, if two bores are used for dewatering. This reduction is predicted to be in the order of 1.9 m if one bore is used.

However, with North-West Backfilled Pit dewatering bores in operation (to reduce water levels in the North-West Backfilled Pit), there was a marked increase in electrical conductivity at CP3 during the closure period due to continuous overflow of treated water from RD27. The primary inflow to RD27 during this period is low flow seepage from the North-West Backfilled Pit that, when treated, has a modelled electrical conductivity of 3700 $\mu\text{S}/\text{cm}$. Alternatively, if dewatering is discontinued at the end of mining (as shown in Scenario 1C and Scenario 1D) the electrical conductivity at CP3 remained below 2100 $\mu\text{S}/\text{cm}$.

Seepage from the North-West Backfilled Pit reporting to Bullgang Corner and diffuse seepage at Ramp 7 is comprised of resurgent seepage as well as interflow. The resurgent seepage is the constant low flow component and interflow occurs in response to rainfall. The low flow component of the seepage ceases to occur with dewatering, however, discharge from the North-West Backfilled Pit will continue due to infiltration and interflow in response to rainfall events.

In the dewatering scenarios trialled, as the water level in the North-West Backfilled Pit is drawn down the resurgent seepage rate declines. The faster the drawdown the lower the resurgent seepage rate. The quantity of high flow diverted around RD27 does not change between scenarios, because there is capacity in RD27 low flow inlets sufficient to manage the constant rate dewatering flow.

A second engineering control has been simulated using the model, that is, application of an improved cover system to the RSA1. On average, there is a 13% reduction in infiltration to the North-West Backfilled Pit; however, this change is insufficient to make a significant change to the water surface elevation in the North-West Backfilled Pit and should not be considered as an engineering control on its own. Based on the performance monitored from the dewatering program, additional improvements to the cover thickness may be considered as a long-term control measure.

10 MANAGEMENT RECOMMENDATIONS

SECTION OVERVIEW

This section outlines the management actions which Stanwell has compiled resulting from the investigations into AMD at the Meandu Mine.

As outlined in Section 9 a base case based on the 2017 Life of Mine Plan has been modelled as a baseline to identify specific areas for consideration of suitable controls to manage AMD at Meandu Mine. Model simulations have focussed on the known source areas of AMD and have simulated the water management network for future operations to closure.

The model has identified that seepage from the North-West Backfilled Pit, without further controls, will continue past the cessation of mining in 2037. It was also identified from the base case modelling that seepage from the North-West Backfilled Pit, while being managed with lime-dosing, is not the main influence on the occurrence of modelled high electrical conductivity events at CP3. Rather, extended periods of low rainfall and low flow conditions are more likely to result in high electrical conductivity.

Two engineering controls were also assessed using the Integrated Water Model:

- Scenario 1: Dewatering of the North-West Backfilled Pit using 1 bore (at 6 L/s) or 2 bores (at 12 L/s).
- Scenario 2: Improving (thickening) the rehabilitation cover to an area of 1 m – 3 m cover on the north-east surface and embankment of the North-West Backfilled Pit referred to as RSA1.

The modelling results indicated that the dewatering of the North-West Backfilled Pit assists with reducing the water level within the pit to below the spill elevation for resurgent seepage at Bullgang Corner and the diffuse seep spill elevation at Ramp 7. However, with North-West Backfilled Pit dewatering bores in operation (to reduce water levels in the North-West Backfilled Pit), there was a marked increase in electrical conductivity at CP3 during the closure period due to continuous overflow of treated water from RD27 (i.e. the water is no longer being used on site).

The modelling results from application of an improved cover system to the RSA1 showed a 13% reduction (on average) in infiltration to the North-West Backfilled Pit; however, this change is insufficient to make a significant change to the water surface elevation in the North-West Backfilled Pit. These results, along with the recommendations from the technical investigation undertaken to inform this environmental investigation, have been used to formulate the management actions outlined in this section. Stanwell has committed to these management actions to manage AMD from the Meandu Mine.

The current management measures (refer to Section 2.6) which commenced in 2015/2016 and summarised in Section 10.1, have been included into the Integrated Water Model. In addition to these management measures, Section 10.2 outlines recommendations for future management measures as an outcome of this environmental investigation. Some of these recommendations relate to continuation of existing management measures.

Specifically, this section addresses requirement B4(iii) and B6(iv) of the Notice:

B4(iii) identify short term and long term measures including (if relevant) further lines of investigation, monitoring requirements, and operational or mine planning measures that should be developed and/or implemented to prevent environmental harm occurring from AMD at Meandu Mine.

B6(iv) provide recommendations in regard to management and treatment of AMD at Meandu Mine.

10.1 CURRENT MANAGEMENT MEASURES

As a result of the identification of AMD issues at the North-West Backfilled Pit, Stanwell has implemented a number of interim controls and made a number of infrastructure and mine planning management changes since 2015/16 to address AMD issues occurring on site. These have been presented in Section 2.6 and include:

- initial changes to water management infrastructure (lime-dosing and water reuse) to minimise the amount of Ramp 7 and Bullgang Corner seepage water reporting to CP3 and Meandu Creek Dam.
- construction of seepage collection dam RD27, automated lime-dosing and pump and pipework.
- installation of solid bowl centrifuges at the CHPP to dewater tailings and decommissioning of North-West B TSF over coming years.
- changes to rejects placement.
- rehabilitation design changes - introducing 6 m of NAF cover as design criteria in the final cover over rejects areas in Hitachi Hill and future areas rehabilitated from 2016 onwards.

These current management measures which commenced in 2015/2016, have been included in the Integrated Water Model developed for this environmental investigation (Section 9). In addition to the controls listed above, Section 10.2 outlines recommendations for future management measures as an outcome of this environmental investigation. Proposed and ongoing management actions as an outcome of this investigation are presented in Table 10.1 and Table 10.2.

Some of these recommendations relate to continuation of existing management measures which are summarised below and outlined in Table 10.2:

- Rejects material placement: actions focussing on limiting storage exposure time of coarse reject materials, combining rejects and tailings stream and placement of reject materials approximately 6 m beneath the final landform profile.
- Material testing: actions focusing on ongoing independent geochemical assessment.
- Application of water modelling as a predictive tool: actions to inform optimisation of site water management.

10.2 FUTURE MANAGEMENT MEASURES

The current management measures presented in Section 2.6 have played an important role in development of engineering AMD control options as an outcome of this environmental investigation. As the short-term measures were established at commencement of this environmental investigation, they have been implemented on-site and incorporated into the predictive model base case simulations and have enabled a more targeted list of management measures that are detailed in Table 10.1. Therefore, as an outcome of this environmental investigation, future management measures have focused on the following:

- Implementation of dewatering program using installed dewatering system bores (GW48, GW49) in the North-West Backfilled Pit to reduce the water level in the pit to well below the spill elevation for diffuse and resurgent seepage (approximately RL432 mAHD in the western area (Ramp 7) and approximately RL435 mAHD in the area where the North-West Backfilled Pit spills to Bullgang Corner). The predictive model shows that by 2037, if two bores are used for dewatering the water level may be reduced by approximately 8 m below the diffuse seepage spill point. This reduction is predicted to be in the order of 1.9 m if one bore is used.
- Based on the outcome of the dewatering program, additional improvements to the cover thickness of Rejects Storage Area 1 (RSA1) may need to be considered.
- Continued verification to improve the reliability of modelling predictions, such as, monitoring of water use in the CHPP following installation of solid bowl centrifuge and water quality monitoring of water stored in pits.
- Establishment of groundwater bore(s) to the west of Meandu Creek to monitor the high electrical conductivity recorded at GW78 and to validate data from geophysics investigations.

- Update of the current Meandu Creek Receiving Environment Monitoring Program (REMP) to include key indicators for AMD (i.e. iron and manganese).

Additional monitoring (i.e. toxicity and bioaccumulation) in sediment at CM2 (in the channel between CP3 and the Meandu Creek Dam) to determine the acute or chronic toxicity of sediment and understand the potential for impacts to downstream reaches. Site CM2 has abundant reeds and fine sediments, and appears to be effectively trapping metals and reducing transportation further downstream to the receiving environment. While there is no evidence of impacts to the environmental values of Meandu Creek under current water conditions, under certain conditions (e.g. low pH and/or low water hardness), metals in sediment could be mobilised and transported further downstream. It should be noted that where pH and electrical conductivity continue to be monitored and managed to remain within acceptable range, as required by current Environmental Authority (EA) (EPML00709113) water contaminant limits for CP1, and CP3 respectively, the release of sediment bound contaminants to the water column is not expected to occur.

Although not related to the AMD investigation that has been undertaken for this environmental investigation report, additional areas for groundwater monitoring have been identified for areas to the north-west of the Queen West void as well as for Black Creek catchment (refer Section 5.2). Both areas will be monitored by Stanwell as part of the ongoing groundwater monitoring program (EA EPML00709113).

10.2.1 DOMAIN SPECIFIC RECOMMENDATIONS AS AN OUTCOME OF THE EIR

10.2.1.1 NORTH-WEST BACKFILLED PIT

Objective: Stanwell will implement a dewatering program using installed dewatering system bores (GW48, GW49) in the North-West Backfilled Pit to reduce the water level in the pit to well below the spill elevation for diffuse and resurgent seepage (approximately RL432 mAHD in the western area of the North-West Backfilled Pit (Ramp 7) and approximately RL435 mAHD in the area where the North-West Backfilled Pit spills to Bullgang Corner). *Refer to Recommendation A1, Table 10.1.* The results of the Integrated Water Model have indicated with dewatering at 6 L/s (Scenario 1A) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by August 2021 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by July 2029 (median of 100 model realisations). With dewatering at 12 L/s (Scenario 1B) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by June 2020 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by September 2024 (median of 100 model realisations).

Note: A second engineering control has been simulated using the model, that is, application of an improved cover system to the RSA1. On average, there is a 13% reduction in infiltration to the North-West Backfilled Pit however, this change is insufficient to make a significant change to the water surface elevation in the North-West Backfilled Pit and should not be considered as an engineering control on its own. Based on the performance monitored from the dewatering program, additional improvements to the cover thickness may be considered as a long-term control measure. *Refer to Recommendation A2, Table 10.1.*

Deposition of tailings to the North-West B TSF, which is currently interpreted to seep directly to the North-West Backfilled Pit, is planned to cease by end of calendar year 2019 (*Refer to Recommendation A3, Table 10.1.*).

Progressive rehabilitation of the North-West B TSF will then commence as per Condition G8 of the EA (EPML00709113) (*Refer to Recommendation A4, Table 10.1.*).

Table 10.1 Proposed recommendations as an outcome of the EIR for the North-West Backfilled Pit

RECOMMENDATION FROM EIR		STATUS	ACTION REQUIRED	PROPOSED TIMING	SOURCE
A	DOMAIN SPECIFIC RECOMMENDATIONS				
A1	Implementation of dewatering program	NEW	Development and implementation of a Dewatering Program for the North-West Backfilled Pit. Based on the recommendations from Golder and JBT (2018), this program is to include as a minimum: — Utilisation of current extraction bores (i.e. GW48 and GW49) for pumping test to monitor efficiency of pumping for reduction of water level in spoil. — Recommendations to monitor flow rate and water quality at the Bullgang Corner and Ramp 7 intakes to RD27 to validate head-seepage relationships and interflow parameters in the model. — Consideration to install instrumentation (i.e. Lysimeter or vertical series of vibrating wire piezometers) or other methods for measuring rainfall infiltration to the North-West Backfilled Pit. — (if required) Proposed installation of additional groundwater extraction bores in spoil within the areas where seepage has currently been identified (JBT 2018). — As an outcome of the program, recommendations in relation to water level in the North-West Backfilled Pit required to validate or refine parameters used for determining interflow and recharge in the pit. Note: Groundwater extraction is an engineering solution that would ideally be reduced or phased out over time as passive control measures become increasingly effective.	Establishment in FY18/19	JBT Golder
A2	Improvement of cover system (target area RSA1)	NEW	(if required) Based on the effectiveness of Recommendation (A1), additional improvements may be considered in the RSA1 area, such as: — Change to the cover thickness — Contouring the spoil to encourage runoff of rainfall and discourage pooling of water that could report to the spoil as recharge (current practice). — Revegetating the spoil to further reduce the potential for recharge to the spoil (current practice).	Long-term measure to be developed (if required) after results of Dewatering Program are known.	Golder JBT

RECOMMENDATION FROM EIR		STATUS	ACTION REQUIRED	PROPOSED TIMING	SOURCE
A3	Cease tailings deposition in North-West B TSF	PLANNED	Decommissioning of North-West B TSF, which is currently interpreted to seep directly to the North-West Backfilled Pit.	Cease of tailings deposition by end of calendar year 2019	Stanwell
A4	Rehabilitation of North-West B TSF	PLANNED	Progressive rehabilitation of the North-West B TSF, as per Condition G8 of the EA (EPML00709113)	To commence after tailings deposition ceases (refer to A3)	Stanwell

10.2.1.2 GENERAL RECOMMENDATIONS AS AN OUTCOME OF THE EIR

LANDFORM AND REHABILITATION

No additional landform and rehabilitation actions have been identified other than those identified previously for the North-West Backfilled Pit.

While no recommendations are identified as an outcome of this environmental investigation, it is acknowledged that the Mineral and Energy Resources (Financial Provisioning) Bill 2018, if passed, will require a Progressive Rehabilitation and Closure Plan. The overall findings from this environmental investigation will inform the Rehabilitation Planning Part of the new Progressive Rehabilitation and Closure Plan for Meandu Mine.

CLOSURE MANAGEMENT

No additional closure management actions have been identified as an outcome of this Environmental Investigation Report.

While no recommendations are identified as an outcome of this environmental investigation, it is acknowledged that the Mineral and Energy Resources (Financial Provisioning) Bill 2018, if passed, will require a Progressive Rehabilitation and Closure Plan. The overall findings from this environmental investigation will inform the Rehabilitation Planning Part of the new Progressive Rehabilitation and Closure Plan for Meandu Mine.

MINE MATERIAL MANAGEMENT

Objective: In addition to short-term management actions itemised in Section 10.1, the potential for oxidation will be further reduced through the incorporation of fine-grade rejects and tailings when the dewatering process is implemented at site, whereby pore voids within the coarse rejects will be filled with highly plastic low permeability tailings limiting oxidation and permeability. *Refer to Recommendation B1 and B2, Table 10.2.*

MINE WATER MANAGEMENT

Objective: In addition to short-term management actions itemised in Section 10.1, site water modelling will be applied to test and confirm future water management changes as required. *Refer to Recommendation B3, Table 10.2.*

RECEIVING ENVIRONMENT

Objective: The current study is considered sufficient to confirm that AMD is not having a negative impact on the environmental values of Meandu Creek. Long-term, ongoing monitoring of water quality parameters (as such pH, water hardness and electrical conductivity) in line with current procedures is recommended in order to detect potential impacts in future. *Refer to Recommendation B4, B5 and B6, Table 10.2.*

Table 10.2 General site recommendations as outcome of the EIR

RECOMMENDATION FROM EIR		STATUS	ACTION REQUIRED	TIMING	SOURCE
B1	Rejects materials placement	EXISTING	This method is established as part of mine planning at Meandu Mine and the performance of this method will be monitored over the life of mine. For example: — Rejects material from the CHPP is being dumped approximately 6 m beneath the final landform profile to allow adequate capping to be constructed over the top of the rejects. When the reject dumps reach their final landform capacity, they will be regraded, capped with a minimum 6 m NAF cover material, and rehabilitated as per EA (EPML00709113) requirements. — Continue with current Meandu Mine management practice of limiting storage/exposure time of coarse reject materials at the reject stockpile to less than two weeks appears to be an effective way of controlling the risk of acidic drainage generation. — The combined reject and tailings stream will be placed into the spoil dumps and progressively co-mingled or encapsulated with overburden and interburden.	In place since 2016	Xenith/ Stanwell
B2	Materials testing (ongoing)	EXISTING	Ongoing independent geochemical assessment and advise on material management to minimise the likelihood of future occurrence of AMD.	Current	RGS/ Stanwell
B3	Application of Integrated Water Model as a predictive tool	EXISTING	In addition to current application of the Integrated Water Model for this environmental investigation, the following actions will be continued to assist in improving the reliability of modelling predictions: — Monitoring of water use in the CHPP following installation of solid bowl centrifuge, including separate monitoring of water from retention dams and raw water use. — Water quality monitoring of water stored in pits (including pH) either directly or indirectly via dewatering lines.	Current	Golder

RECOMMENDATION FROM EIR		STATUS	ACTION REQUIRED	TIMING	SOURCE
B4	Groundwater monitoring	NEW	Stanwell will establish additional monitoring bore(s) to the west of Meandu Creek to monitor the high electrical conductivity as recorded at GW78 and to validate data from geophysics investigations.	Establishment in FY18/19	JBT
B5	Update of Meandu Creek REMP	NEW	Meandu Creek REMP is updated to include: — Key indicators for AMD (e.g. including concentrations of iron and manganese – Note cobalt, nickel and zinc are already included). Where a change is detected and are outside the WQOs or historical range, an additional investigation procedure will be triggered, as per the Meandu Creek REMP.	Establishment in FY18/19	ESP
B6	Further monitoring of toxicity of sediment between CP3 and Meandu Creek Dam (detected at site CM2)	NEW	Monitoring of toxicity and bioaccumulation of the build-up of metals in sediment at site CM2 in the channel between CP3 and the Meandu Creek Dam. While Meandu Creek upstream of Meandu Creek Dam is not managed to protect aquatic ecosystem values, further monitoring to determine the acute or chronic toxicity of sediment at site CM2 will be undertaken to understand the toxicity at this site. In accordance with the Revision of the Sediment Quality Guidelines (Simpson et al. 2013), the following testing will be undertaken: — Direct toxicity tests (three tests including one whole sediment test). — The concentration of metals in local biota tissue to assess bioaccumulation (Note: this has previously been completed at Meandu Creek Dam, however metal concentrations in sediment at site CM2 are higher than those in the dam).	Establishment in FY18/19	ESP

11 CONCLUSIONS

Based on the environmental investigation undertaken in response to the Notice, there is no evidence of negative impacts to the environmental values of Meandu Creek as a result of AMD from Meandu Mine.

Overall, aquatic ecological communities in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam. Aquatic flora and fauna communities in Meandu Creek downstream of Meandu Creek Dam were in a similar or better condition than would be expected in the broader catchment. The perennial flow regime, resulting from the consistent releases from Meandu Creek Dam, allows for stable and diverse aquatic habitats to occur, which in turn are colonised by a diverse range of macroinvertebrates (including some sensitive and very sensitive taxa), along with aquatic plants, fish and turtles, where habitat is suitable. This confirms that the quality of water released from Meandu Creek Dam, and the sediment quality of the receiving environment, is suitable for protecting the downstream aquatic ecosystem.

Future potential impacts on the environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine are considered unlikely given:

- The information presented in this environmental investigation shows there is no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment.
- The static and kinetic geochemical data combined with the geological model, overburden model and material balances, site-based evaluations and the long-term water quality data, indicate that the potential for acidic drainage to be produced in pits is very low or unlikely (other than from the North-West Backfilled Pit).
- The geochemical characterisation, based on over 14 months data of kinetic leach column testing, established that the AMD issues at Meandu Mine are considered relatively minor and able to be managed through the implementation of changes to mining and the placement of mined materials.
- The commitment to continuation of monitoring measures as outlined in this environmental investigation report.
- The continuation of current management measures along with the implementation of future actions as identified from this environmental investigation.

As a result of the identification of AMD issues at the North-West Backfilled Pit, Stanwell has implemented controls and made a number of infrastructure and mine planning management changes since 2015/2016. These have included:

- initial changes to water management infrastructure
- construction of seepage collection dam RD27, automated lime-dosing and pump and pipework
- installation of solid bowl centrifuges at the CHPP to dewater tailings
- changes to rejects placement
- rehabilitation design changes.

These current management measures which commenced in 2015/2016, have been included in the Integrated Water Model developed for this environmental investigation.

In addition to the controls listed above, Section 10.2 outlines recommendations for ongoing and future management measures as an outcome of this environmental investigation. Some of these recommendations relate to the continuation of existing management measures as summarised below:

- Rejects material placement: with actions focusing on limiting storage exposure time of coarse reject materials, combining rejects and tailings stream and placement of reject materials approximately 6 m beneath the final landform profile.
- Material testing: with actions focusing on ongoing independent geochemical assessment.
- Application of water modelling as a predictive tool: actions to inform optimisation of site water management.

The recommendations for future actions from Section 10.2 are:

- Implementation of dewatering program using installed dewatering system bores (GW48, GW49) in the North-West Backfilled Pit to reduce the water level in the pit to well below the spill elevation for diffuse and resurgent seepage (approximately RL432 mAHD in the western area (Ramp 7) and approximately RL435 mAHD in the area where the North-West Backfilled Pit spills to Bullgang Corner). The predictive model shows that by 2037, if two bores are used for dewatering the water level may be reduced by approximately 8 m below the diffuse seepage spill point. This reduction is predicted to be in the order of 1.9 m if one bore is used.
- Based on the outcome of the dewatering program, additional improvements to the cover thickness of RSA1 may need to be considered.
- Continued verification to improve the reliability of modelling predictions, such as, monitoring of water use in the CHPP following installation of solid bowl centrifuge and water quality monitoring of water stored in pits.
- Establishment of groundwater bore(s) to the west of Meandu Creek to monitor the high electrical conductivity recorded at GW78 and to validate data from geophysics investigations.
- Update of the current Meandu Creek Receiving Environment Monitoring Program (REMP) to include key indicators for AMD (i.e. iron and manganese).
- Additional monitoring (i.e. toxicity and bioaccumulation) in sediment at CM2 (in the channel between CP3 and the Meandu Creek Dam) to determine the acute or chronic toxicity of sediment and understand the potential for impacts to downstream reaches. Site CM2 has abundant reeds and fine sediments, and appears to be effectively trapping metals and reducing transportation further downstream to the receiving environment. While there is no evidence of impacts to the environmental values of Meandu Creek under current water conditions, under certain conditions (e.g. low pH and/ or low water hardness), metals in sediment could be mobilised and transported further downstream. It should be noted that where pH and electrical conductivity continue to be monitored and managed to remain within acceptable range, as required by current Environmental Authority (EA) (EPML00709113) water contaminant limits for compliance point CP1, and CP3 respectively, the release of sediment bound contaminants to the water column is not expected to occur.

While no recommendations for closure are identified as an outcome of this environmental investigation, it is acknowledged that the Mineral and Energy Resources (Financial Provisioning) Bill 2018, if passed, will require a Progressive Rehabilitation and Closure Plan. The overall findings from this environmental investigation will inform the Rehabilitation Planning Part of the new Progressive Rehabilitation and Closure Plan for Meandu Mine.

With the implementation of the recommendations from this environmental investigation (Section 10.2) and continued compliance with current EA water quality limits (both Meandu Mine and Tarong and Tarong North power stations), future impacts on environmental values of surface water (Meandu Creek) are considered unlikely.

12 LIMITATIONS

This Report is provided by WSP Australia Pty Limited (*WSP*) for Stanwell Corporation (*Client*), in response to specific instructions from the Client and in accordance and agreement with the Client (*Agreement*).

PERMITTED PURPOSE

This Report is provided by WSP for the purpose described in the Agreement and no responsibility is accepted by WSP for the use of the Report in whole or in part, for any other purpose (Permitted Purpose).

QUALIFICATIONS AND ASSUMPTIONS

The services undertaken by WSP in preparing this Report were limited to those specifically detailed in the Report and are subject to the scope, qualifications, assumptions and limitations set out in the Report or otherwise communicated to the Client.

Except as otherwise stated in the Report and to the extent that statements, opinions, facts, conclusion and / or recommendations in the Report (Conclusions) are based in whole or in part on information provided by the Client and other parties identified in the report (Information), those Conclusions are based on assumptions by WSP of the reliability, adequacy, accuracy and completeness of the Information and have not been verified. WSP accepts no responsibility for the Information.

WSP has prepared the Report without regard to any special interest of any person other than the Client when undertaking the services described in the Agreement or in preparing the Report.

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This Report can only be relied upon for the Permitted Purpose and may not be relied upon for any other purpose. The Report does not purport to recommend or induce a decision to make (or not make) any purchase, disposal, investment, divestment, financial commitment or otherwise. It is the responsibility of the Client to accept (if the Client so chooses) any Conclusions contained within the Report and implement them in an appropriate, suitable and timely manner.

In the absence of express written consent of WSP, no responsibility is accepted by WSP for the use of the Report in whole or in part by any party other than the Client for any purpose whatsoever. Without the express written consent of WSP, any use which a third party makes of this Report or any reliance on (or decisions to be made) based on this Report is at the sole risk of those third parties without recourse to WSP. Third parties should make their own enquiries and obtain independent advice in relation to any matter dealt with or Conclusions expressed in the Report.

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APPENDIX



Copy of Notice



Notice

Environmental Protection Act 1994

Environmental Evaluation

Notice to conduct or commission an environmental evaluation

This notice to conduct or commission an environmental evaluation is issued by the administering authority pursuant to 326B of the Environmental Protection Act 1994.

TEC Coal Pty Ltd
Level 13, 42 Albert Street
BRISBANE QLD 4000

Your reference:

Our reference: CA34208

21 December 2016

Take notice: that under the *Environmental Protection Act 1994* (the Act) a notice to conduct or commission an environmental investigation is issued to TEC Coal Pty Ltd (you) by the administering authority. The administering authority is the Chief Executive of the Department of Environment and Heritage Protection (the department).

The notice to conduct or commission an environmental investigation is issued in respect of the activities of TEC Coal Pty Ltd at Meandu Coal Mine on land described as Mining Lease (ML) 6674 located 4 kilometres west of Yarraman).

A. Grounds

The notice to conduct or commission an environmental investigation is issued on the following grounds:

- An activity is causing or is likely to cause environmental harm.

The facts and circumstances forming the basis for these grounds are:

- Acid and metalliferous drainage (AMD) has been identified at Meandu Coal Mine (MCM) which is operated by TEC Coal Pty Ltd (TEC) on mining lease (ML) 6674. The full nature source and extent of the AMD is unknown. There is potential for impacts on downstream aquatic ecosystems and other water users in the event of AMD releases from MCM. These impacts could be either acute impacts or long term chronic impacts as a result of the build-up of metals due to gradual oxidation and sedimentation in sectors of the downstream environment; there is also potential for adverse impacts on groundwater quality, including contamination by mobilised metals and metalloids.
- AMD is currently reporting by overland flow to Retention Dam (RD) 7 in the retention dam network on the western side of the mine, where it is mixing with other mine affected water. Water from RD7 flows to RD8 where it is either re-used for site processes or reports to the Meandu Creek Dam via release point CP3.
- AMD reporting to RD7 is believed to be originating from two (2) closely associated seepage locations these are:

Notice to conduct or commission an environmental evaluation

- 'Bullgang Corner' located approximately 600m southeast of RD7; and
 - A covered (vegetated) coal rejects area between Ramp 7 and the western side of the NWA tailings void (NWA tailings). This coal rejects area is assumed to be rehabilitated in the current Plan of Operations for Meandu Coal Mine. This area will need to be evaluated to determine if remedial works will be necessary in the future.
- Deposition of tailings to the NWA tailings ceased in December 2005; and tailings are currently deposited in the NWB tailings void.
 - TEC appointed an external consultant hydro-geochemist in October 2015 to evaluate AMD at MCM and has engaged in regular meetings with the department to provide updates in relation to AMD issues.
 - The department was advised in February 2016 by TEC that, an 'AMD impact focused' monitoring data review by the consultant hydro-geochemist had identified that AMD has occurred periodically at MCM since the 1980's.
 - Existing surface flows of AMD are being intercepted and treated by TEC to raise the pH and attempt to precipitate and settle soluble metals in the AMD; and ensure that released mine-affected water does not result in EA exceedances in receiving waters (monitored in-stream at CP3). The EA requires monitoring of EC at CP3.
 - The department requires that an investigation be undertaken to determine whether adverse environmental impacts to Meandu Creek could result from release of AMD impacted water with elevated metals from MCM. It is not at this stage known if the concentrations of metals resulting from the release of AMD to Meandu Creek are causing an exceedance of the relevant guideline values for protection of aquatic ecosystem and any other relevant environmental values.
 - The department has determined that investigations are required to:
 1. Determine whether environmental harm has occurred as a result of AMD at MCM.
 2. Identify and characterise the AMD and material with potential to generate AMD in the NW tailings void/ spoil dump and rehabilitated rejects to assess the extent of environmental harm likely to be caused by the AMD; and to determine the effects of AMD ingress to stored historical tailings .e.g. potential dissolution of metal contaminants in the tailings which may be transported to the receiving environment in the seepage.
 3. Identify other locations at MCM where AMD is occurring; and to identify potential AMD source materials at MCM.
 4. Determine the potential for AMD related environmental harm (acute and/or chronic impacts on the aquatic ecosystem and other relevant WQO's) that could occur from future (ongoing) activities at MCM, including potential Impacts from:
 - build-up of metals in sediment downstream of Meandu Creek Dam; and
 - elevated metal concentrations in Meandu Creek waters; and
 - alteration of the pH of Meandu Creek Dam waters and release of sediment bound contaminants to the downstream environment; and
 - elevated salinity levels in Meandu Creek waters.

B. Requirements

The report on the environmental investigation must address the following relevant matters:

Notice to conduct or commission an environmental evaluation

- (1) An **appropriately qualified person(s)** as defined in this notice must provide background and baseline information for the coal mining activity relevant to the environmental investigation including:
- i) a description of MCM (ML6674) operations and a brief history of operations on MCM; and
 - ii) a (dedicated) site plan showing the location of key features of the MCM; and
 - iii) a summary of water quality data relevant to the investigation; and
 - iv) a summary of geochemical data relevant to the investigation; and
 - v) a (dedicated) topographic map of the MCM; and
 - vi) a brief history and overview of the AMD at the site (from first known (historic) indicators to current awareness).

- (2) An **appropriately qualified person(s)** as defined in this notice must identify and characterise the environmental values that may be impacted by AMD from MCM.

This characterisation must include land and groundwater environmental values that may be impacted by AMD from MCM.

The characterisation of Meandu Creek must:

- i) identify any Environmental Values (EV's) and Water Quality objectives (WQO's) scheduled for Meandu Creek under the EPP Water; and
- ii) if none are identified propose EV's/WQO's where required for Meandu Creek; and
- iii) provide a description of the existing qualities, characteristics and resilience of Meandu Creek; and
- iv) with reference to items (i) to (iii) above determine the mine-affected water release quality that must be achieved to protect the relevant EV's of Meandu Creek.

- (3) An **appropriately qualified person(s)** as defined in this notice must undertake studies to determine the presence and extent of AMD at MCM, and to determine the acid generating potential of materials at MCM; the studies must include:

- i) geochemical assessments to characterise the chemical and physical properties of any materials at MCM (soil, overburden, in-pit side cast coal, product coal, rejects, tailings, ash etc.) with potential to generate AMD so these materials can be classified and then managed appropriately; and
- ii) contaminant hydrogeological investigations inclusive of drilling and installation of monitoring bores (if required); and
- iii) studies to identify the extent and locations of potential AMD source materials at MCM; and
- iv) investigations to identify physical and/or environmental influences relating to storage areas (coal rejects, overburden, waste rock, and topsoil) that may determine the occurrence, rate of progression, or volume of AMD generated at MCM for example: stockpile location, size, surface area, profile/geometry, water infiltration and drainage characteristics.
- v) a dedicated site plan showing the location and extent of AMD at MCMs, including existing seepage flow paths.

- (4) An **appropriately qualified person(s)** as defined in the notice must undertake studies to determine whether AMD at MCM has impacted on or has the potential to impact on the environmental values of groundwater and/or surface waters including Meandu Creek. The studies must include

Notice to conduct or commission an environmental evaluation

- i) water quality investigations to determine any impacts on environmental values of groundwater and surface waters (Meandu Creek) that have occurred as a result of AMD at MCM; and
 - ii) water quality investigations to determine future potential impacts on environmental values of groundwater and surface waters (Meandu Creek) resulting from AMD at MCM; and
 - iii) identify short term and long term measures including (if relevant) further lines of investigation, monitoring requirements, and operational or mine planning measures that should be developed and/or implemented to prevent environmental harm occurring from AMD at MCM.
- (5) An **appropriately qualified person(s)** as defined in the notice must develop a predictive model for MCM in relation to potential AMD impacts to provide information relevant to development of:
- Mine material management plans
 - Mine water management plans
 - Landform and rehabilitation management plans
 - Closure plans
- The predictive model must include:
- i) a material model (based on geochemical characterisation); and
 - ii) mine water modelling that takes into account surface water, ground water and in pit and in mine spoil water; and
 - iii) potential contaminant pathways; and
 - iv) capacity to predictively model acid production at MCM; and
 - v) capacity to predictively model the dissolution and transport of metals to the receiving environment from MCM; and
 - vi) capacity to predictively model water quality impacts from AMD on groundwater and Meandu Creek.
- (6) An **appropriately qualified person(s)** as defined in the notice must develop a report detailing and evaluating the findings from requirements (1) to (5) above and prepare a report based on these findings for submission to the department. The report must:
- i) Summarise the findings of requirements (1) to (5) above; and
 - ii) Identify the level of impact AMD from MCM has had on environmental values of receiving environments: and
 - iii) Identify potential impacts of AMD from MCM on environmental values of receiving environments: and
 - iv) Provide recommendations in regard to management and treatment of AMD at MCM.
- (7) Provide the department with a progress update on actions and outcomes of investigations to date, associated with requirements (1) to (5) on or before the following dates;
- i) 31 May 2017;
 - ii) 29 September 2017;
 - iii) 31 May 2018;

Notice to conduct or commission an environmental evaluation

The environmental investigation must be carried out, and the environmental report prepared, by an appropriately qualified person. An **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.

The environmental report must be submitted to the department on or before:

- **5pm Friday 14 September 2018**

As the recipient of this notice, you are also required to provide a statutory declaration in the form attached, to accompany the environmental report submitted to the department. The **appropriately qualified person (s)** who prepares the environmental report must also provide a statutory declaration in the form attached to accompany the environmental report submitted to the department.

You can view an electronic version of the statutory declaration for a recipient using the following search term (EM494).¹

An electronic version of the statutory declaration for an appropriately qualified person form is available using the search term (EM471).

Take notice:

1. the requirements of the notice to conduct or commission an environmental investigation take effect immediately upon service of this notice;
2. this notice remains in force until further notice from the department; and
3. you are responsible for meeting the costs of conducting or commissioning the environmental evaluation, preparing the environmental report and providing any further information as requested by the department.

C. Reviews and appeals

The provisions regarding reviews of decisions and appeals are found in sections 519 to 539 of the Act.

A person who is dissatisfied with certain decisions of the department, may be able to apply to have the department review that original decision.

Generally, a request to have a decision reviewed must be made:

- within 10 business days of the decision being notified to the person;
- be supported by enough information to enable the department to decide the application for review; and
- be made using the application for review of an original decision form (EM709).

Where an application has been made for a decision to be reviewed, the applicant may also apply to the relevant court for a stay of the decision to secure the effectiveness of the review.

Once the original decision has been reviewed, a person who is dissatisfied with the review decision may be able to appeal against that decision to the relevant court within 22 business days after receiving notice of the review decision.

¹ This is the publication number. The publication number can be used as a search term to find the latest version of a publication at <www.ehp.qld.gov.au>.

Notice to conduct or commission an environmental evaluation

A person whose interests are or would be adversely affected by a decision of the department may also be able to request a statement of reasons for a decision or a statutory order review under the *Judicial Review Act 1991*.

For further information about reviews and appeals see the:

1. Information sheet - internal review and appeal to the Planning and Environment Court (EM1866).
2. Information sheet - internal review and appeal to the Land Court (EM1157).

You may have other legal rights or obligations and should seek your own legal advice.

D. Penalty

Failure to comply with a notice to conduct or commission an environmental evaluation is an offence.

- i) The maximum penalty for an individual is 300 penalty units, totalling \$36,570.
- ii) The maximum penalty for a corporation is 1500 penalty units, totalling \$182,850.

Should you have any queries in relation to this notice, please contact Carol Hardy of the department on telephone number (07) 41211935.



Signature

21 DECEMBER 2016

Date

Tony Baker

A/Manager (Compliance)

Delegate of the Chief Executive

Department of Environment and Heritage Protection

Environmental Protection Act 1994

Enquiries:

Carol Hardy

Ph: (07) 41211935

Email: carol.hardy@ehp.qld.gov.au

APPENDIX

B

Check list against
Notice Requirements



B1 CHECKLIST AGAINST NOTICE REQUIREMENTS (SECTION B)

SECTION NUMBER	REQUIREMENT	RELEVANT SECTION OF ENVIRONMENTAL INVESTIGATION REPORT
B1	Provide background and baseline information for the coal mining activity relevant to the environmental investigation including:	
	(i) A description of Meandu Mine (ML6674) operations and a brief history of operations on Meandu Mine	Section 2
	(ii) a (dedicated) site plan showing the location of key features of the Meandu Mine	Figure 1.1a and b
	(iii) a summary of water quality data relevant to the investigation	Sections 4 and 7 Appendix F Appendix G
	(iv) a summary of geochemical data relevant to the investigation	Section 3.2 Appendix E
	(v) a (dedicated) topographic map of the Meandu Mine	Figure 6.1
	(vi) a brief history and overview of the AMD at the site (from first known (historic) indicators to current awareness.	Section Error! Reference source not found. Appendix E
B2	Identify and characterise the environmental values that may be impacted by AMD from MCM. This characterisation must include land and groundwater environmental values that may be impacted by AMD from MCM. The characterisation of Meandu Creek must:	
	(i) identify any Environmental Values (EV's) and Water Quality objectives (WQO's) scheduled for Meandu Creek under the EPP Water	Section 6.3 Appendix F Appendix G
	(ii) if none are identified propose EV's/WQO's where required for Meandu Creek	Section 6.3 Appendix F Appendix G
	(iii) provide a description of the existing qualities, characteristics and resilience of Meandu Creek	Sections 7, 8.1 and 8.2 Appendix F Appendix G
	(iv) with reference to items (i) to (iii) above determine the mine-affected water release quality that must be achieved to protect the relevant EV's of Meandu Creek	Section 6.3 Appendix F Appendix G

SECTION NUMBER	REQUIREMENT	RELEVANT SECTION OF ENVIRONMENTAL INVESTIGATION REPORT
B3	Undertake studies to determine the presence and extent of AMD at MCM, and to determine the acid generating potential of materials at MCM; the studies must include:	
	(i) geochemical assessments to characterise the chemical and physical properties of any materials at Meandu Mine (soil, overburden, in-pit side cast coal, product coal, rejects, tailings, ash etc.) with potential to generate AMD so these materials can be classified and then managed appropriately	Section 3 Appendix E
	(ii) contaminant hydrogeological investigations inclusive of drilling and installation of monitoring bores (if required)	Section 4 Appendix F
	(iii) studies to identify the extent and locations of potential AMD source materials at Meandu Mine	Section 3 Appendix E
	(iv) investigations to identify physical and/or environmental influences relating to storage areas (coal rejects, overburden, waste rock, and topsoil) that may determine the occurrence, rate of progression, or volume of AMD generated at Meandu Mine for example: stockpile location, size, surface area, profile/geometry, water infiltration and drainage characteristics	Sections 3, 4 and 5 Appendix E Appendix F
	(v) a dedicated site plan showing the location and extent of AMD at Meandu Mine, including existing seepage flow paths.	Section 5 Appendix F
B4	Undertake studies to determine whether AMD at Meandu Mine has impacted on or has the potential to impact on the environmental values of groundwater and/or surface water including Meandu Creek. The studies must include:	
	(i) Water quality investigations to determine the impacts on environmental values of groundwater and surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine	Sections 4 and 7 Appendix F Appendix G
	(ii) Water quality investigations to determine future potential impacts on environmental values of groundwater and surface waters (Meandu Creek) resulting from AMD at MCM	Sections 4 and 7 Appendix F Appendix G
	(iii) Identify short-term and long term measures including (if relevant) further lines of investigation, monitoring requirements and operational or mine planning measures that should be developed and/or implemented to prevent environmental harm occurring from AMD at Meandu Mine	Section 2.6 and Section 10 Appendix E Appendix F Appendix G Appendix H

SECTION NUMBER	REQUIREMENT	RELEVANT SECTION OF ENVIRONMENTAL INVESTIGATION REPORT
B5	Develop a predictive model for Meandu Mine in relation to potential AMD impacts to provide information relevant to the development of: — Mine material management plans — Mine water management plans — Landform and rehabilitation management plans — Closure plans. The predictive model must include: (i) a dedicated site plan showing the location and extent of AMD at Meandu Mine, including existing seepage flow paths. (ii) mine water modelling that takes into account surface water, ground water and in pit and in mine spoil water. (iii) potential contaminant pathways (iv) capacity to predictively model acid production at Meandu Mine (v) capacity to predictively model the dissolution and transport of metals to the receiving environment from Meandu Mine (vi) capacity to predictively model water quality impacts from AMD on groundwater and Meandu Creek	Section 9 Appendix H Appendix E Appendix F
B6	Develop a report detailing and evaluating the findings from requirements (1) to (5) above and prepare a report based on these findings for submission to the department. The report must: (i) Summarise the findings of requirements (1) to (5) above (ii) Identify the level of impact AMD from Meandu Mine has had on environmental values of receiving environments (iii) Identify potential impacts of AMD from Meandu Mine on environmental values of receiving environments (iv) Provide recommendations in regard to management and treatment of AMD at Meandu Mine	Summary of Notice Requirement Findings This report Section 8 Section 8 Section 10
B7	Provide the department with a progress update on actions and outcomes of investigations to date, associated with the requirements (1) to (5) on or before the following dates: — 31 May 2017 — 29 September 2017 — 31 May 2018.	Section 1.7.2

APPENDIX



Statutory Declarations

Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Recipient

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. In accordance with section 326E of the Environmental Protection Act 1994 (the Act), this Statutory Declaration must be completed by the recipient of an environmental evaluation notice and must accompany the environmental report submitted to the Department of Environment and Heritage Protection (the department).

Oaths Act 1867

QUEENSLAND

TO WIT

I

Javier Cabrera

Insert the name of the person making this declaration

of

4 Bourbon Court Morayfield

Insert the street address of the person making this declaration

in the State of Queensland do solemnly and sincerely declare that in accordance with section 326E of the *Environmental Protection Act 1994* (the Act), I have:

- not knowingly given any false or misleading information; and
- given all relevant information

to the person who carried out the environmental evaluation, over the period:

21 December 2016 to 10 September 2018

Insert start date

Insert end date

for the purpose of submitting a report in accordance with the environmental evaluation notice issued by the department under the Act to:

TEC Coal Pty Ltd

Insert name of recipient of the notice

21 December 2016

Insert date of the notice

**Statutory Declaration
Recipient**

A copy of the report is attached to this statutory declaration and marked "A".

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at

Brisbane, Queensland.

Insert location

this

11th

day of

September

in the
year

2018

Insert day (e.g. 18th)

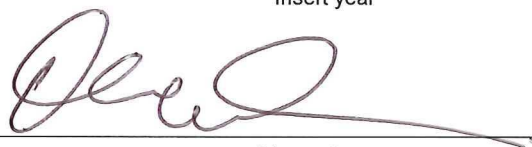
Insert month

Insert year



Signed

(Person making this declaration)



Signed

Solicitor

Rachael Warren

Printed name and registration number (if
applicable)

Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Suitably qualified person

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. This Statutory Declaration must be completed by the person who conducted the environmental evaluation and accompany the environmental report submitted to the Department of Environment and Heritage Protection (the department).

Oaths Act 1867

QUEENSLAND TO WIT

I

Amanda O'Kane

Insert the name of the person making this declaration

of

WSP Australia

Insert the street address of the person making this declaration

69 Ann Street, Brisbane, 4000. Queensland

in the State of Queensland do solemnly and sincerely declare that:

- I am the suitably qualified person and author of an environmental report entitled
Environmental Investigation Report. Meandu Mine. September 2018

Insert title of the environmental report

In accordance with the environmental evaluation issued by the department under the Act to:

TEC Coal Pty Ltd

21 December 2016

Insert name of recipient of the notice

Insert date of the notice

A copy of my report is attached to this statutory declaration and marked "A".

I possess the following qualifications and experience relevant to this environmental evaluation:

Bachelor of Science (Applied Geology), CEnvP. 25 years in environmental impact assessment

I have not knowingly included any false, misleading or incomplete information in the report; and

I have not knowingly failed to reveal any relevant information or document to the department.

I certify that:

Statutory Declaration
Suitably qualified person

- The report addresses the relevant matters for the evaluation and is factually correct; and
- The opinions expressed in it are honestly and reasonably held.

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at

BRISBANE

Insert location

this

11th

Insert day (e.g. 18th)

day of

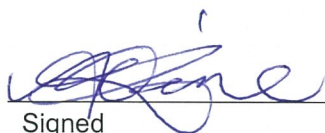
September

Insert month

in the year

2018

Insert year



Signed

(Person making this declaration)

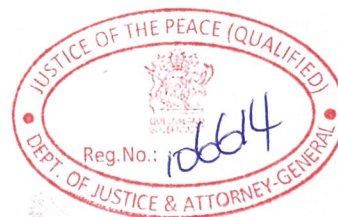


Signed

~~<INSERT Justice of the Peace / Commissioner
for Declarations / Lawyer>~~

ANGELEENA PRASSLER

Printed name and registration number (if applicable)



APPENDIX

D

2017 Life of Mine



Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Suitably qualified person

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. This Statutory Declaration must be completed by the person who conducted the environmental evaluation and accompany the environmental report submitted to the Department of Environment and Heritage Protection (the department).

Oaths Act 1867

QUEENSLAND

TO WIT

I

MATTHEW JOHN CLARKE

Insert the name of the person making this declaration

of

C/O KENITH CONSULTING, LEVEL 6, 40 CREEK STREET, BRISBANE, 4000

Insert the street address of the person making this declaration

in the State of Queensland do solemnly and sincerely declare that:

- I am the suitably qualified person and author of an environmental report entitled

Meandu Mine 2017 LOM Plan to inform the Environment and Engineering Evaluation Project

Insert title of the environmental report

In accordance with the environmental evaluation issued by the department under the Act to:

TEC Coal Pty Ltd

Insert name of recipient of the notice

21 December 2016

Insert date of the notice

A copy of my report is attached to this statutory declaration and marked "A".

I possess the following qualifications and experience relevant to this environmental evaluation:

BACHELOR OF CIVIL ENGINEERING, 14+ YEARS ENGINEERING EXPERIENCE

I have not knowingly included any false, misleading or incomplete information in the report; and

I have not knowingly failed to reveal any relevant information or document to the department.

I certify that:

Statutory Declaration
Suitably qualified person

- The report addresses the relevant matters for the evaluation and is factually correct; and
- The opinions expressed in it are honestly and reasonably held.

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at

BRISBANE

Insert location

this

11th

day of

SEPTEMBER

in the year

2018

Insert day (e.g. 18th)

Insert month

Insert year



Signed

(Person making this declaration)



Signed

<INSERT Justice of the Peace / Commissioner
for Declarations / Lawyer>

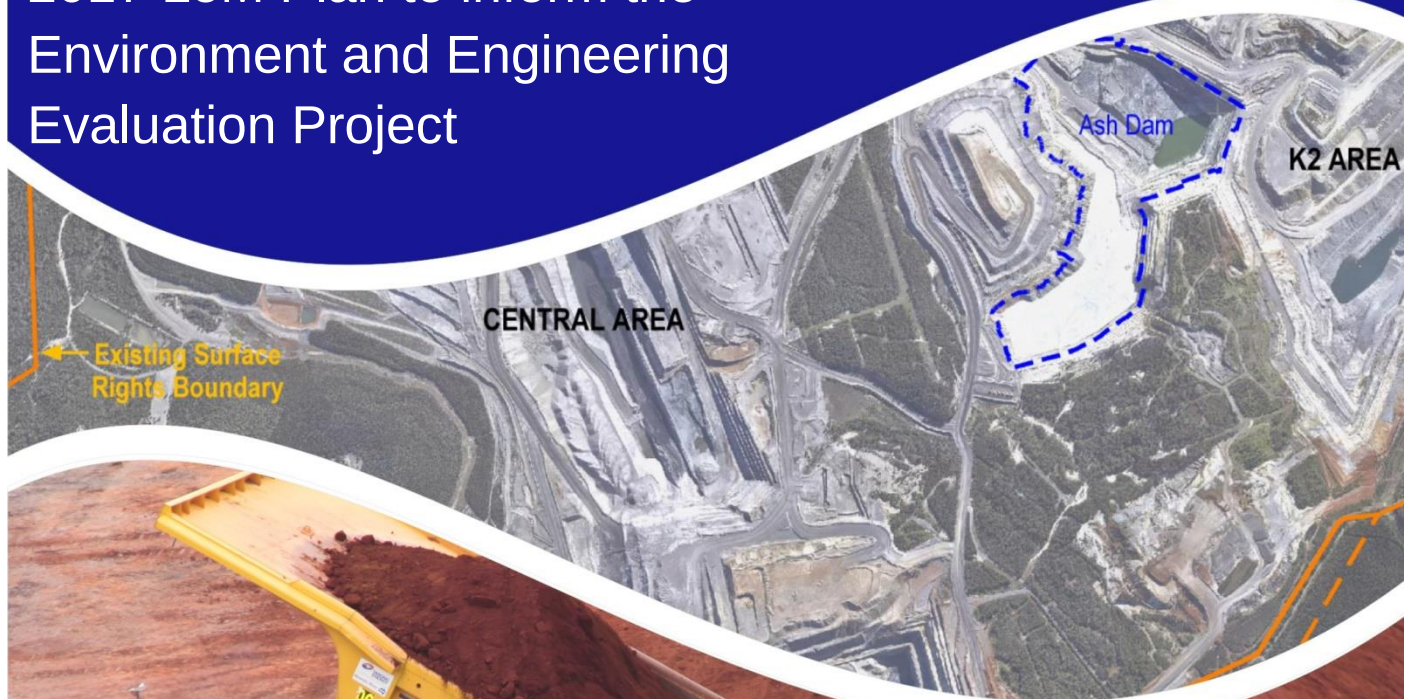
KENNETH JOHN WADDEY

Printed name and registration number (if
applicable)

CDEC 65241



Stanwell Corporation Limited
Meandu Mine
2017 LoM Plan to inform the
Environment and Engineering
Evaluation Project



May 2017



DOCUMENT ISSUE APPROVAL

Project & Document No:	Date:
1468SWEL	28 th August 2018 – Rev B
Title:	Revision No:
Meandu 2017 AMD LoM Plan	Rev B: 28/8/18 Final
Client:	- Incorporates feedback from Stanwell and WSP
Stanwell Corporation Limited	

	Name	Position	Signature	Date
Prepared by:	John Cawte	Manager – Mining Solutions		29/5/17
Reviewed by:	Mat Lynch & Matthew Clarke	Consultant Manager		17/8/18
Approved by:	Matthew Clarke	Manager		28/8/18

DISTRIBUTION

Organisation	Attention	No of hard copies	No of electronic copies	Actioned ¹
Stanwell Corporation Limited		0	1	Matthew Clarke

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1 EXECUTIVE SUMMARY

1.1 Summary Project Description

Background

Meandu Mine is an open cut coal mine located in Queensland's South Burnett region, approximately 150 km north-west of Brisbane, 14 km south-west of Nanango and approximately 1.5 km to the south of the Tarong and Tarong North power stations.

TEC Coal Pty Ltd (TEC Coal), a 100% subsidiary company of Stanwell Corporation Limited (Stanwell) purchased Meandu Mine from Rio Tinto Coal Pty Ltd in 2008.

All product coal produced from Meandu Mine is used to supply the adjacent Stanwell owned Tarong Power Station and Tarong North Power Station. TEC Coal contracts all mining services at Meandu Mine to a mining contractor. Between 2008 and 2012 the mining contractor was Thiess Mining Services Pty Ltd, and from 2013 Downer EDI Mining Pty Ltd.

On 21 December 2016, the former Department of Environment and Heritage Protection (EHP) (now Department of Environment and Science (DES)) issued TEC Coal Pty Ltd with a notice to conduct or commission an environmental evaluation under Section 326B of the *Environmental Protection Act 1994* (EP Act) (the Notice). To address the requirements of the Notice, Stanwell has commissioned an Environmental and Engineering Evaluation (EEE) into acid and metalliferous drainage (AMD) at the Meandu Mine site.

The grounds for the environmental evaluation relate to the identification of AMD at Meandu Mine and the potential for this AMD to cause environmental harm. As the full nature and extent of the AMD was unknown, EHP (now DES) required that an environmental investigation be undertaken to determine whether environmental harm has occurred as a result of AMD at the Meandu Mine. AMD was identified as reporting by overland flow to retention dam 7 (RD7) in the retention dam network on the western side of the mine, where it was mixing with other mine affected water. Water from RD7 flows to RD8 where it is either re-used for site purposes or reports to the Meandu Creek Dam via release (compliance) point CP3. AMD reporting to RD7 is believed to be originating from two closely associated seepage locations:

1. Bullgang Corner, located approximately 600 m south-east of RD7; and
2. a covered (vegetated) coal rejects area between Ramp 7 and the western side of the North West (NW) A tailings void (NWA tailings).

A key part of the EEE Project is the completion of the Life of Mine (LoM) plan (based on existing controls) and running this through an Integrated Water Model model to determine if the current mine plan will result in environmental harm to surface or groundwater environmental values as a result of AMD.

Xenith was commissioned in late 2016 to prepare this LoM Plan for the EEE Project. The aim of this study is to ensure that Meandu Mine continues to provide coal to the Tarong and Tarong North power stations until 2037, while specifically modelling the placement at the mine

of waste materials within a range of geochemical properties. This LoM Plan with its final landforms and modelled placement of waste materials forms the basis of subsequent water modelling and environmental studies.

Scope

A LoM Plan has been developed to capture the effects of operation of the Meandu Mine on the landform and materials placement. This plan targets coal production of 6 Mtpa and assigns a dumping strategy for the selective placement of waste depending on the geochemical properties of the overburden (JB Mining, Meandu Overburden Units Memo. 8 Feb 2017). This scenario allows the mine to progress into the proposed K2E Extension (K2EE) area to the east of the mine in FY27, avoiding the high strip ratio (more expensive) resource in Boundary West and Boundary East Pits consistent with the current approved LoM strategy.

Waste material has been classified in conjunction with JB Mining and RGS, as Potentially Acid Forming (PAF) or Non-Acid Forming (NAF). Selective placement of waste has allowed for the waste material classified as PAF to be placed in the lower reaches of the waste dumps while the NAF waste material is able to be placed on the surface as a capping material. This selective placement of waste increases the haulage distances required compared to a similar mine schedule created without this constraint.

2 INTRODUCTION

2.1 Background

Meandu Mine is an open cut coal mine located in Queensland's South Burnett region, approximately 150 km north-west of Brisbane, 14 km south-west of Nanango and approximately 1.5 km to the south of the Tarong and Tarong North Power Stations.

TEC Coal Pty Ltd (TEC Coal), a 100% subsidiary company of Stanwell Corporation Limited (Stanwell) purchased Meandu Mine from Rio Tinto Coal Pty Ltd in 2008.

All product coal produced from Meandu Mine is used to supply the adjacent Stanwell owned Tarong Power Station and Tarong North Power Station. TEC Coal contracts all mining services at Meandu Mine to a mining contractor. Between 2008 to 2012 the mining contractor was Thiess Mining Services Pty Ltd, and from 2013 Downer EDI Mining Pty Ltd.

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The grounds for the environmental evaluation relate to the identification of acid and metalliferous drainage (AMD) at Meandu Mine and the potential for this AMD to cause environmental harm. As the full nature and extent of the AMD was unknown, EHP (now DES) required that an environmental investigation be undertaken to determine whether environmental harm has occurred as a result of AMD at the Meandu Mine. AMD was identified as reporting by overland flow to retention dam 7 (RD7) in the retention dam network on the western side of the mine, where it was mixing with other mine affected water. Water from RD7 flows to RD8 where it is either re-used for site purposes or reports to the Meandu Creek Dam via release (compliance) point CP3. AMD reporting to RD7 is believed to be originating from two closely associated seepage locations:

1. Bullgang Corner, located approximately 600 m south-east of RD7; and
2. a covered (vegetated) coal rejects area between Ramp 7 and the western side of the North West (NW) A tailings void (NWA tailings).

Specifically, the Notice requires that investigations are undertaken to:

1. Determine whether environmental harm has occurred as a result of AMD at Meandu Mine.
2. Identify and characterise the AMD and material with potential to generate AMD in the North-West tailings void/ spoil dump and rehabilitated rejects to assess the extent of environmental harm likely to be caused by the AMD; and to determine the effects of AMD ingress to stored historical tailings (e.g. potential dissolution of metal contaminants in the tailings which may be transported to the receiving environment in the seepage).

3. Identify other locations at Meandu Mine where AMD is occurring; and to identify potential AMD source materials at Meandu Mine.
4. Determine the potential for AMD related environmental harm (acute and/or chronic impacts on the aquatic ecosystem and other relevant Water Quality Objectives (WQO's)) that could occur from future (ongoing) activities at Meandu Mine, including potential impacts from:
 - build-up of metals in sediment downstream of Meandu Creek Dam
 - elevated metal concentrations in Meandu Creek waters
 - alteration of the pH of Meandu Creek Dam waters and release of sediment bound contaminants to the downstream environment
 - elevated salinity levels in Meandu Creek waters.

To address the requirements of the Notice, Stanwell has commissioned an Environmental and Engineering Evaluation into AMD at the Meandu Mine site. This investigation incorporates studies across of range of technical disciplines including:

- mine planning and life of mine (future) (Xenith Consulting) (this assessment)
- material classification assessments (geochemical) (RGS Environmental Pty Ltd)
- hydrogeological assessments (JBT Consulting Pty Ltd)
- surface water quality, sediments and aquatic ecology investigations (Ecological Services Professionals Pty Ltd)
- water modelling and development of engineering solutions (Golders Associates Pty Ltd).

A key part of the EEE Project is the completion of the Life of Mine (LoM) plan (based on existing controls) and running this through an Integrated Water Model to determine if the current mine plan will result in environmental harm to surface or groundwater environmental values as a result of AMD.

Xenith was commissioned in late 2016 to prepare this LoM Plan for the EEE Project. The aim of this study is to ensure that Meandu Mine continues to provide coal to the Tarong and Tarong North power stations until 2037, while specifically modelling the placement at the mine of waste materials within a range of geochemical properties. This LoM Plan with its final landforms and modelled placement of waste materials forms the basis of subsequent water modelling and environmental studies.

2.2 Scope of Work

The LoM Plan examines a 6 Mtpa scenario that varies the operation by selectively placing the waste of the Meandu Mine according to geochemical properties. The mine planning work included a LoM planning process from an initial margin rank and pit optimisation. High level

costing of options were scheduled with haul simulations while accounting for selective placement of waste. The outputs from this LoM Plan will form the basis of the water modelling for the EEE Project.

The process undertaken to develop the LoM Plan was to:

- Run a pit optimiser and margin rank across the Meandu deposit to confirm the suitability of the current adopted LoM plan sequence and coal targets
- Development of practical pit designs based on the current approved LoM plan at Meandu Mine including:
 - Realignment of existing strips where required
 - Design of overall batters, pit walls and dump areas.
- Generation of insitu reserves (quantity and quality) in Deswik CAD - This incorporated the updated geological model (November 2016, JB mining) as well as waste material classification for NAF / PAF
- Undertake the mining scheduling across Meandu Mine including:
 - Dragline driven operation with excavator prestrip
 - Varying coal demand schedules as supplied by Stanwell
 - Dump and haulage optimisation in Deswik CAD for Meandu Mine - Accounted for selective placement of overburden waste based upon its geochemical properties. It also accounted for the co-disposal of tailings and rejects within defined areas of the overburden dump. The filling of the ash dams were also modelled within the same process.
- Landform reshaping and modelling for Meandu Mine, closely integrated with the haulage modelling

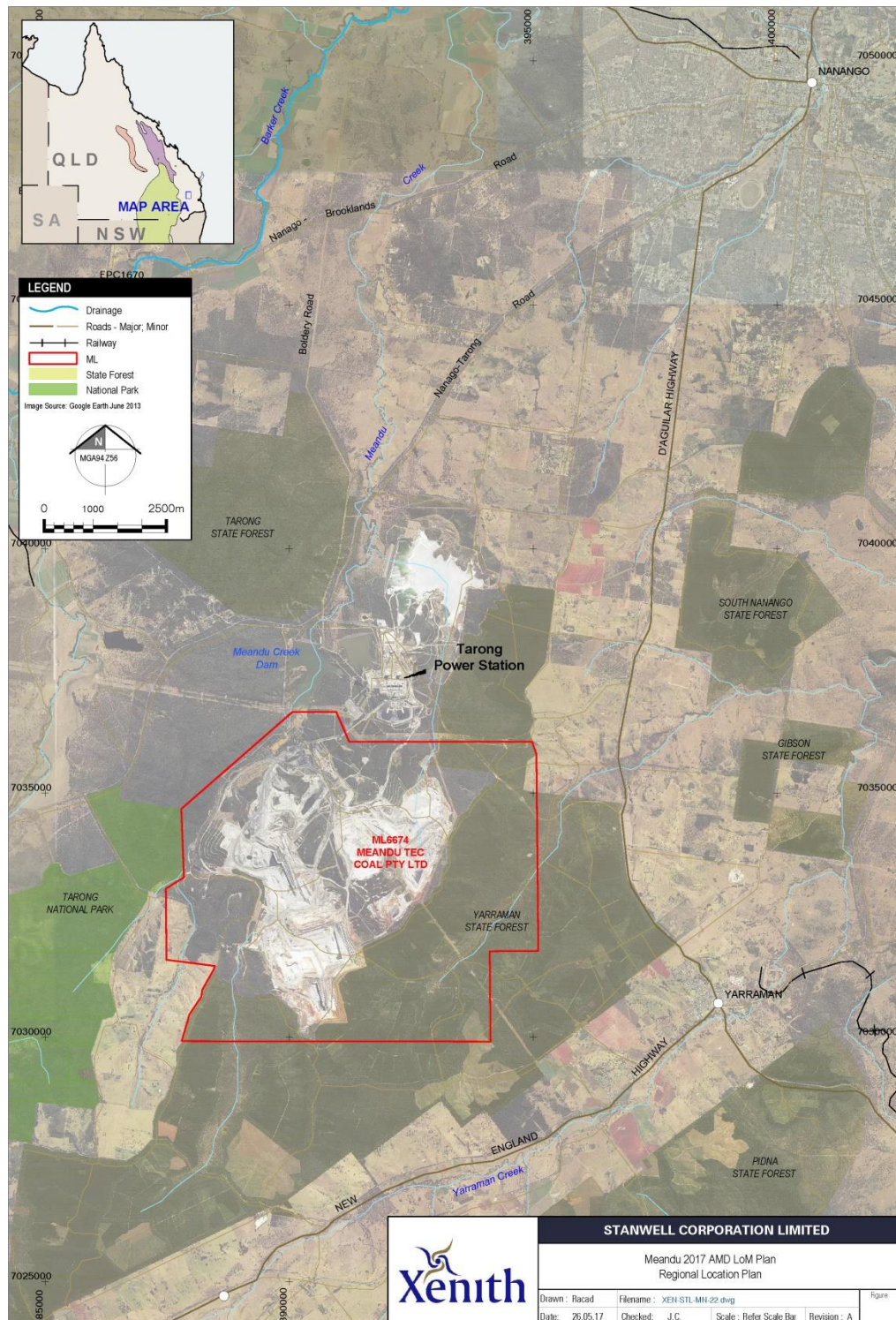
Key outputs were provided to the water modellers, including:

- Mine surfaces at various stages of mine progression, including dump surfaces
- Pits shells (progressive pit floors) at those same stages
- Location of waste placement by category of NAF / PAF
- Location of placement of reject / tailings in the waste dump
- Location of ash and ash levels over time within the ash dams
- Cross sections across the mine.

2.3 Location

Stanwell's Meandu Mine is located approximately 150 km north-west of Brisbane, and 30 minutes' drive from Kingaroy, in Queensland's Tarong Basin. Figure 2.1 shows the regional location of the mine.

Figure 2.1 – Regional Location



2.4 Meandu History

Rio Tinto Coal secured an authority to prospect in the Tarong area near the town of Yarraman in 1967. Drilling in subsequent years showed thermal coal occurring at substantial thicknesses, indicating the likelihood of a sufficient coal resource to support on-site power generation.

Work first began on Meandu mine in 1978 after the Queensland government made the decision to proceed with the construction of the adjacent Tarong Power Station. In 1984, the mine began regular deliveries to the power station utilising a 1.5 km conveyor, increasing supply to Tarong Power Station as more power station units were commissioned. The construction of Tarong North Power Station in 2003 resulted in the mine increasing its supply of coal.

Tarong Energy gained ownership of the Meandu Mine from Rio Tinto Coal in 2008. In July 2011, following a restructure of the Queensland government owned generators; ownership of Meandu Mine and the Tarong and Tarong North power stations was transferred to Stanwell.

Tarong was granted approval in 2008 to deposit waste ash from the power stations into a void in the Meandu Mine via an overland pipeline.

2.5 Tenements

Meandu Mine is located on ML6674. The surface rights do not extend across all of the mining lease, however, the basis of this mine plan does extend beyond the current surface rights and into the proposed K2E Extension (K2EE) as shown in Figure 2.2.

2.6 Operations

Meandu Mine operates under EA EPML00709113. Meandu Mine has been operated by contract miner, Downer EDI, since January 2013. The mine currently has multiple working pits and supplies the adjacent Tarong and Tarong North power stations with thermal coal. The site layout of the Meandu Mine is shown in Figure 2.2. Historically, mining has achieved production of approximately 7 Mtpa ROM coal. The seams are gently dipping, with shale and sandstone in between. Coal quantity estimates at current production rates suggest the mine will be able supply the power stations until at least 2037, the nominal end of life for the Tarong and Tarong North power stations.

Figure 2.3 shows the current start surface and an outline of the current pit areas. Current operations are based around the following pits and seams:

- Central (Queen seams)
- K4S (Ace, King, Queen seams)
- K4E (Ace, King, Queen seams) (located in the south-west area of the labelled Boundary West Pit in Figure 2.3)
- Ramp 5 (Queen seams)

Figure 2.2 – Meandu Mine Site Layout

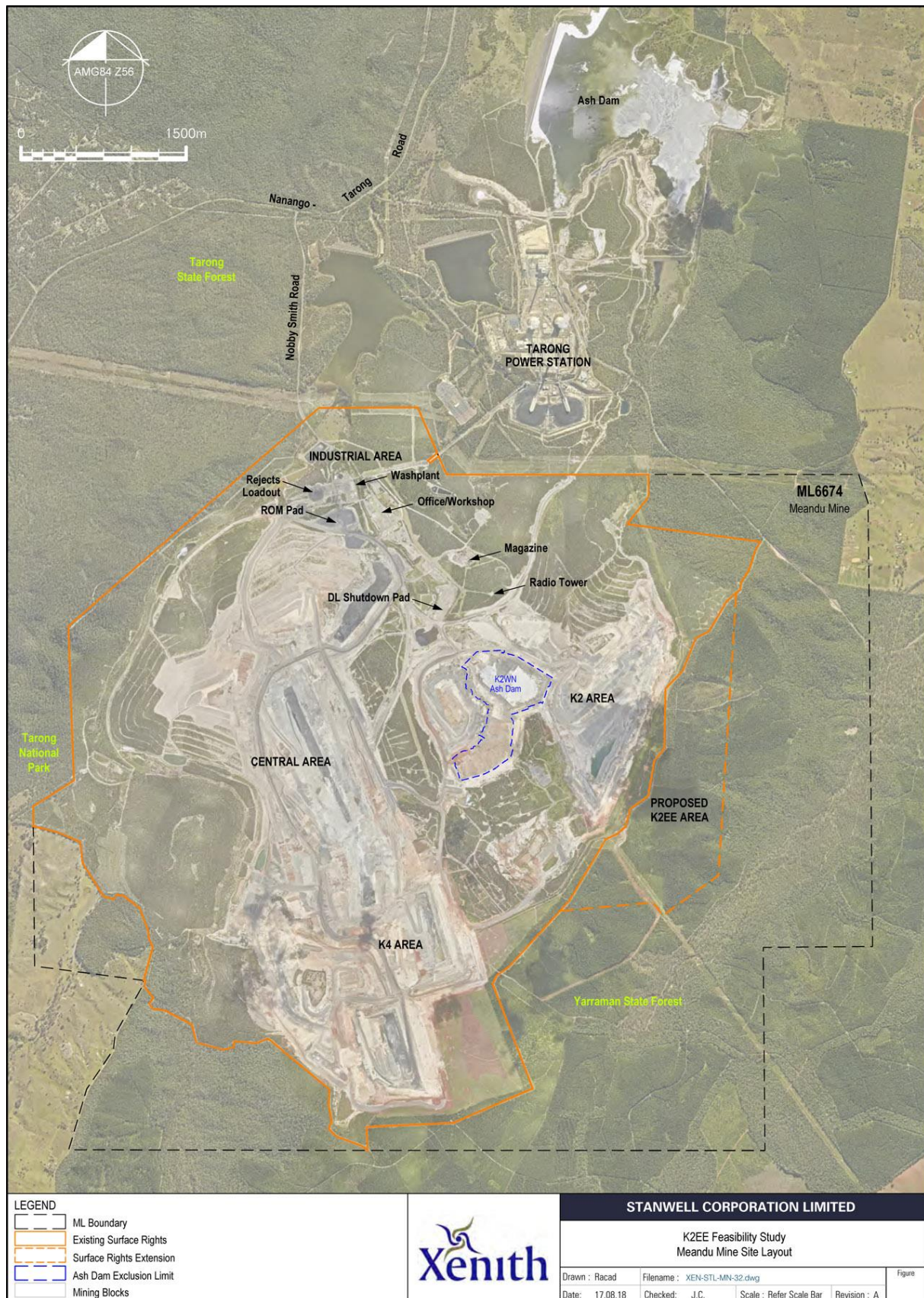


Figure 2.3 – Meandu Mine Pit Layout and Starting Surface



3 GEOLOGY

3.1 Regional Geology

The following section on regional geology has been summarised from Geoscience Australia (Geoscience Australia, Australian Stratigraphic Units Database, 2017).

Meandu Mine is situated in the Tarong Basin. The basin is a NNW-SSE trending basin approximately 75 km in length and about 10 km in width, located approximately 10 km west of Nanango and a few kilometres west of Yarraman.

The Tarong Basin is a Triassic aged basin made up of clastic sedimentary rocks ranging in grainsize and bedding characteristics from laminated mudstone to massive cobble-boulder polymictic conglomerate. The basin contains significant economically important coal reserves that are currently being exploited for power generation.

Thick deposits of laminated mudstone are present within the basin, most notably close to the coal deposits, and are interpreted as representing waning flood sedimentation in a lacustrine environment. Sandstones and finer-grained facies are common in the Tarong Basin and were deposited as distal fans or as sandy braid-plains. They also predominate in the main coal bearing areas of the basin and consist of labile poorly sorted sandstones associated with polymictic conglomerates, minor siltstones, mudstones and claystones.

3.2 Local Geology – Meandu

The Tarong Basin has been in-filled by the Tarong Beds which have a preserved thickness of approximately 450m and comprise predominantly coarse grained, clastic sediments and thick coal accumulations (Pegrem, 1995). Sediments stratigraphically near to the coal seams are mostly fine grained sandstone, siltstone and mudstone. The coal seams are inter-bedded with fine grained stone bands that are often highly variable in both thickness and composition. In Jell, 2013 the coal within the basin was referred to as “high-ash, high-volatile, bituminous, low-sulphur, steaming coal with poor coking properties”.

Meandu Mine coals show an overall trend of increasing ash with stratigraphic depth. The most noticeable exception is the A seam at the top of the Queen sequence.

In the Meandu area, the Tarong Beds have been affected by strike-slip faults that are generally oriented to the NNW-SSE (Jones, 2007). Vertical throws within the modelled area have been interpreted up to 80m while horizontal displacements are largely unknown. The faults within the coal measures generally appear with a normal displacement at an angle of 30-60 degrees and often form horst and graben structures. Some small scale reverse faults have been identified but are interpreted as scissor faults.

Parts of the deposit are unconformably overlain by the Tertiary-aged Main Range Volcanics which are dominated by thick basalt flows intercalated with poorly consolidated lithic sediments. The unconformity is generally undulose and is not always readily identifiable in cuttings from drillholes due to the depth of Triassic and Tertiary weathering.

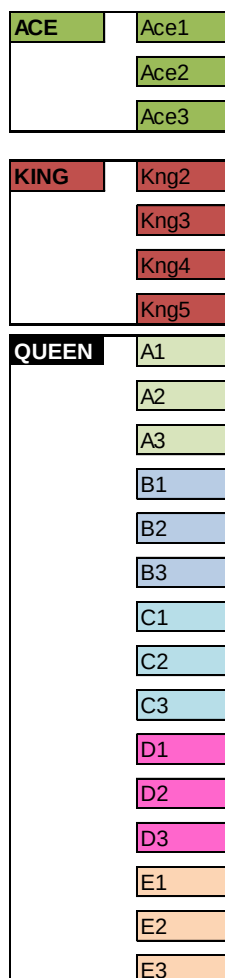
A thin veneer of unconsolidated Quaternary cover is present and is confined to the beds of watercourses and associated floodplains.

The Main Range Volcanics are predominantly thick basalt flows. Between flows, thin beds of soft claystone, loose sandstone and lignite have been recorded that have, on occasion, created difficult drilling conditions. Only one intrusion has been identified to date: a dyke that cuts through bedded conglomeratic sandstones on the northern entrance road to Meandu Mine. The Main Range Volcanics are generally found in the topographically high areas but can also be found infilling deeply incised Tertiary valleys resulting in the thick basalt occurrences such as that dividing King 4 East (K4E) and King 4 South (K4S) Pits. In the higher areas the basalts have been subjected to Tertiary weathering that has resulted in deep lateritic profiles. Three flows are currently modelled although up to five flows have been recognised in the past.

Quaternary sediments are generally restricted to the western part of ML6674 near Meandu Creek and near Rocky Creek in the valley to the east of the surface rights area.

The major coal bearing seams (above the current basal seam Queen E seam), in order of stratigraphy, are shown below in Figure 3.1. Plies beneath the scheduled basal seam E grouping are generally not economic in the Meandu deposit due both to their incremental depth and reduction in quality (energy) per tonne.

Figure 3.1 – Seam Hierarchy



3.3 Overburden Model and classification of materials

3.3.1 Description of overburden modelling process

The process of modelling overburden according to the material geochemistry was completed in the following steps:

1. Modelling the structural overburden by material type (JB Mining)
2. Determining geochemistry of each material type (RGS)
3. Classifying the material types as PAF or NAF material according to geochemistry (JB Mining and RGS)
4. Applying these classifications to the structural overburden model to create a model with overburden classified as PAF or NAF.

3.3.2 Structural Overburden Model

The geological model (JB Mining, November 2016) incorporated an overburden model in Vulcan software. The overburden model is a structural model only and contains no chemical or physical properties of the overburden units. Only the overburden units situated above the Ace Seam have been modelled in the overburden model. (JB Mining, Coal Resources at Meandu, 2016 Model Presentation). Figure 3.2 to Figure 3.5 are provided by JB Mining and show the sections which display the overburden units above the Ace Seam from the K2E, Central, K4E and K4S pits. The key units that have been modelled and displayed are:

- Tertiary (TE)
- Basalt (BA)
- Upper Triassic (UT)
- Conglomerate (CG)
- Shale (SH)
- Base of Tertiary (BUTE) and
- Base of Weathering (BoW)

In the following sections reproduced for convenience from the JB Mining presentation (JB Mining, 2017) only the units above the uppermost coal seam (Ace) are labelled. Beneath the Ace seam the King grouping is coloured red, the various Queen plies are blue, purple and green.

Figure 3.2 – K2E Overburden Section (JB Mining, 2017)

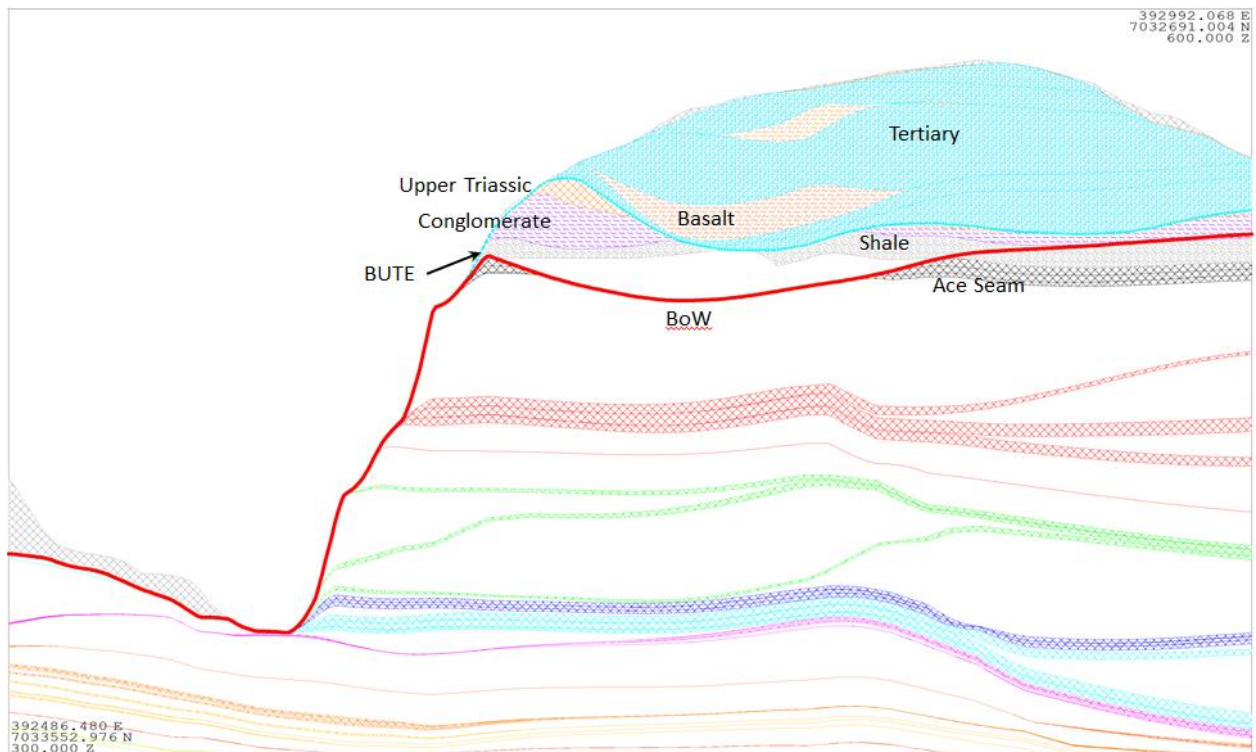


Figure 3.3 – Central Overburden Section (JB Mining, 2017)

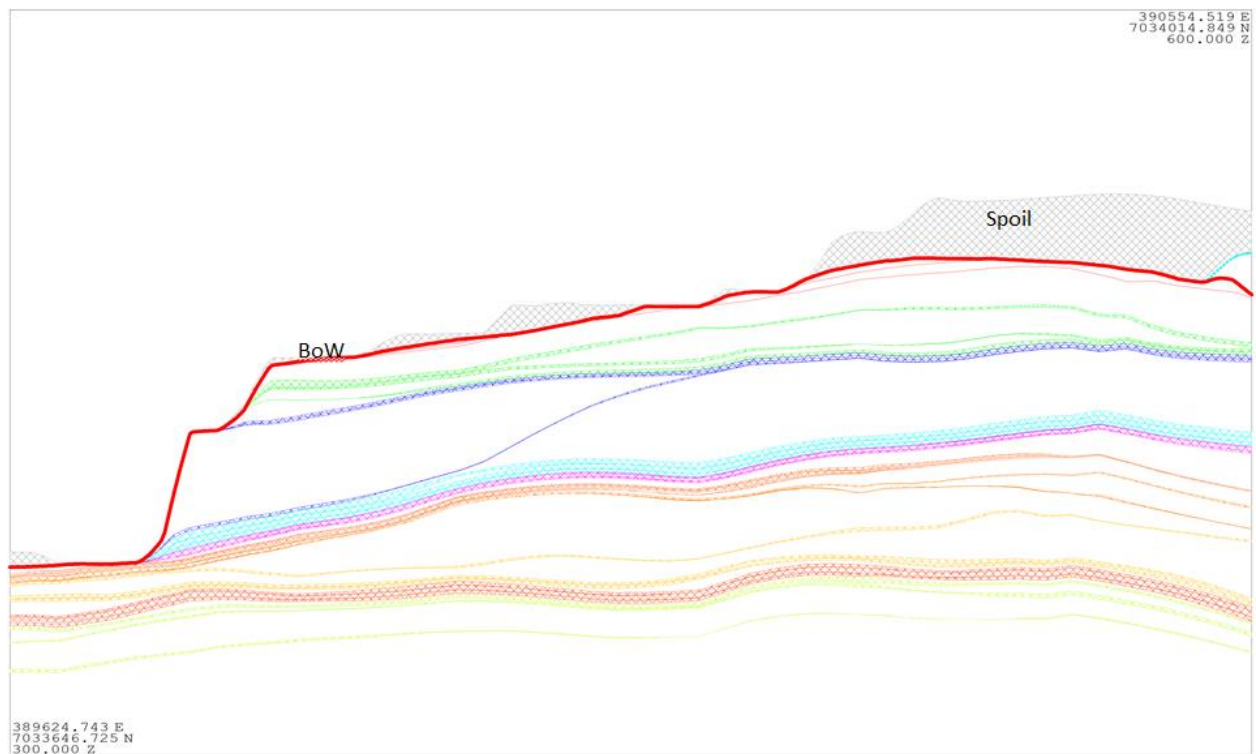


Figure 3.4 – K4E Overburden Section (JB Mining, 2017)

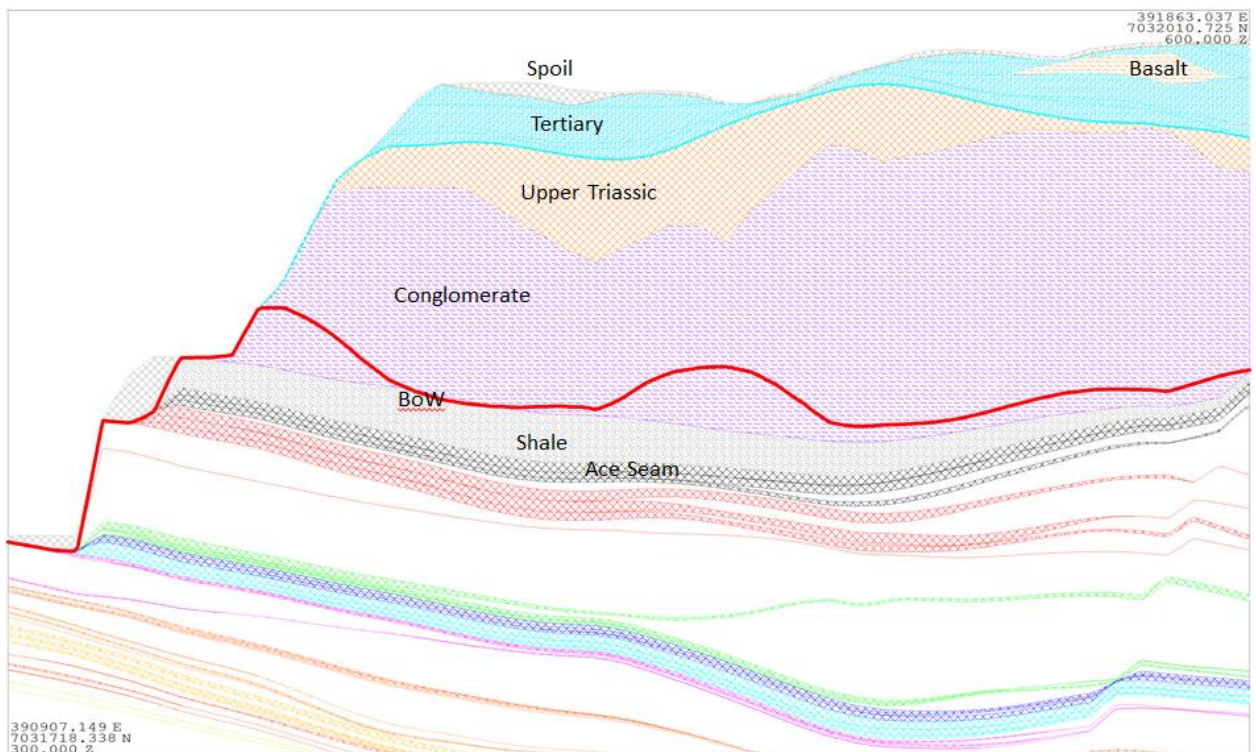
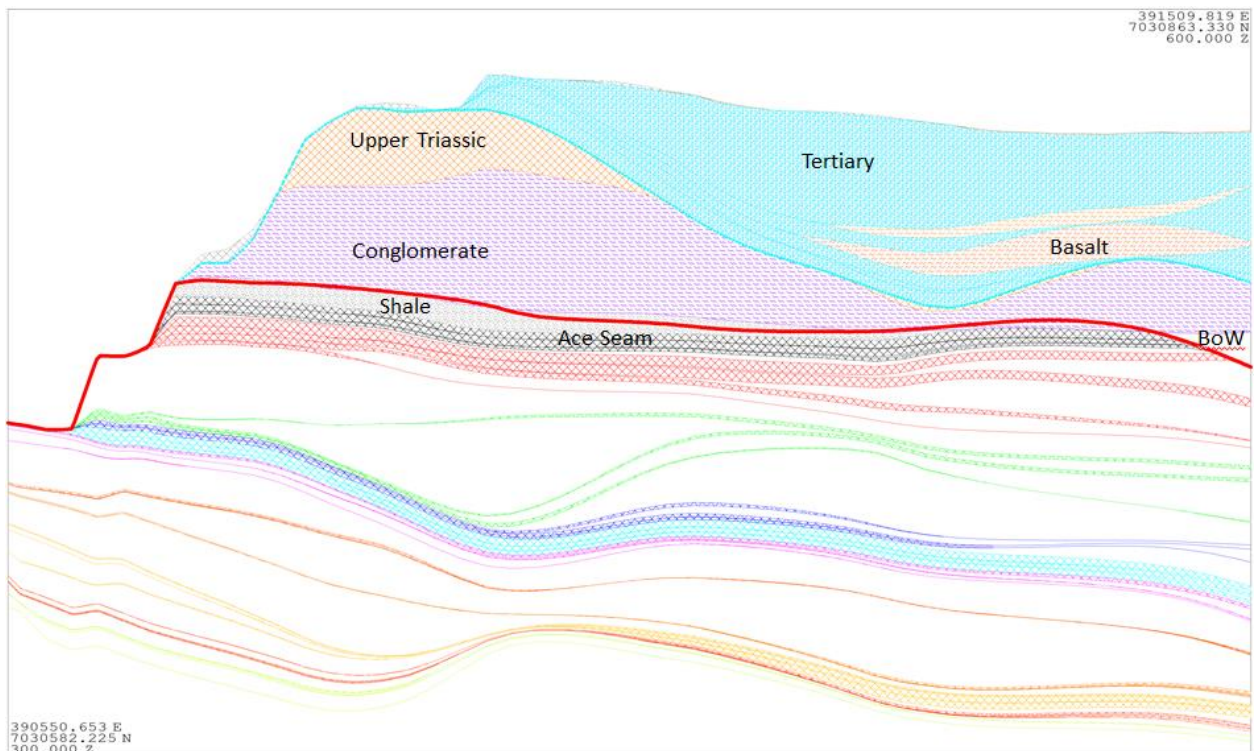


Figure 3.5 – K4S Overburden Section (JB Mining, 2017)



3.3.3 Chemical classification of overburden modelled

The overburden units of the strata have been assessed with respect to their geochemical properties and classified as either potentially acid forming (PAF) or non-acid forming (NAF). The classification for the 2017 LOM Plan was largely based upon four fully cored holes and applied to the overburden structural model (JB Mining, November 2016). It is of note that the classification for the 2017 LOM plan does not preclude that in future after analysing more materials data Stanwell may implement different classification methods to future life of mine plans.

The application of the overburden classification to the overburden structural model was recommended via a combined assessment by JB Mining and RGS (JB Mining, Meandu Overburden Units Memo. 8 February 2017). This classification work was only undertaken on overburden waste above Ace seam located in the pits of K4S, K4E / Boundary West, Boundary East and Powerline Pit. The spoil in the path of the mining schedule also had some classification applied to it. All other material that has not specifically been classified has been conservatively treated as potentially acid forming material.

The summation of the classification provided by JB Mining and RGS in their assessment is as follows:

K4S and K4E:

- TE plus UT as NAF rehabilitation resource
- Top 20m of CG as NAF secondary rehabilitation reserve
- Remainder CG as PAF
- SH as NAF primary rehabilitation reserve

K2E:

- TE plus top 10m of UT as PAF
- Lower UT as NAF rehabilitation resource
- CG as NAF rehabilitation reserve
- SH as PAF

Central and Ramp 5

- Spoil can be considered as general fill if screened as NAF.

3.3.4 Historical Waste Dump Identification

Historical information (Stanwell, Meandu AMD Project – 3D Concept Models Rev1. December 2016) has been used to determine the location of tailing, rejects and ash placement within the waste dumps of Meandu Mine. These areas have been defined using 3 dimensional solids within a Vulcan Model, supplied by Stanwell to Xenith, for use when creating reserves for mine scheduling and for consideration for dump placement and dump reshaping. These areas have been classified as PAF and are shown in Figure 3.6. Other areas of the spoil had been tested and determined to be PAF and are shown in Figure 3.7.

Figure 3.6 – Historical Reject Tailings and Ash (Stanwell, 2016)

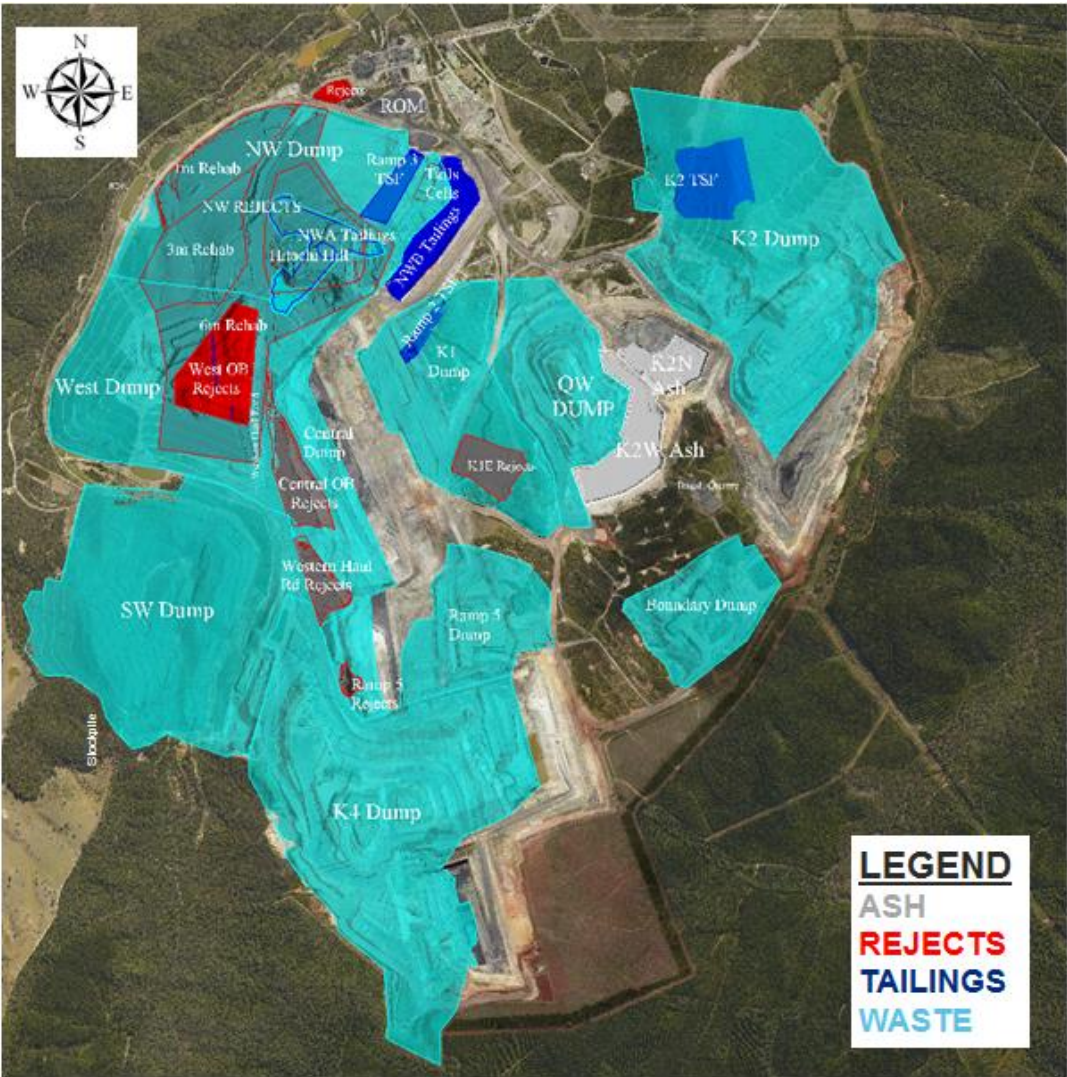
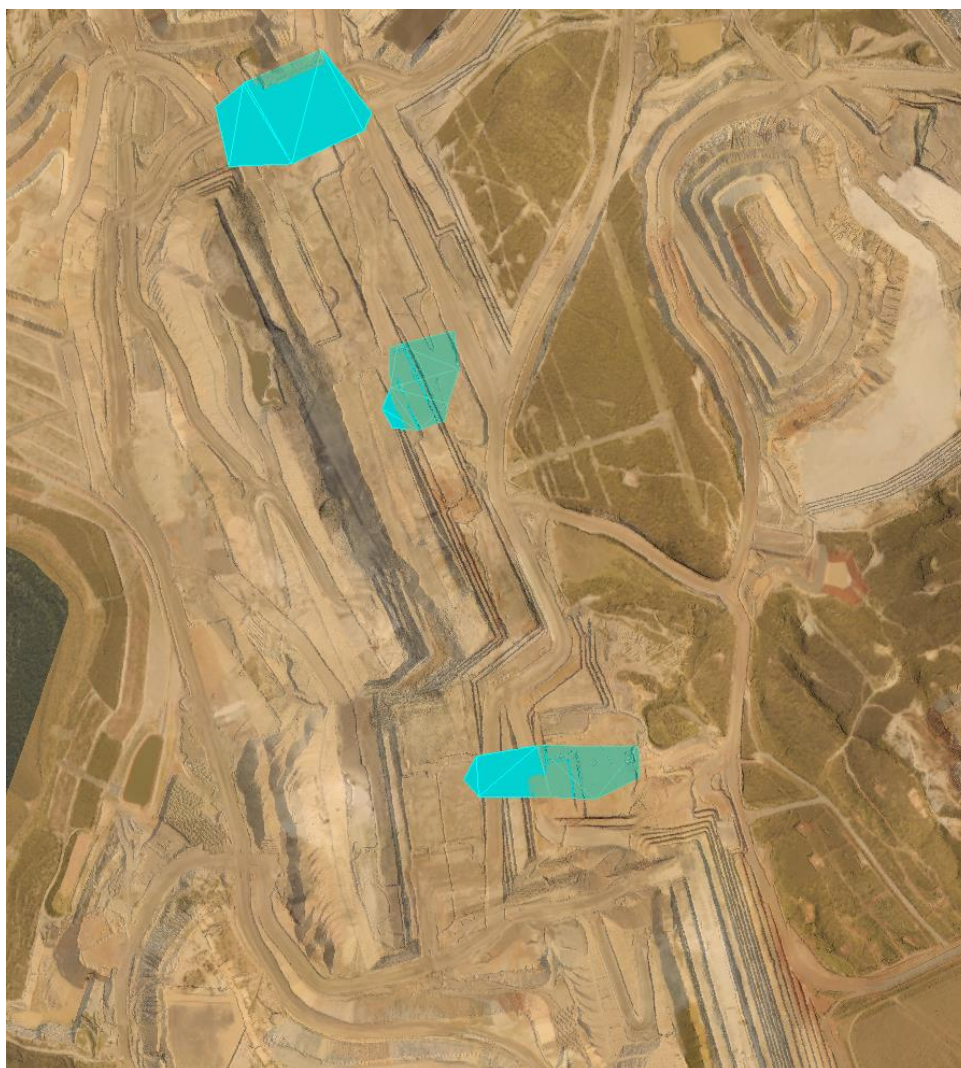


Figure 3.7 – Central and Ramp 5 PAF Zones



4 MINE LAYOUT

4.1 Pit Optimiser

4.1.1 Description of Optimiser Process

Xenith has used the Minex Pit Optimiser software (version 6.42) ('Optimiser') to establish the mining pit limits and indicative development strategies. Key Optimiser inputs and assumptions include:

- ROM seam structure and quality grids in Minex format,
- Site operating costs including mining, product transport and overheads,
- Slope design criteria,
- Yield and washing assumptions
- Product quality assumptions, and
- Coal sales price.

Optimiser runs the Lerchs-Grossman algorithm at different "Forcing Factors" (FF) where 100% FF represents application of 100% of the nominated coal price and 50% FF represents application of half the coal price. This produces a series of nested pit shells that depict the increase and decrease in cash positive resource with varying coal price. For the Meandu deposit, pit shells have been given FF's from 55 to 85 in increments of five. The key focus for the Meandu Mine optimisation process was to identify or prioritise the best or first 140 Mt for the deposit which was enabled with the data supplied.

Multiple scenarios have been tested in the currently approved LoM plan which formed the basis for the work undertaken in the EEE project. The mine plan examined in the current study emulates the preferred mining schedule from previous studies and utilises the updated geological model (JB Mining, November 2016).

Constraints were applied to JORC inferred and unclassified coal to reflect the reduced confidence in the tonnage present. This scenario is constrained to the mining lease and investigates the ideal pit limits when operating under this constraint.

4.1.2 Pit Optimiser Results

Schematics from Optimiser for FF 75% is shown in Figure 4.1, and the optimised pit limits reflect a similar size and shape as the current LoM Plan in the vicinity of the surface rights and the proposed surface rights. The FF 75% shell results in a total pit shell tonnage of 290 Mt Product tonnage equivalent (PTE).

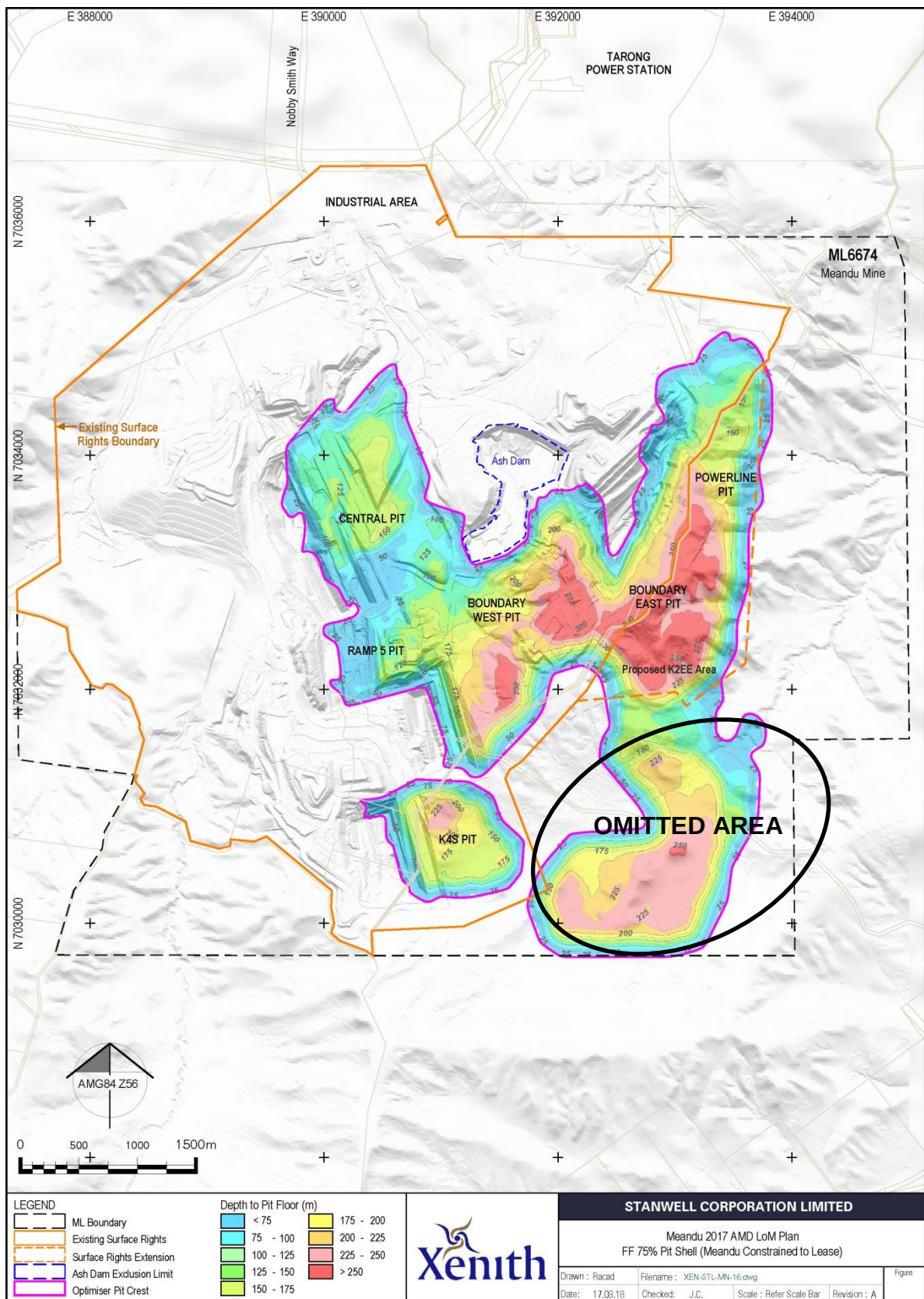
Meandu mining operations that are not constrained to the current surface rights area give favourable results in terms of increased coal quantities at lower forcing factors (FF). This is because mining is able to progress into the low strip ratio area to the east of the current surface rights boundary.

Based on this, Xenith recommended to Stanwell, to use the optimised pit limits proposed by the FF 75% Pit Shell with adjustments made for the fact that Ramp 5 is already committed and to reduce the risk of engaging the lower seams in Central Pit.

4.1.3 Omitted Areas

Optimiser often includes areas that are small or irregular in shape that would not be practical or economic to mine. These areas have been omitted from the pit design and are shown in Figure 4.1. After accounting for existing pits, the area in the south east provides significantly more reserves than the mine life requires without providing additional benefit, which is coupled with difficulties related to access and would require a new environmental approval.

Figure 4.1 – FF 75% Pit Shell (Constrained to Lease)



4.2 Pit Layout and Quantities

Optimiser shells were used as the basis for the generation for practical pit design at Meandu Mine. Deswik Suite software (Version 2016.1.1522) has been used to create the pit layouts and generate the quantities.

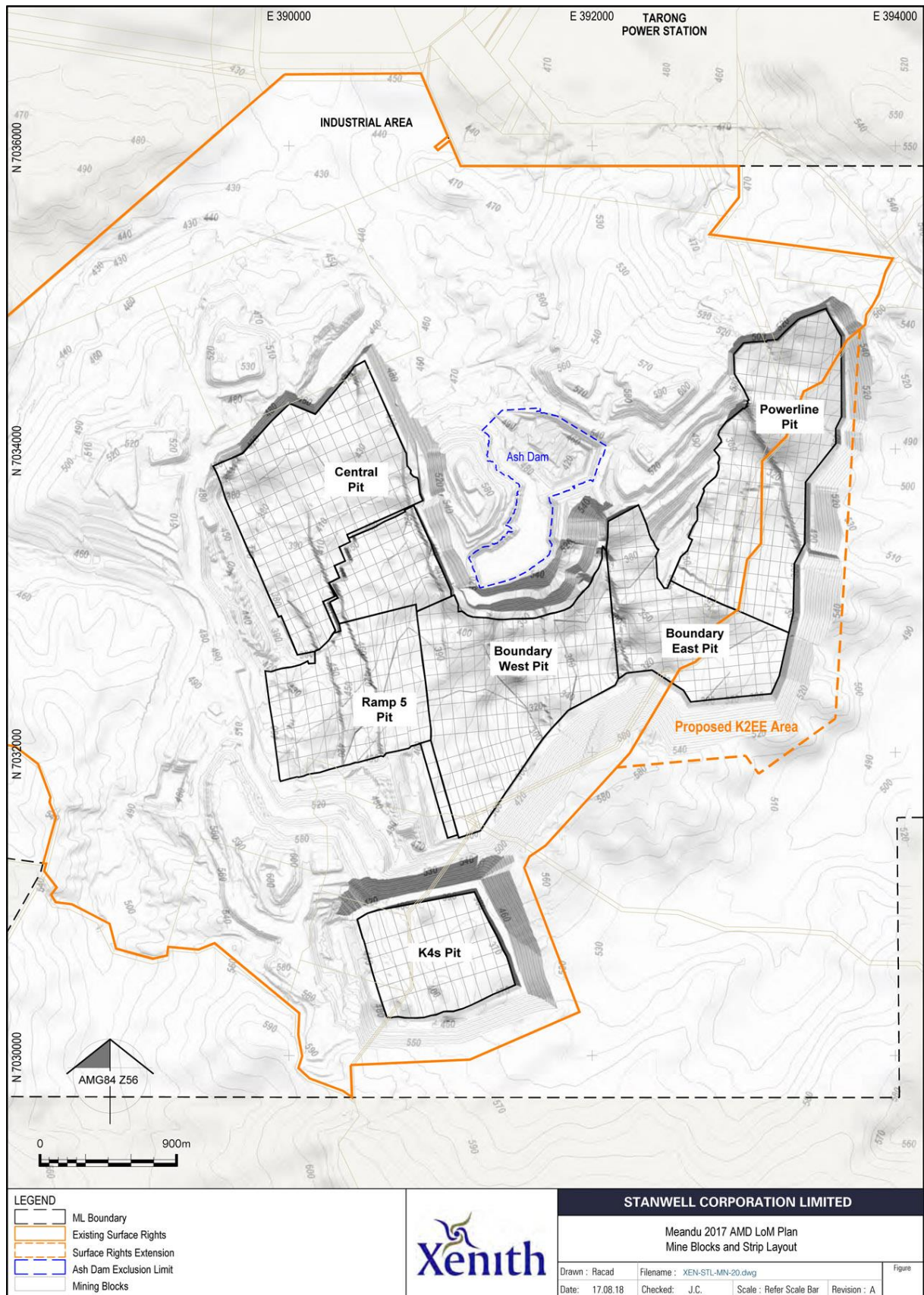
4.2.1 Meandu Pit Layout and Strip Alignment

Figure 4.2 shows the final pit layout and strip alignment for Meandu Mine.

In summary, all pits have been retained while maintaining their current strip alignment and boundaries as the optimiser pit shell did not alter them. Boundary East and Powerline Pits have had the pit floors adjusted as the geological model had been updated in this area (2016), which was reflected in Optimiser. However, these adjustments were minor. Strip widths are displayed in Table 4.1.

For Boundary East Pit, a portion which represented a boxcut, was designed with batters in two directions to enable alternative approaches to be scheduled.

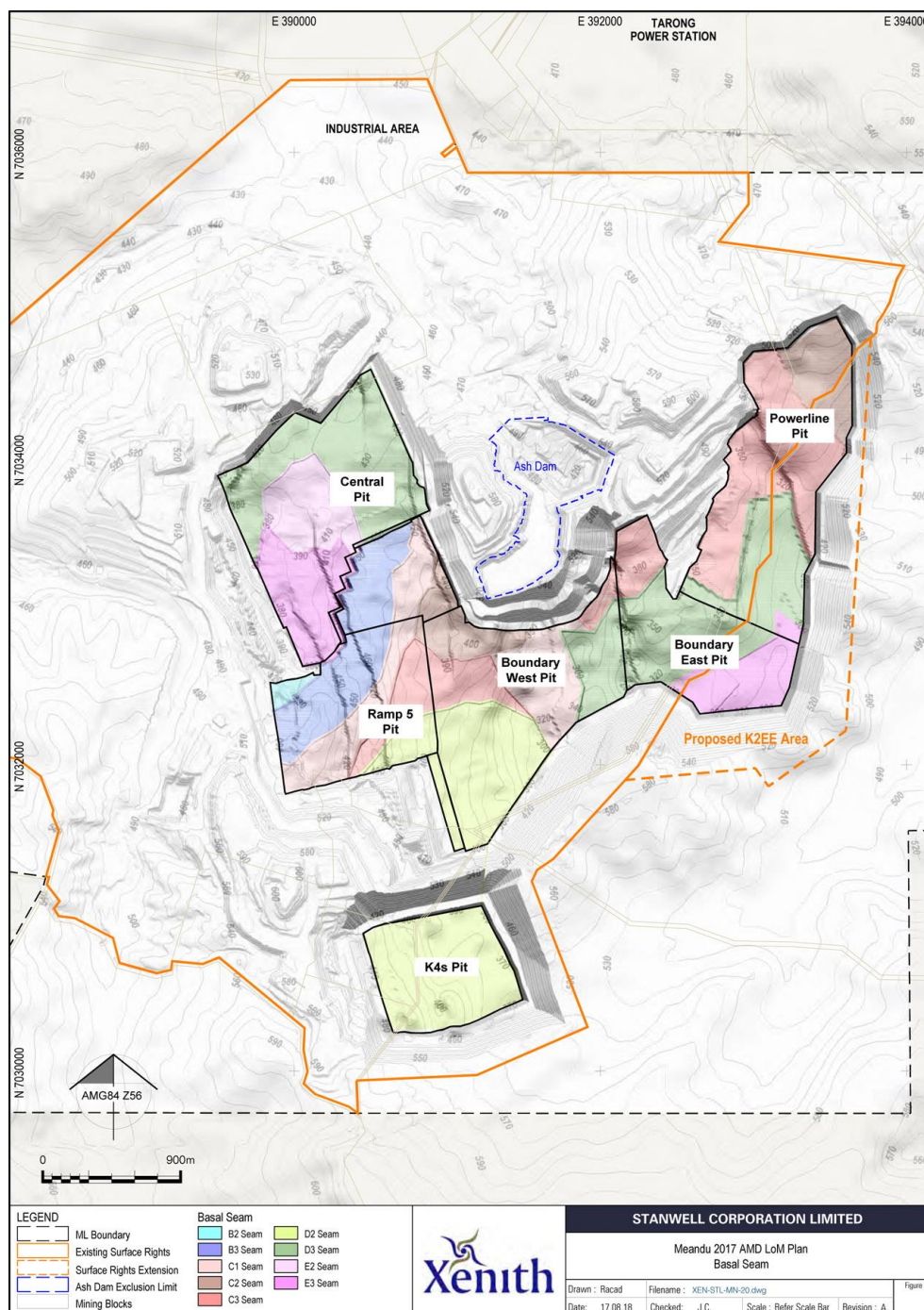
Figure 4.2 – Meandu Mine Pit Layout and Strip Alignment



4.2.2 Meandu Basal Seams

The basal seams were derived from the pit shells FF 60%, FF 75% and FF 85% for the “Mining constrained to lease” Optimiser case. The floor of this shell predominantly varied from the B3 seam to the E3 seam and appears to be primarily influenced by interburden thicknesses. Figure 4.3 shows the basal seams overlaid with the pit layout.

Figure 4.3 – Meandu Mine Basal Seams



4.2.3 Meandu Design Assumptions

The key design assumptions for the pit, as well as pit layout and strip alignment, were wall profile and dragline horizon. Strip widths used on site in strip designs, varied from 70m to 100m and are displayed in Table 4.1. An additional ramp access was also assumed on one end of each pit, based on endwall profiles.

For the purposes of LoM planning, simple wall profiles were used to design the pit and generate the raw mining quantities. The schematic of the highwall profile can be seen in Figure 4.4. It consists of a 70° wall angle from the pit floor to the top of the dragline horizon, a 25m wide bench at the dragline horizon followed by wall angled through to the topography at an angle that varies from pit to pit and is shown in Table 4.1. These profiles were used for the highwall where no additional ramp access was assumed. The endwall profile had a 50m bench at the dragline horizon and then battered up to the topography at 37°. Where endwall ramp access was assumed, an additional 50m wide bench at the base of weathering. The endwall profiles are shown in Figure 4.5.

Figure 4.4 – Meandu Mine Wall Profile

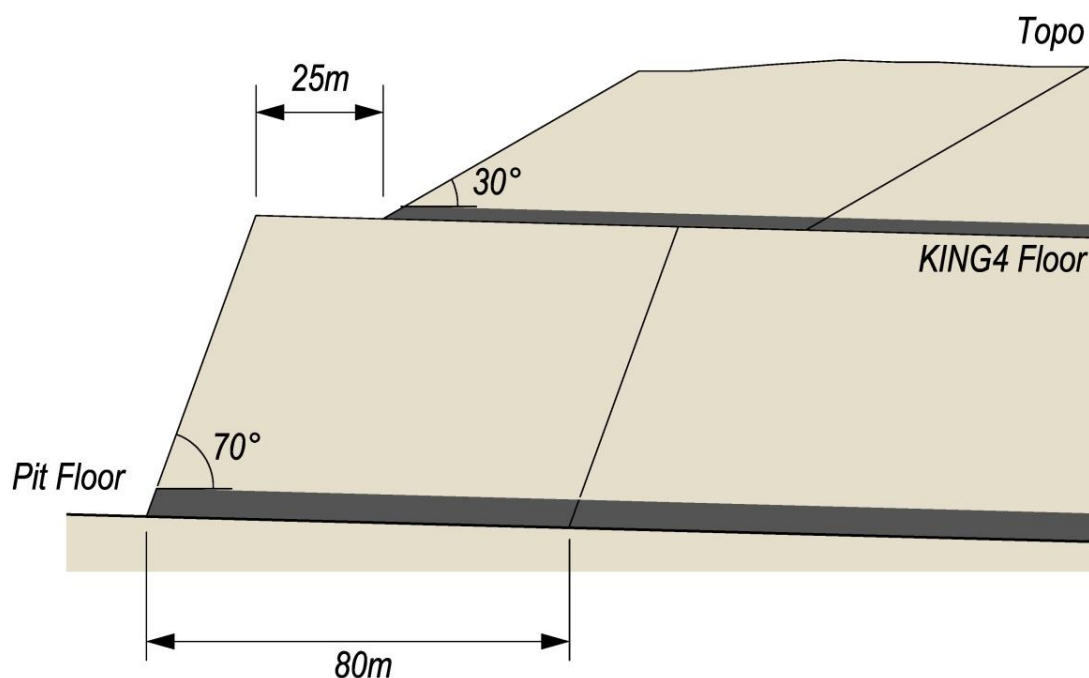


Figure 4.5 – Endwall Wall Profiles

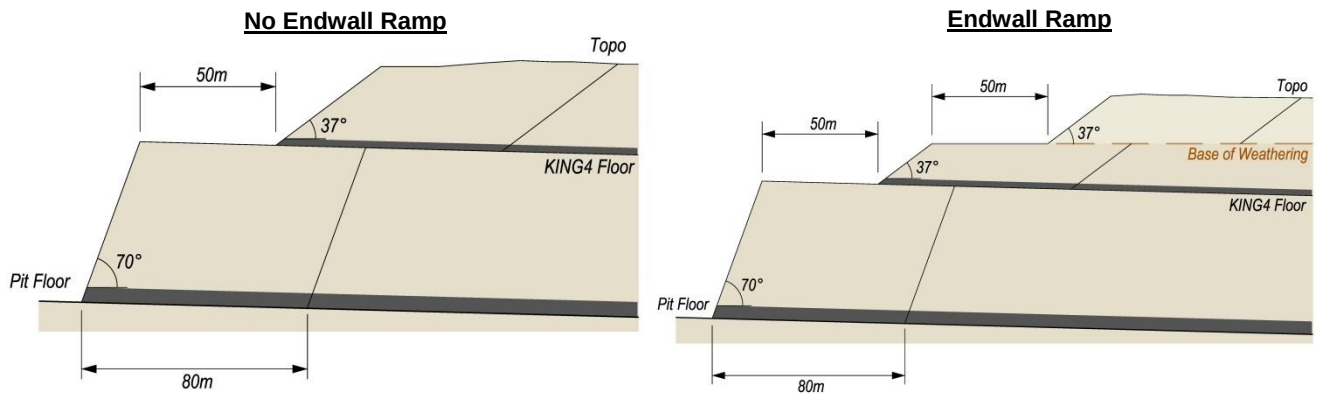


Table 4.1 – Meandu Mine Pit Design Parameters

Pit	Strip Width (m)	Dragline Batter (deg)	Dragline horizon	Bench width (m)	Prestrip Batter (deg)
Central	80	70	RL430	25	21
Ramp 5	100	70	King 4 Floor	25	21
K4S	80	70	King 4 Floor	25	30
Boundary	70	70	King 4 Floor	25	30
Powerline	70	70	King 4 Floor	25	30

4.2.4 Raw Mining Quantities

The resultant mining quantities generated in DeswikCAD (Deswick Suite Version 2016.1.1522) are summarised in Table 4.2.

Table 4.2 – Meandu Mine Insitu Quantities

Pit	Insitu Waste (Mbcm)	Insitu Coal (Mt)
K4E	11	2
K4S	105	26
CENTRAL	77	23
RAMP 5 NORTH	24	7
RAMP 5	53	13
BOUNDARY WEST	228	52
BOUNDARY EAST	244	46
POWERLINE	224	50
Total	966	219

5 MINE AND DUMP SCHEDULING

5.1 Approach

The raw mining quantities generated in DeswikCAD* (Deswick Suite Version 2016.1.1522) have been imported into the reserves database within Spry* mining software (Mitrais, Version 1.4.0.670). Here the scheduled mining quantities have been calculated and waste allocations performed based on the agreed assumptions. The outputs have been imported into a Deswik landform and haulage model to calculate truck travel times. Results of the schedule and associated haulage data were then used as an input into the financial analysis.

** Spry and DeswikCAD are reserving and scheduling software used by mining engineers to plan a mine.*

5.2 Reserves Model

Reserves database was prepared for Meandu Mine using the 2016 LoM version of the reserves database in Spry.

The database takes imported reserves from Deswik and provides a calculated database for insitu coal and waste, ROM coal and waste and product coal. It calculates a coal Product Tonnage Equivalent (PTE) by normalising product tonnes to a standard specific energy of 19.6GJ/t at product moisture. The database also provides a scheduling section which assigns waste volumes to the equipment type and process.

The parameters in Table 5.1 are used by the reserves database model to calculate schedule quantities and the resultant scheduling quantities are displayed for Meandu Mine in Table 5.2.

The dragsim logic allocates waste to the dragline system driven by the dip of the seam, waste thickness, the number of coal seams / dragline passes within the dragline horizon and the dragline method selected. At Meandu Mine, the dragline is less dependent on seam dip and the dragline horizons have been allocated in a more prescriptive manner on a pit by pit basis.

Table 5.1 – Reserves Model Parameters

Waste Properties	Density	2.37t/bcm
	Ash	80% (average)
Default Coal Properties	Insitu Moisture	7.1%
	Product Moisture	12%
	PTE Conversion Factor	19.6GJ/t
Loss	Roof Loss	0.2m
	Floor Loss	0.1m
	Edge Loss	0.15m
Dilution	Roof Dilution	0.1m
	Floor Dilution	0.2m
	Edge Dilution	0.15m
Mining Constraints	Minimum Coal Thickness	0.5m
	Minimum Waste Thickness	0.5m
	Partings	Waste less than 4.0m

Table 5.2 – Meandu Mine Scheduling Quantities

Pit	ROM Waste (Mbcm)	ROM Coal (Mt ar)	PTE (Mt)	Product (Mt ar)
K4E	11	2	2	2
K4S	105	28	22	20
CENTRAL	76	26	18	16
RAMP 5 NORTH	24	8	6	6
RAMP 5	52	15	11	10
BOUNDARY WEST	227	58	46	42
BOUNDARY EAST	243	50	43	38
POWERLINE	224	54	45	40
Total	963	241	192	175

5.3 Dragline Design

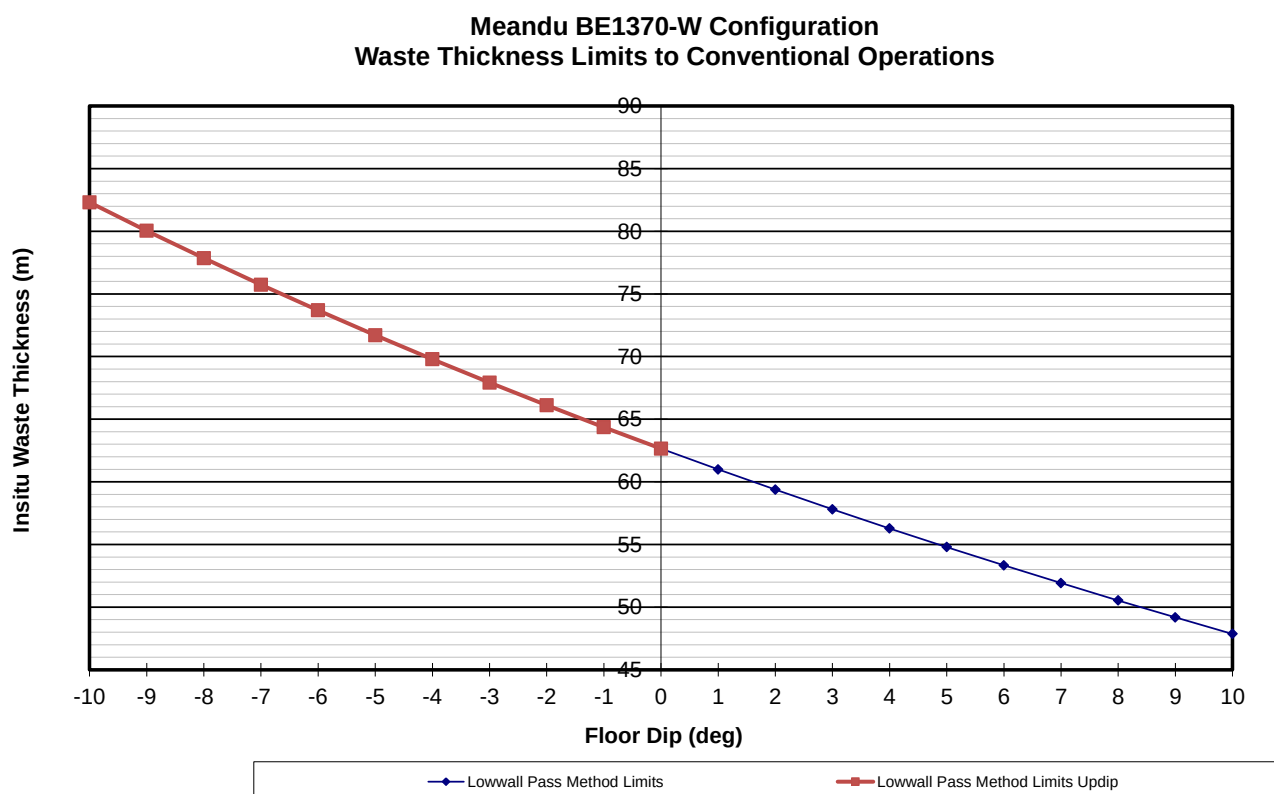
The Dragsim simulation system has been used to simulate each of the methods and derive relationships that can be used to closely estimate the volumes attributing to each equipment type involved in the method.

5.3.1 Dragline Mining Horizon

For the purposes of this study the maximum amount of waste (or waste thickness limit) that can be assigned to each of the draglines is dependent on the dragline size, the seam dip and the method of operation. A fundamental assumption in all dragline options is that the dragline will always work within its dimensional constraints (i.e. when completing final passes, the dragline is always able to reach the toe of the material that is required to be removed to uncover coal) so that excessive rehandle operations such as “spoil pull-back” or “elevated pads” are avoided.

Figure 5.1 shows the variation in maximum waste thickness limits as seam dip changes. Note that this maximum horizon can be adjusted down if necessary to during the scheduling process.

Figure 5.1 – Maximum Burden Thickness Assigned to Draglines vs Seam Dip



5.3.2 Meandu Mining Methods

In a previous study conducted by Xenith (“*Meandu Dragline Optimisation, May 2015*”) a full series of detailed dragline method curves have been developed for the Meandu Mine on a Pit-

by-Pit basis. These curves have been considered suitable for use in this study and have therefore been applied. In addition to these curves, Double Inpit Elevated Bench (DIEB) methods (a pullback method) has been developed and included for use when required within Powerline Pit and Boundary East Pit. As the dragline is expected to have lower utilisation within the schedule when it is confined to these pits, DIEB can be applied and allocate more waste to the dragline from truck and excavator. This will better utilise the dragline, increasing the prime quantities albeit increasing rehandle also.

5.3.3 ITF Curves

The Dragsim simulation system allows direct calculation of the dragline volume moved in each dragline dig block, along with parameters such as blast-to-final-spoil, doze-to-final-spoil and dragline rehandle. The factor that has been derived for scheduling purposes to calculate the total waste moved by the dragline is the Insitu to Total Factor (ITF). The ITF Factor is defined by:

$$ITF = \frac{\text{Total Dragline Waste moved in Block (bcm)}}{\text{Dragline Insitu Waste in Block (bcm)}}$$

such that:

$$\text{Total Dragline Waste moved (bcm)} = \text{Dragline Insitu Waste} \times ITF$$

Similar relationships (curves) have been developed for Blast-to-final-spoil, Dozer Volume pushed, and doze-to-final-spoil. The curves are all designed as a factor of Dragline Insitu Waste, which is the unblasted waste allocated to the dragline in each mining reserves block. For each mining block in the database, the Dragline Insitu Waste is the total block reserves waste less the upper waste removed by the truck and excavator fleet, and less the thin and in seam partings which are planned to be removed by secondary stripping equipment. For easy transfer into the mining database, a series of multivariate regression curves have also been developed.

5.4 Scheduling

5.4.1 Schedule scenario

The 6 Mtpa scenario described in this study is specifically designed so that the haulage modelling simulates the selective placement of NAF material either directly into a cap on top of the dump or a NAF stockpile on top of the dump which will cap particular areas post reshaping.

5.4.2 Scheduling Model

All scheduling has been performed using a LoM Spry model. The model has been designed to produce target PTE schedules, whereby the results show how much dragline and prestrip capacity is required on a financial yearly basis. Some limited balancing of dragline and truck and excavator capacities, such as capping the dragline capacity, has been performed to

provide a viable schedule. The truck and excavator requirement is essentially a demand to service the dragline and PTE production needs. The demand outputs can have some significant variation from one year to the next. The truck and excavator requirement subsequently gets 'smoothed' through the fleetings process to allow for the equipment purchasing requirements to be managed.

5.4.3 Mining Processes

The equipment in the model has been established as coal mining, dragline, and truck and shovel waste processes. A coal PTE target schedule is the driver of the schedules. A combination of using an input path for the dragline and the coal mining process drives the schedule toward the targets and is limited to the relevant coal PTE target for each year. The dragline capacity is limited however the truck and shovel process is not limited by capacity, but instead is reported as a demand. In this way, the coal mining process and dragline guides the schedule, while the dragline and truck and shovel processes report how much waste material must be removed to keep these processes on target. Dragline delays may occur when the coal supply is more than required, effectively making the dragline coal bound for a period.

5.4.4 Scheduling Model Parameters

The following parameters have been used for scheduling:

- The dragline capacity is 16.9 Mbcm per annum. This incorporates all operating factors of availability (excluding major shutdowns), utilisation and production rate.
- The major shutdown maintenance regime for the dragline is a 2 month shutdown every five years and a 1 month shutdown in between the larger shutdowns.
- As discussed in Section 5.2, the dragline rehandle is determined by the seam dip, method allocated and dragline pass thicknesses. ITF curves are incorporated within the Spry model.

5.4.5 Process Dependencies

The Spry scheduling model can use dependencies to assist to control the schedule. The dependency used was the 'Top to Bottom' dependencies which ensures the mining occurs from top to bottom in the block. It was also used to ensure that the truck and excavator requirement for the next strip was completed prior to the dragline commencing in the current strip.

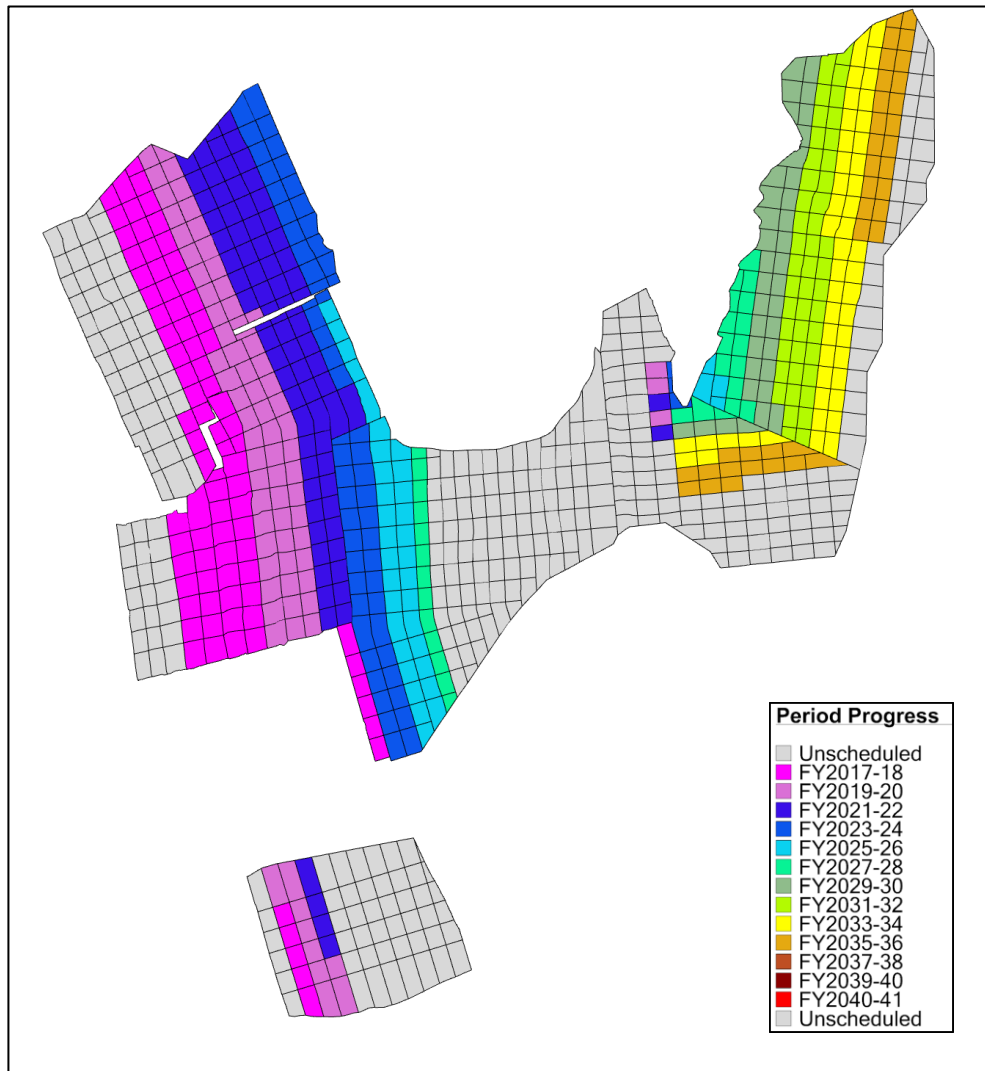
5.5 Progress of Schedules

Progress plots have been established to illustrate the development of the mine for the case scheduled. The progress plot timing is based upon the mining of the lowest seam in the block and does not reflect when the block is first touched for mining of waste. The schedules are described in this section and illustrated with the progress plot in Figure 5.2. Further illustrations of stage plans are shown in Appendix B.

Key points for the 6 Mtpa EEE Project Lom Schedule are:

- Ramp 5 and Central strips were aligned with central pit advancing slightly faster in this case
- Mining progressed to Boundary West
- To target lower cost areas, K4S mining was limited
- Opened Boundary East boxcut to increase dragline strike length with Powerline Pit

Figure 5.2 – 6 Mtpa EEE Project sequence



5.6 Schedule Results

Figure 5.3 to Figure 5.7 show plots illustrating the results of the mine scheduling.

Figure 5.3 – Annual Strip Ratio

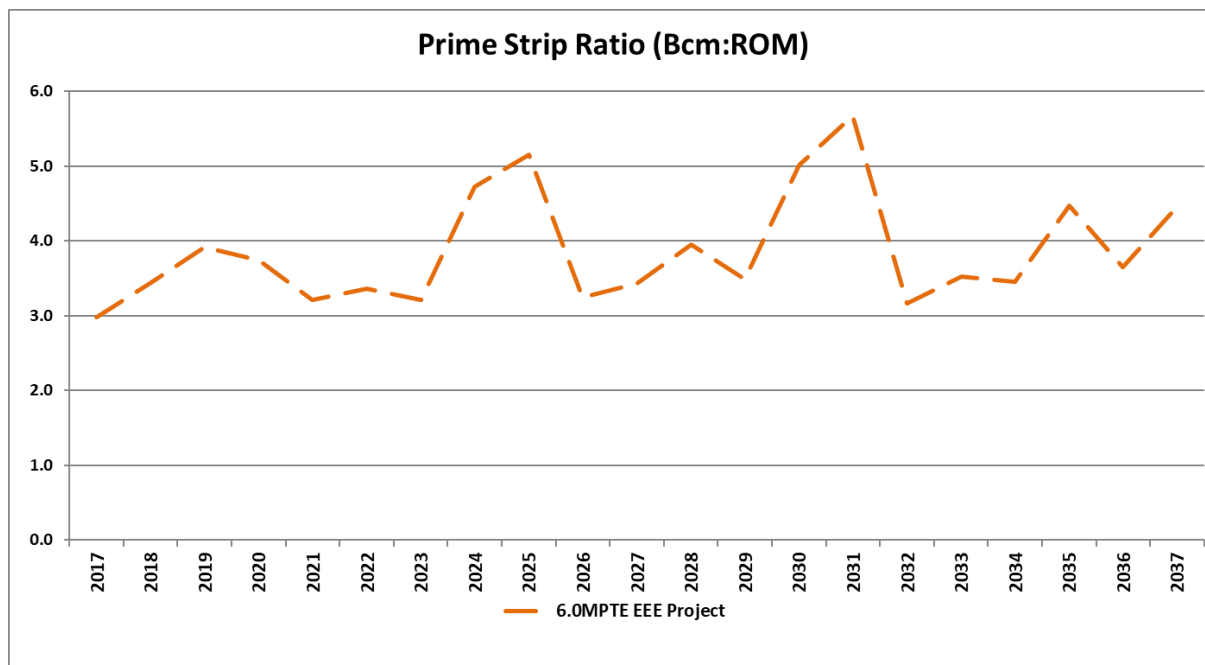


Figure 5.4 – Cumulative Prime Waste

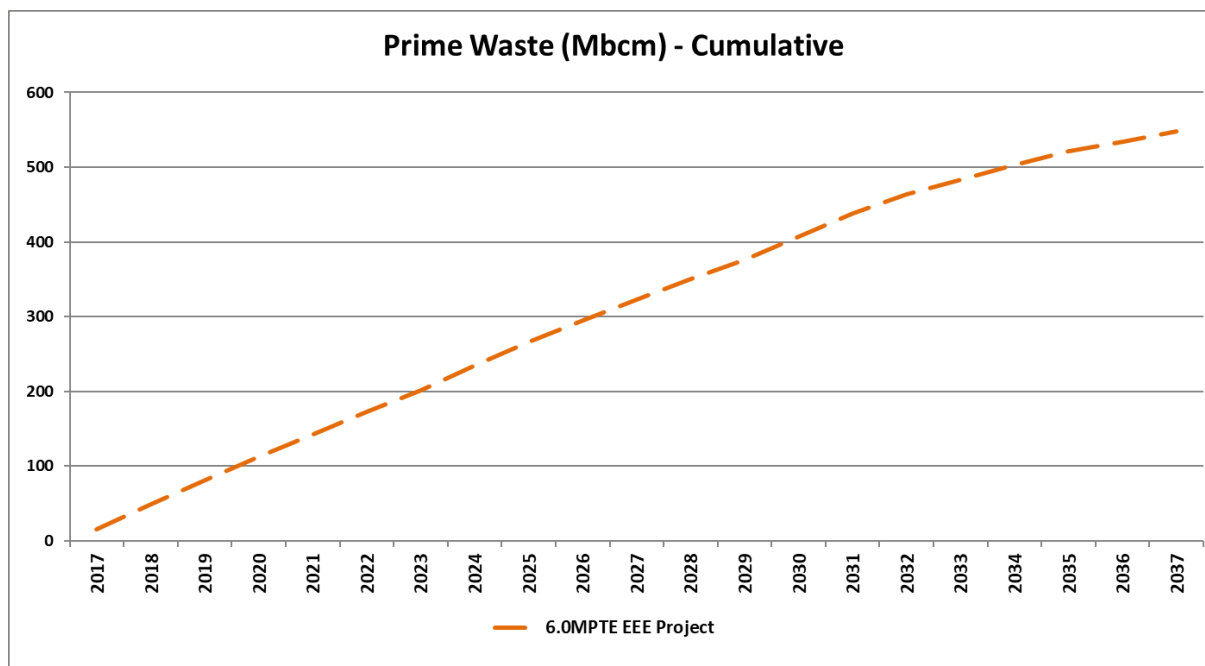


Figure 5.5 – Prime Waste

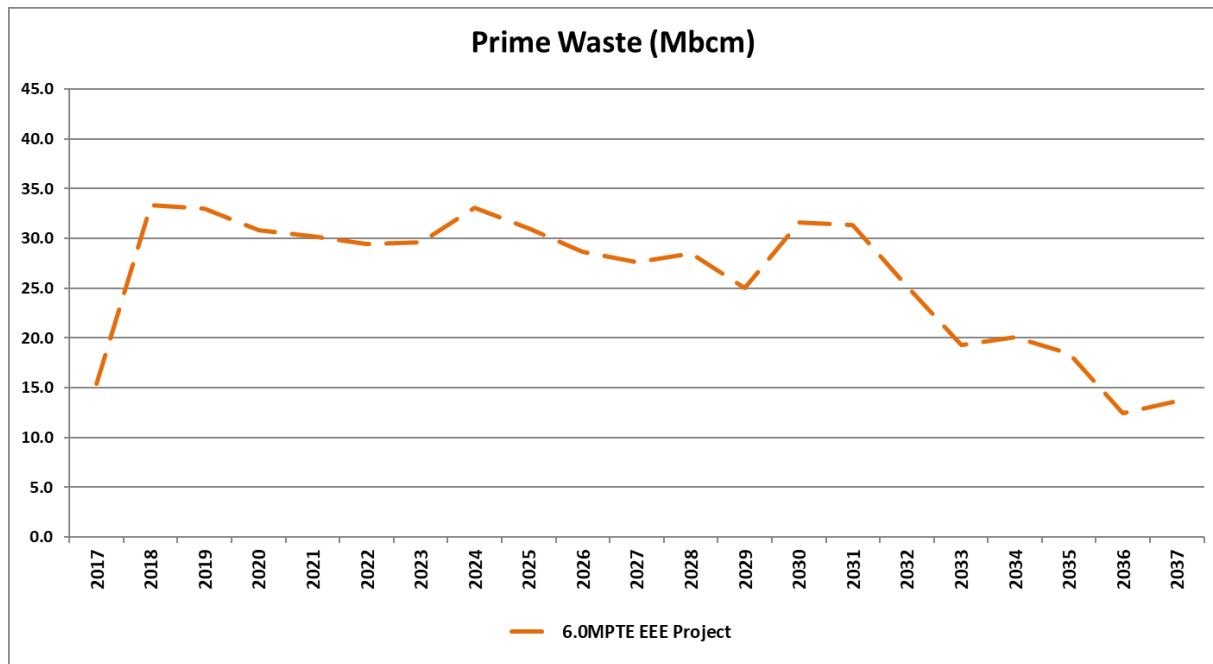


Figure 5.6 – Coal Mined

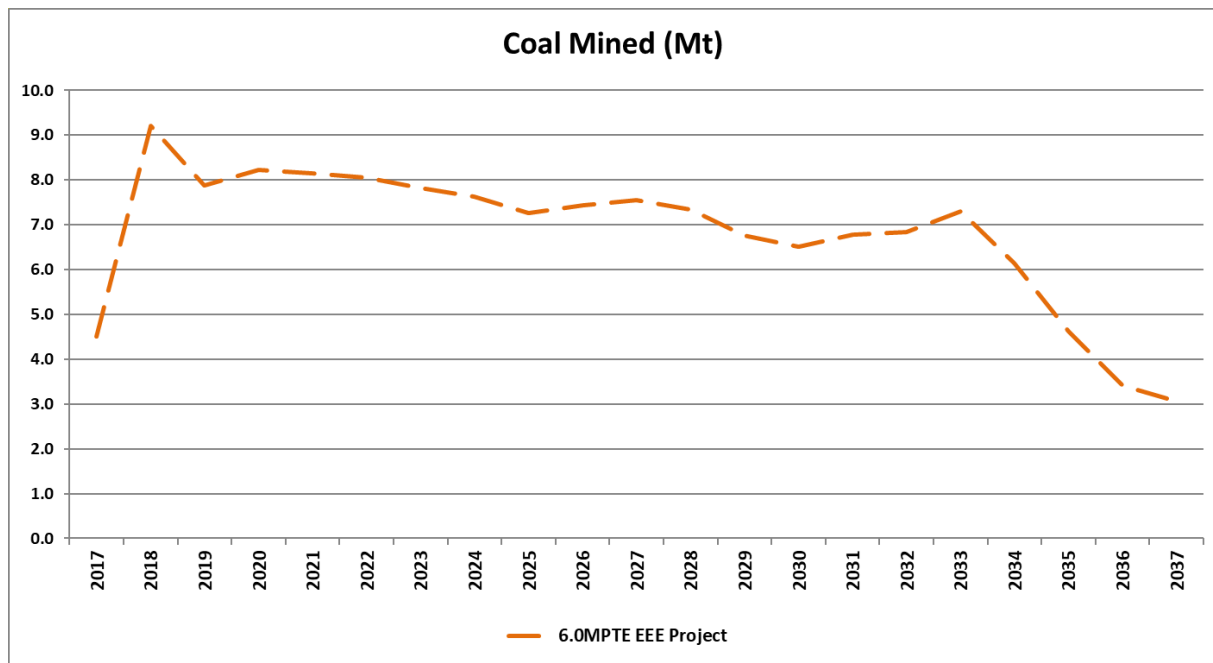
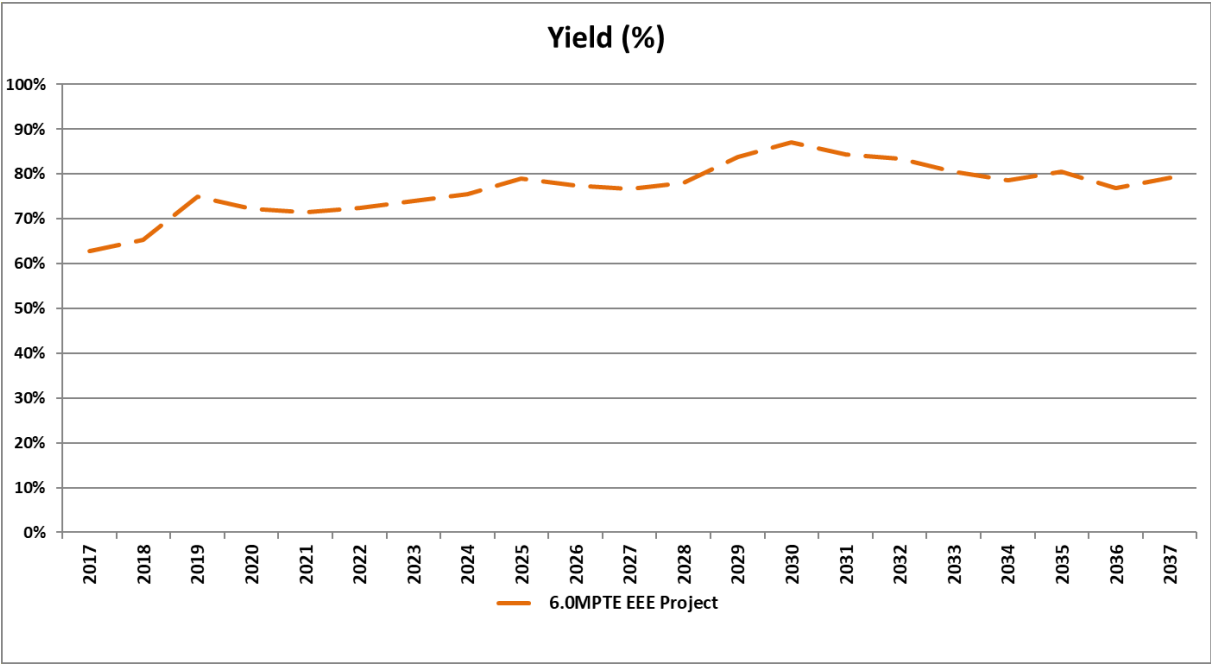


Figure 5.7 – Product Yield



5.7 Landform and Haulage model

The Deswik landform and haulage module was used to build a landform and haulage model for the mine schedule. Inputs into the Deswik model included the mining schedule output paths, quantities and the design dump shells.

An iterative approach was undertaken to integrate the haulage modelling with the landform rehabilitation reshaping to enable more representative modelling of the haulage to suit the desired landform. The categorisation of the waste material was utilised in the haulage modelling and reshaping work to plan for the capping of the waste dump with NAF material.

The key outputs of the landform and haulage model are:

- average truck travel time per year for coal and waste;
- the proposed final landform shape were the key outputs.

This section describes the inputs and the outputs to the landform and haulage modelling. Some of the dump progression can be observed in the stage plans in Appendix B.

5.7.1 Assumptions

Table 5.3 outlines the assumptions that were applied in the landform and haulage model for Meandu Mine.

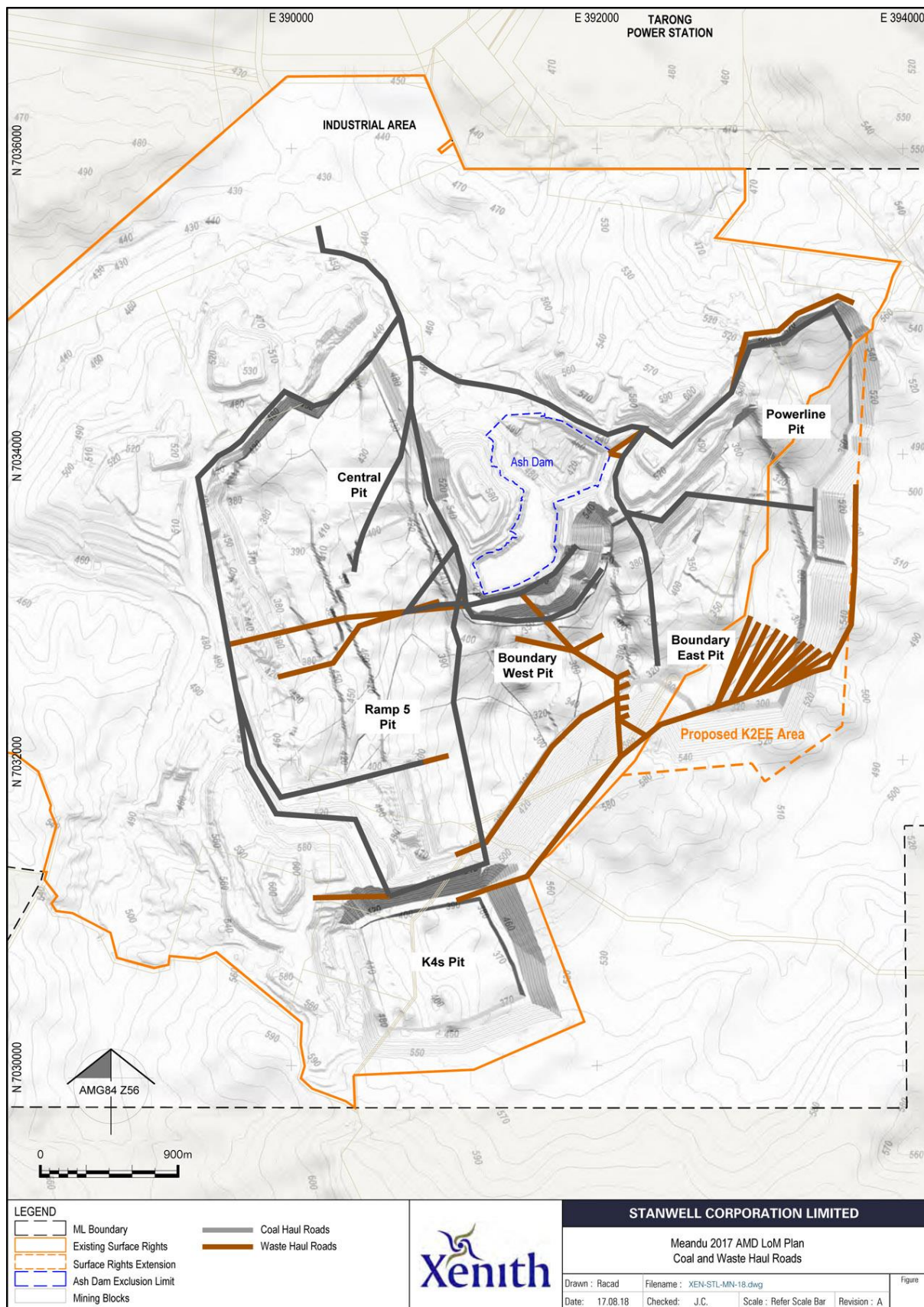
Table 5.3 – Assumptions for Landform and Haulage Model

Assumption	Value
Dragline spoil swell	25%
Existing spoil swell	0%
Truck & Excavator spoil swell	20%
Advancing dump face dependency	18°
Maximum ramp grades	10%
Haul trucks for coal and waste	Komatsu 830E
Haul trucks for waste only	Hitachi EH5000
Dumping Strategy	Minimise RL & Minimise Distance
Truck dump lifts	20m
Outside dump batter	14%
Angle of Repose	37°
Maximum dump height	RL 600

5.7.2 Haul Road Locations

The haul road locations at Meandu Mine for waste and coal are shown in Figure 5.8. These haul roads follow existing haul routes initially and then account for the pits advancing. They consist mainly of conventional ramp access and endwall access roads. The lowwall ramp and rolling coal haul road strategy in Central Pit has been emulated which allows the north-western haulroad to be dumped over and rehabilitated.

Figure 5.8 – Meandu Mine Coal and Waste Haul Roads



5.7.3 Dumping Limits

The dump limits are defined by a dump shell. The dump shell used in the haulage model is shown in Figure 5.9. The construction of the dump must progress in a logical sequence. To assist in controlling this progress, the dump is divided into smaller sections that can be used to apply dependency rules.

Figure 5.9 – Meandu Mine Dump Shell



5.7.4 Truck Travel Times

The resultant truck travel times for each case are used to calculate truck productivities. The resulting average annual travel times and subsequent truck productivities are compared between cases that are testing like aspects of the plan, using Hitachi EH5000 on waste and Komatsu 830E on coal. The travel times for the waste are impacted by the selective placement of the NAF material which in turn adversely impacts the truck productivities. These impacts are however, relatively minor.

5.7.5 Spoil Fit

“Overflow” is a quantity reported out in the Deswik landform and haulage model that refers to the volume of material that is not able to fit in the dump at that point of time in the schedule and is a measure of scheduling effectiveness and efficiency. There was no overflow of any consequence in the model so therefore there are no concerns regarding spoil fit for these cases.

5.7.6 Mine Landform Reshaping

One of the key outputs from the landform and haulage modelling is the final landform surface. The term final landform refers to the dump and pit landform surface at the conclusion of productive operations. To allow the mine to close down and relinquish the lease, the site must be rehabilitated to a sustainable and stable surface. This requires the final landform to be reshaped through the use of dozers, scrapers and truck and excavator. The ash dam and tailing dam are required to be capped with overburden waste. Infrastructure also needs to be demolished and rehabilitated. All final reshaped surfaces need to be topsoiled and revegetated.

5.7.6.1 Assumptions

The key assumptions for the reshaping of the final landform are:

- Max grade on spoil: 14%
- Max grade on highwall: 37°
- Min ash / tailings dam NAF cap: 6m
- Target waste dump NAF cap: 6m
- Free flowing drainage except for final voids.

5.7.6.2 Modelling Process

The landform reshaping was conducted using the reshaping tool in 3Ddig Plus modelling software (version 3.4). The mine site is divided into logical portions to allow for the movement of the existing dump to fill adjacent voids and hollows in what is essentially a cut and fill exercise. 3Ddig plus enables a smoother finish to the surface.

This work was undertaken in an iterative process with the haulage modelling. An optimised haulage model was executed without selective placement of NAF material and was then reshaped to achieve the assumption requirements with particular modification for free-flowing drainage. The surface was used as a landform surface to dump to, still without selective NAF

placement, where practical. This new dumped surface was then reshaped and became the new target surface for haulage where the selective placement for NAF is considered.

5.7.6.3 Reshaped Landform

Modelled progression to the reshaped landform for 6 Mtpa EEE Project Case is shown in Figure 5.10 as a before snapshot and Figure 5.11 as an after reshaping snapshot. To achieve this result, a cut and fill volume of 56Mm³ was exercised.

Figure 5.10 is the start surface in the reshaping exercise. This image shows the predicted landform shape at the end of waste movement operations, but prior to the final reshaping and rehabilitation exercise required to achieve a free-draining and stable surface. This picture shows that the majority of the final landform shape is achieved during the operating period of the mine, and that NAF material has been placed as a cap on the majority of the western areas of the mine. Allowance has been made to store NAF material where needed for final reshaping activities.

Figure 5.11 shows the stable reshaped landform at the completion of the reshaping exercise in 3Ddig plus. The coloured regions highlight major reshaping and cut/fill balance areas that were undertaken during this process (in contrast to the final profiles achieved in the non-coloured regions by the main haulage schedule in Deswik).

These areas are:

- Powerline Pit final void (grey);
- K4E (Boundary West) Pit final void (blue – south);
- Central Pit proposed ash storage void – cut and fill cover (blue – north);
- K4S existing out of pit dump reshaping at the south west extent of the operation (maroon); and
- Reshaping of the BMT and Hitachi Hill dump areas at the north west extent of the operation (grey).

These colours do not necessarily delineate an area of significance with respect to material characteristics, only that they are areas of major reshaping works that occur after the main coal mining operation will have ceased.

Figure 5.10 – Landform Start Point – 6Mtpa EEE Project Case

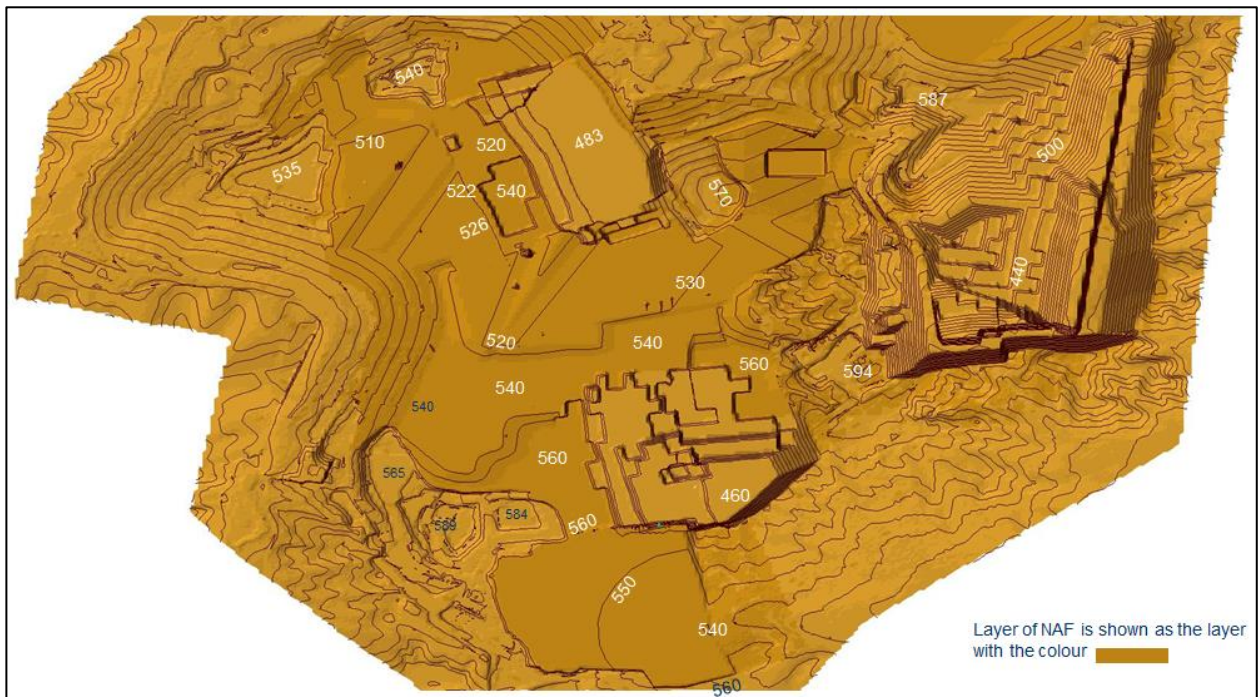
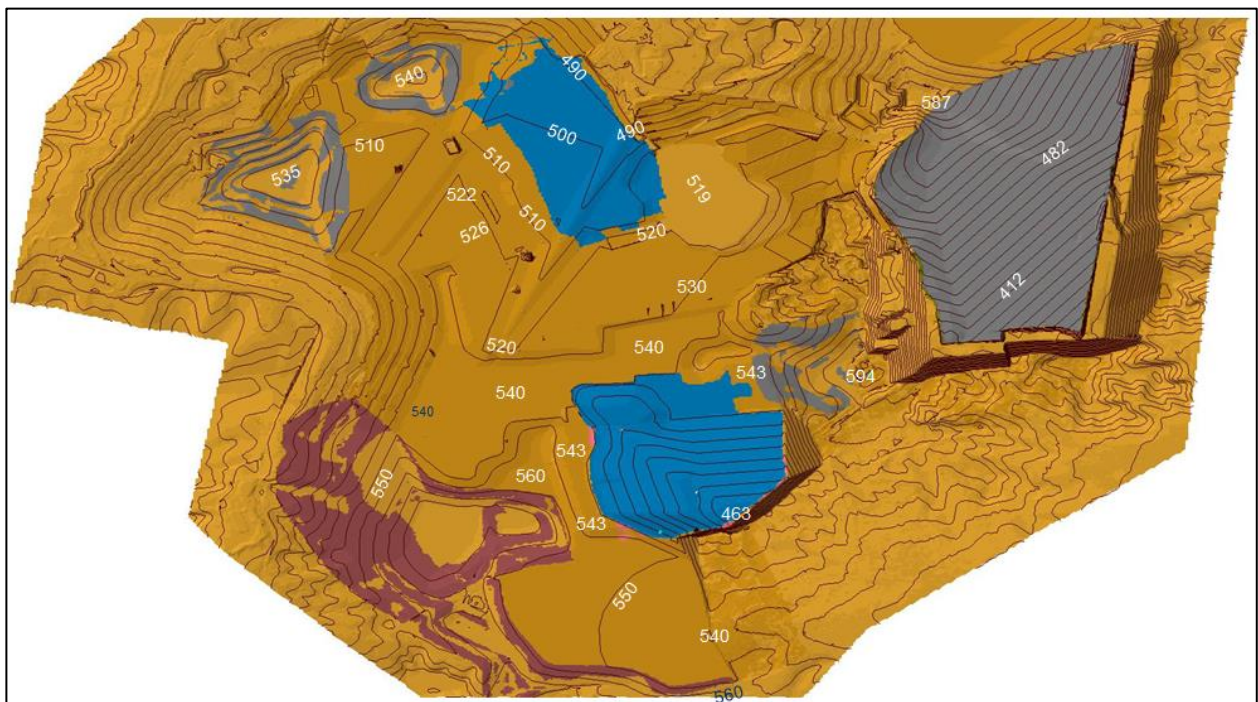


Figure 5.11 - Landform Reshaped – 6Mtpa EEE Project Case



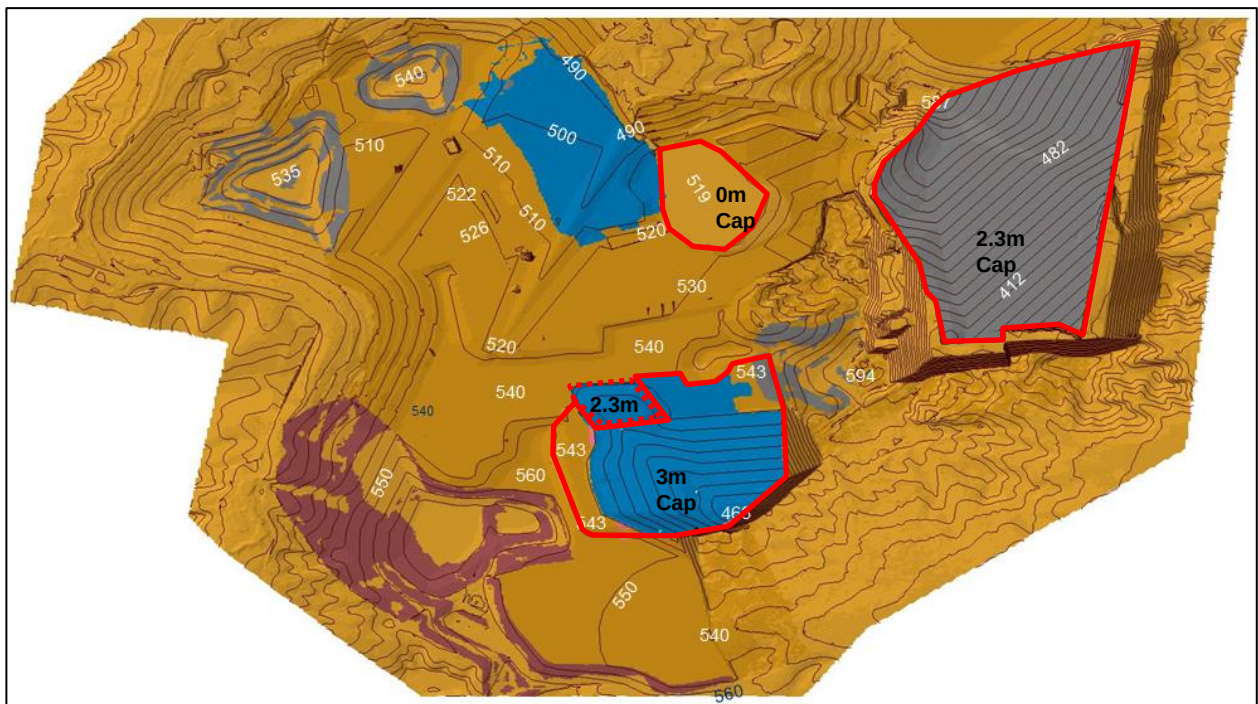
5.7.6.4 Reshaped Landform – Capped Surface

Whilst a 6 m capping was targeted across the site for the reshaped surface, there were some exceptions (i.e. final voids) where a thinner capping was applied. The capping exceptions are shown in Figure 5.12.

Both of the final void areas (Powerline Pit and K4E/Boundary West Pit) had a reduced capping thickness applied in order to match the available NAF material in the region to the surface area available.

A 0m cap was applied to the former K2W dump area (centrally located in Figure 5.12) as the information received from Stanwell in their historic mapping showed this to be an area (at that level) that was highly likely to be classified as NAF material.

Figure 5.12 - Landform Capping Exceptions

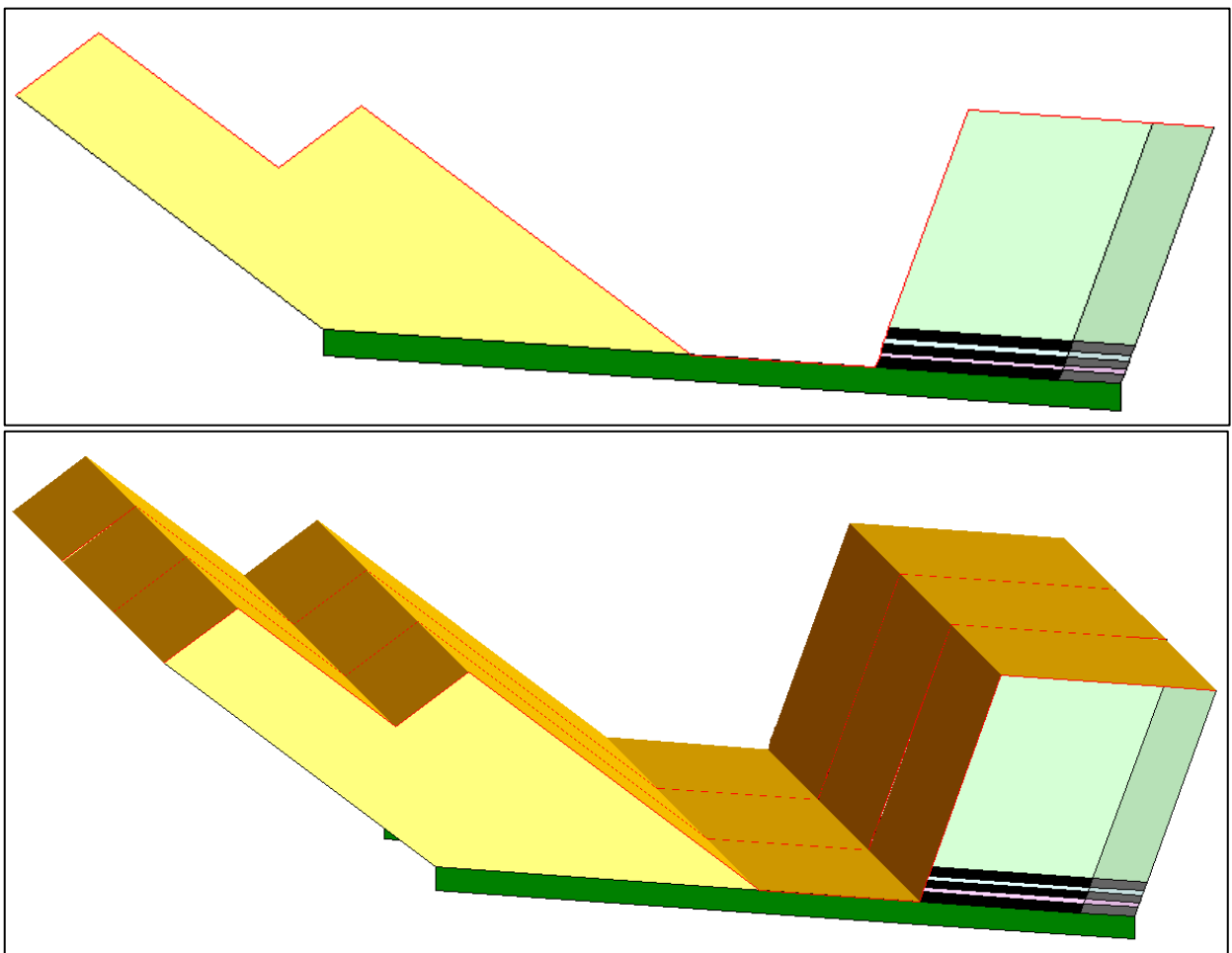


Appendix A. DRAGLINE METHODS

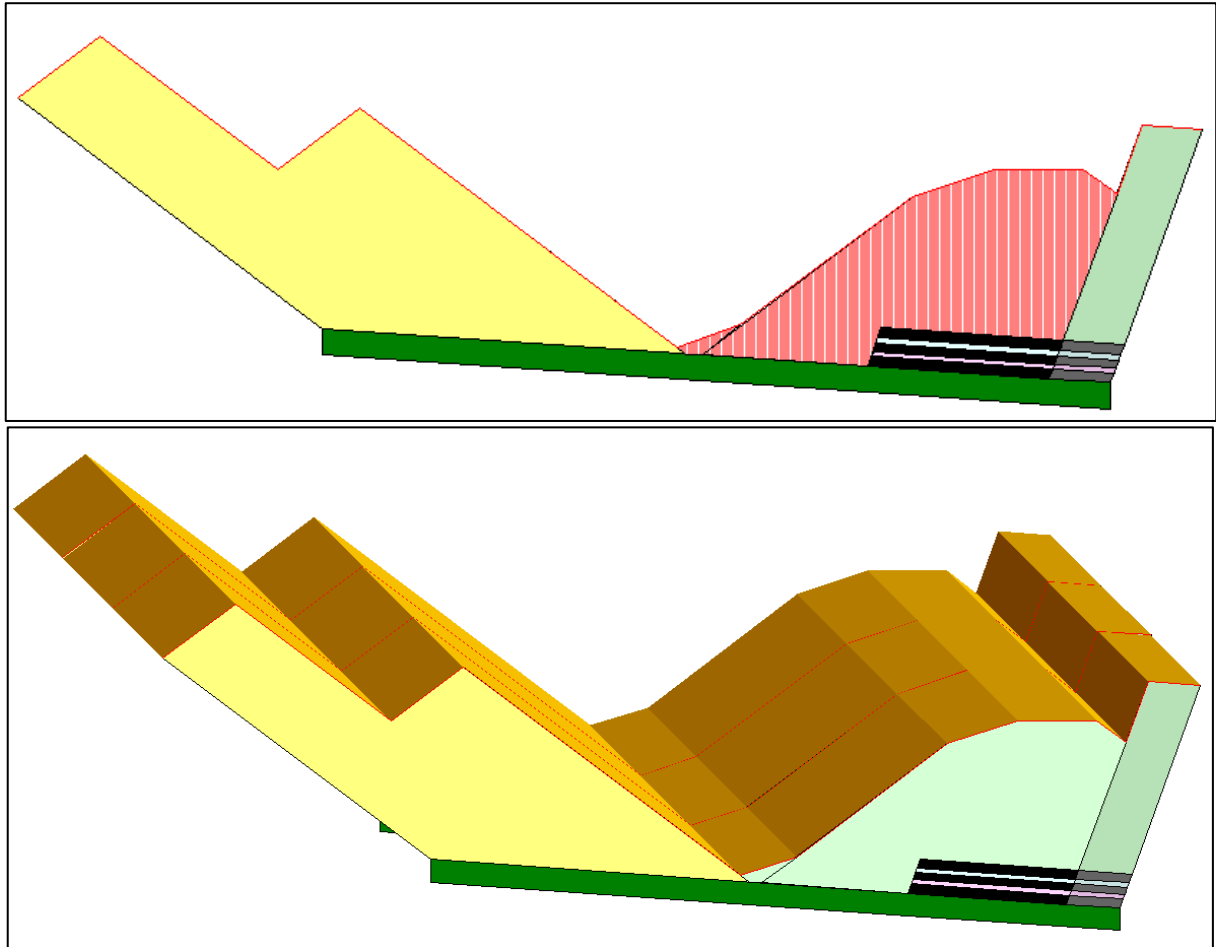
SINGLE SEAM ZONE, DEIB PULLBACK METHOD

The following series of cross sections show the Double Elevated Inpit Bench (DEIB) pullback dragline method simulated for a single coal seam Zone area. The method allows more waste to be taken than could normally be handled using conventional methods. The method involves the dragline working on two lowwall bench pads (one high and one low) in order for the dragline to stack the spoil higher.

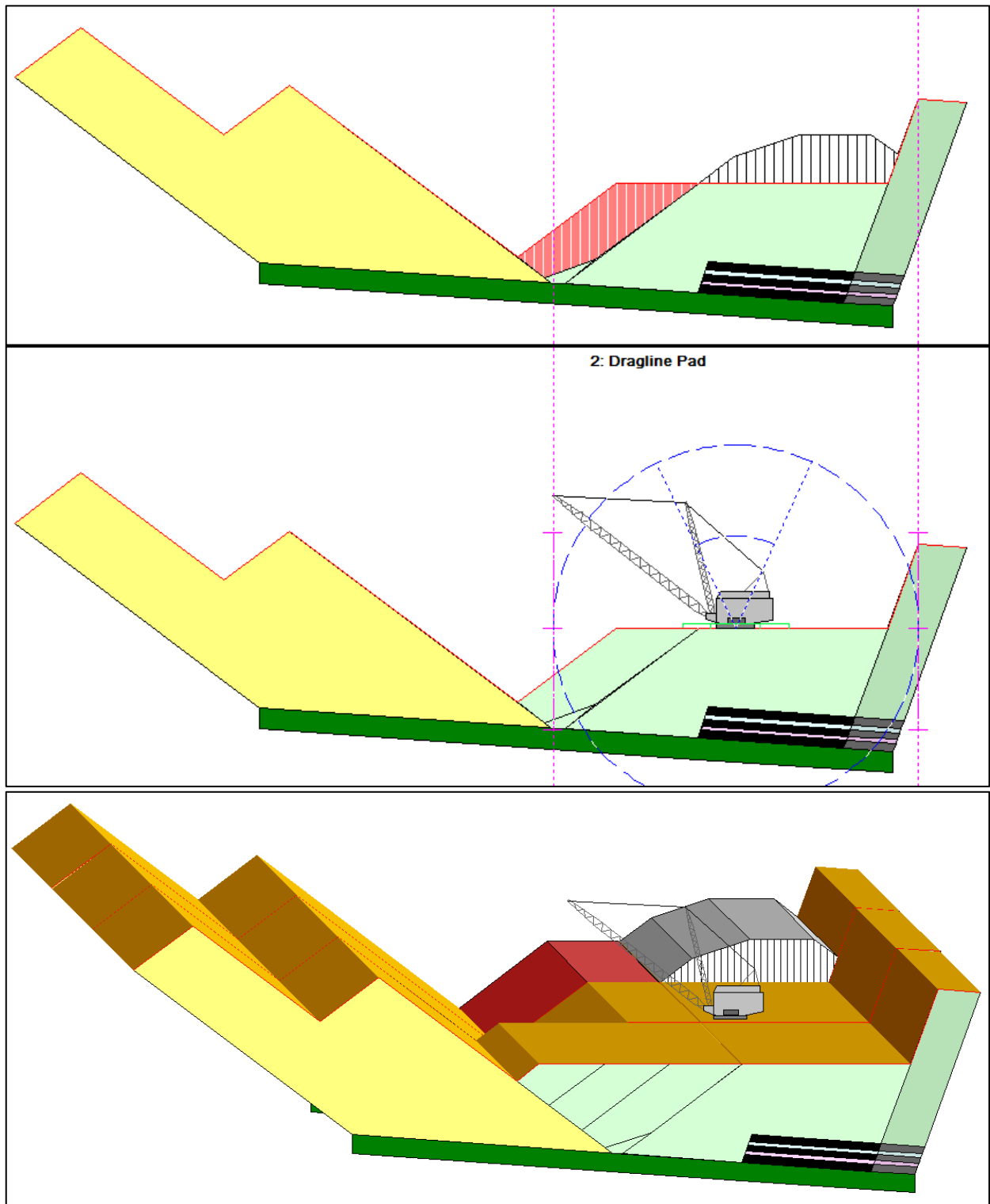
The following series of cross sections describes the method. The cross sections directly below show the unblasted pit.



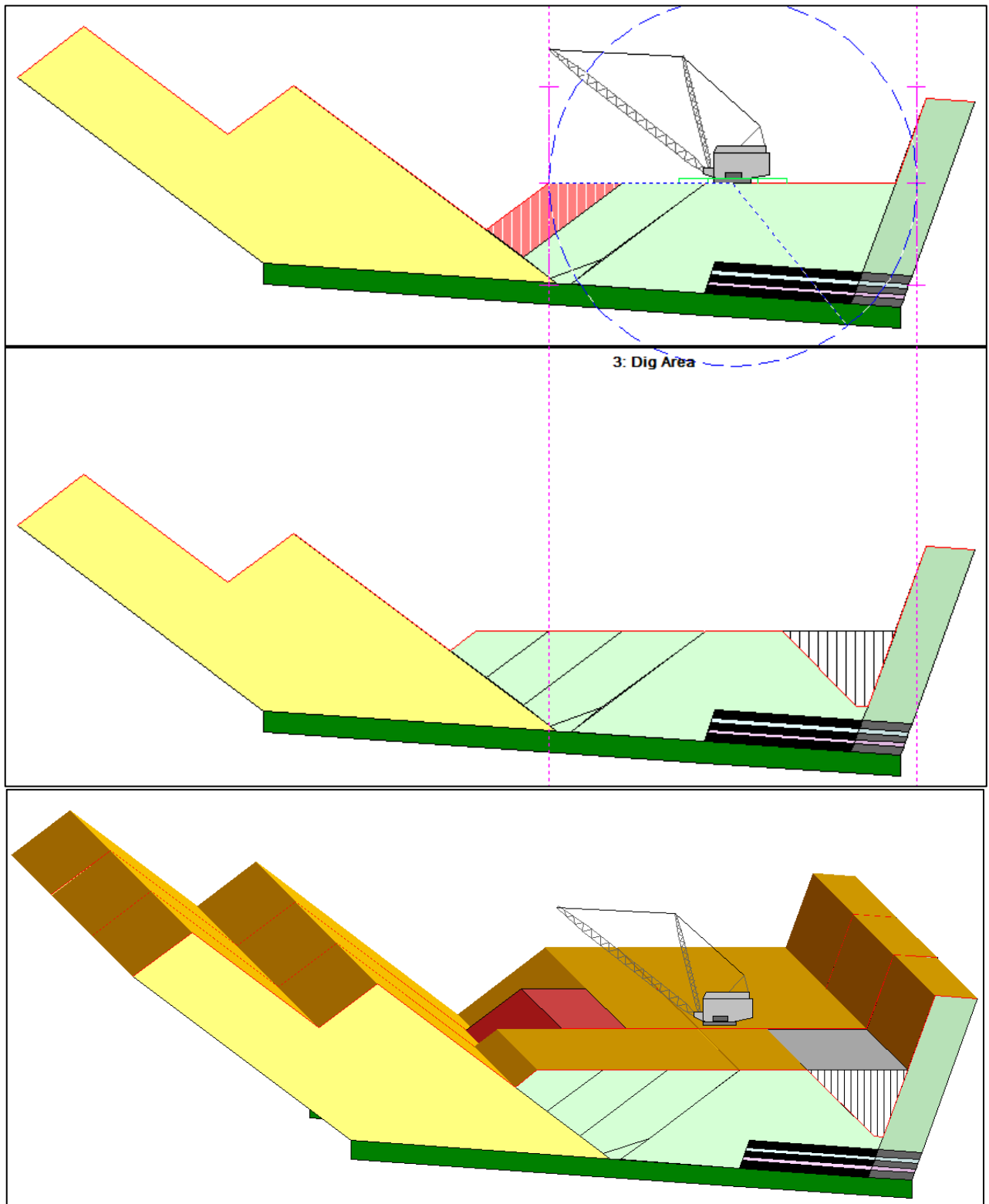
The overburden is blasted. A relatively conventional production blast has been assumed, but throw blasting could be used to lower the blasted profile and thereby save some dragline and dozer work later on.



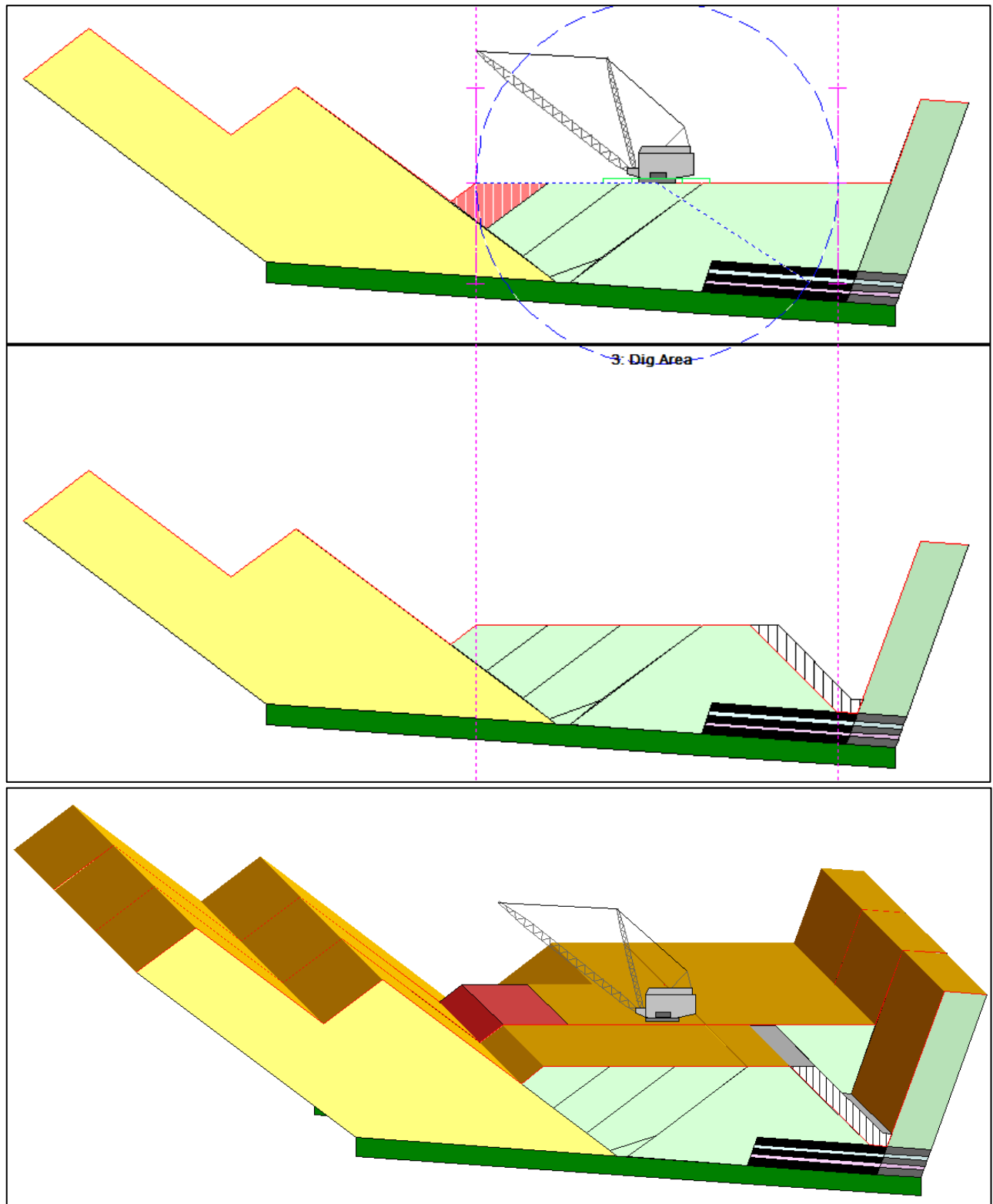
The initial dragline pad is prepared on front of the dragline by either the dragline in overhand mode, or by dozers.



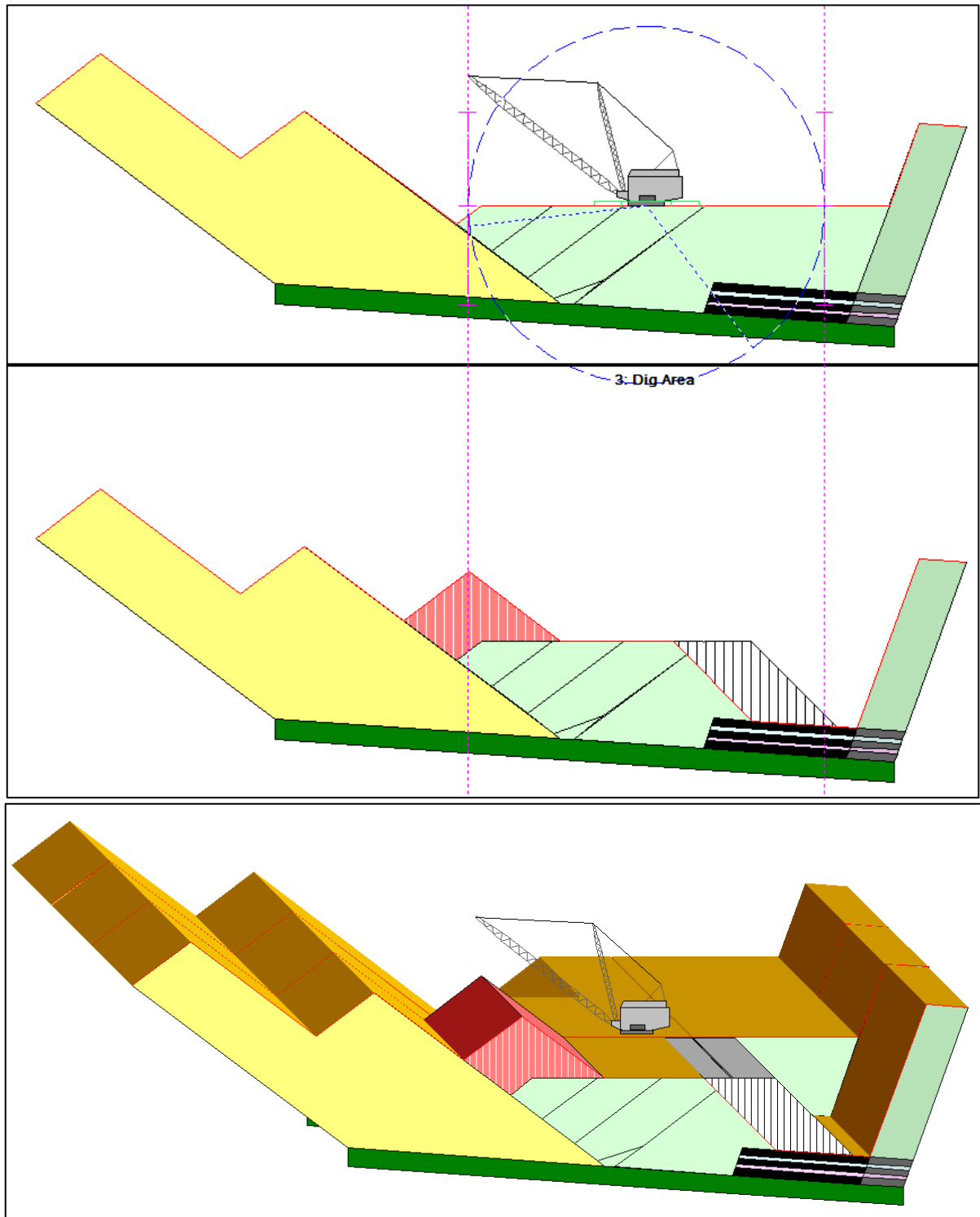
The dragline excavates the key pass by excavating the highwall key using an offline chop method. The material is used to widen the initial extended bench.



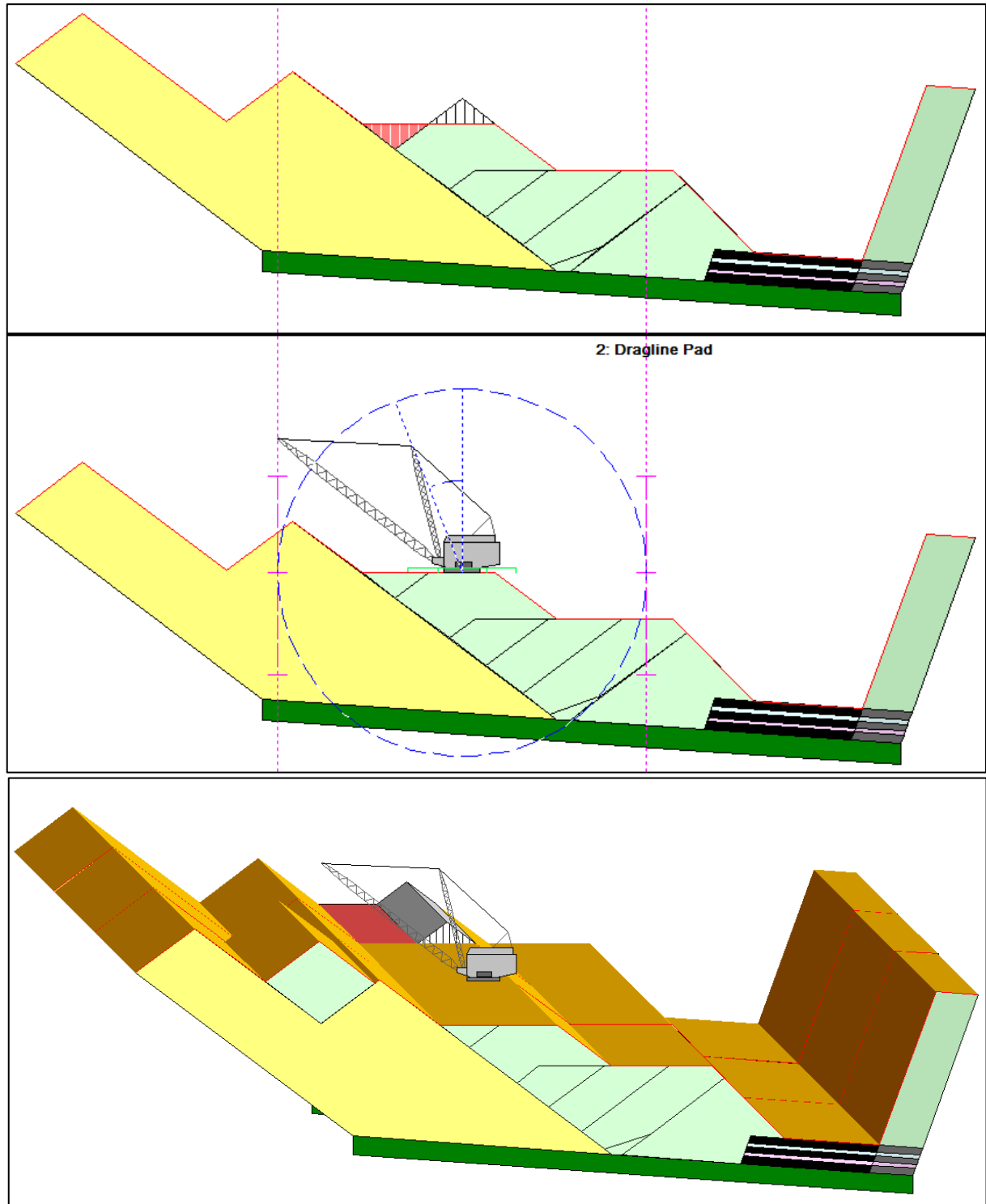
The key cut is successively widened until the extended bench is of adequate length. Excess material from the key area can be allowed to build up at the end of the bench if limited reach becomes an issue.



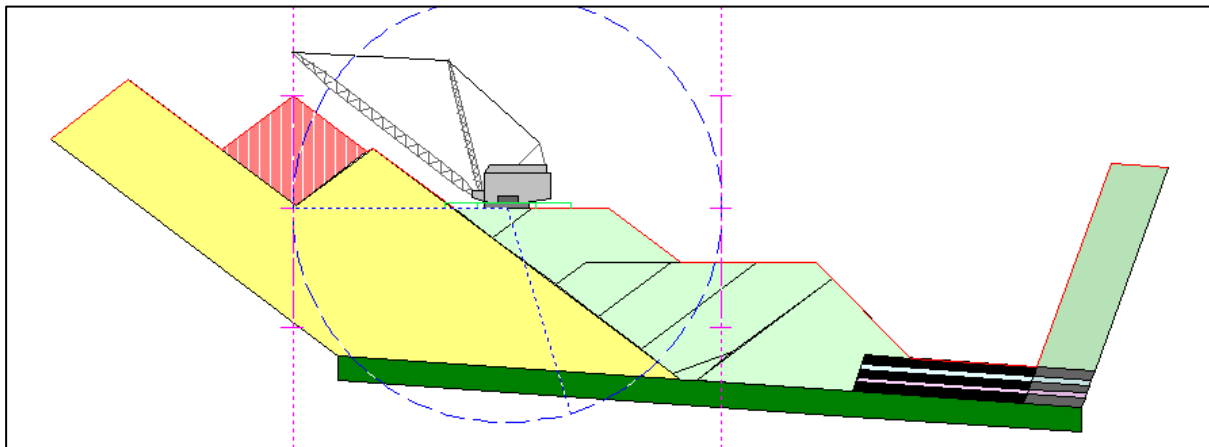
The cut is successively widened and the material is used to build the intermediate spoil pile to the correct height.



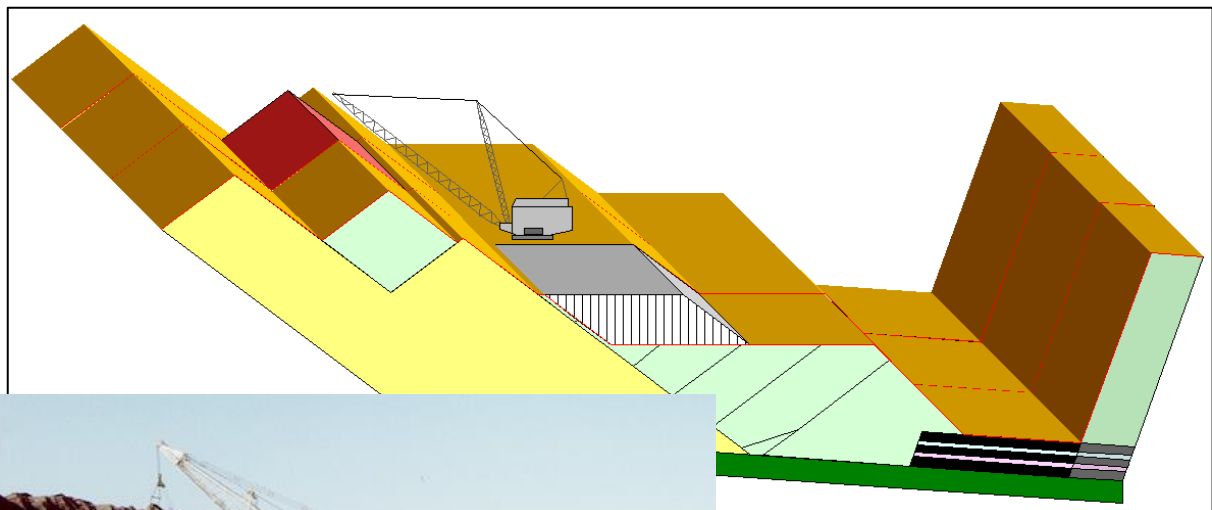
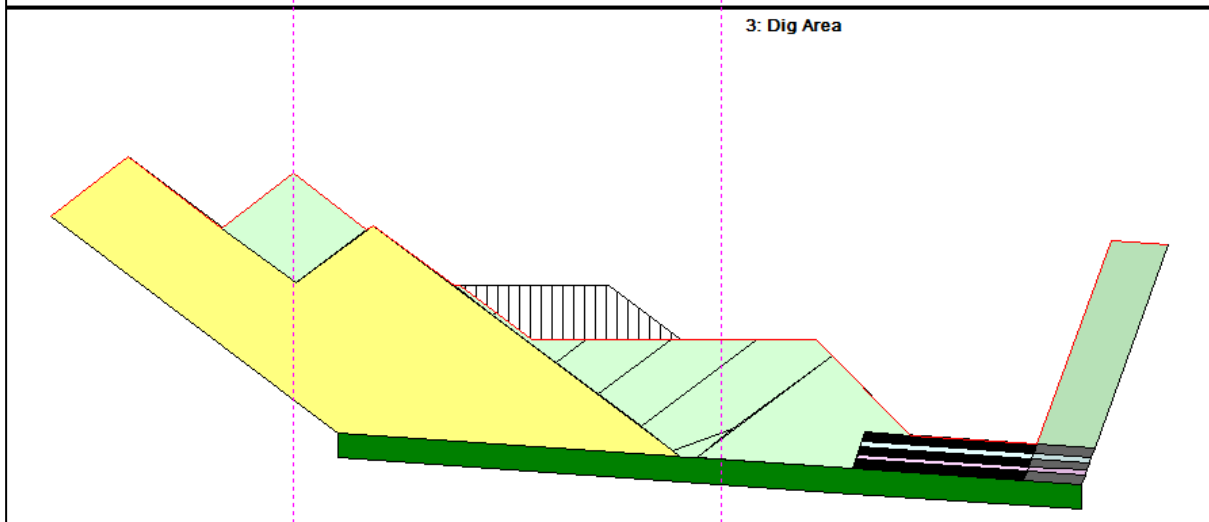
Now on the high pass, the dragline relocates to the high bench and levels the pullback pad. The simulations allow for the dragline to do this, but it is preferable if this is previously carried out by dozers, particularly to avoid cable handling issues.



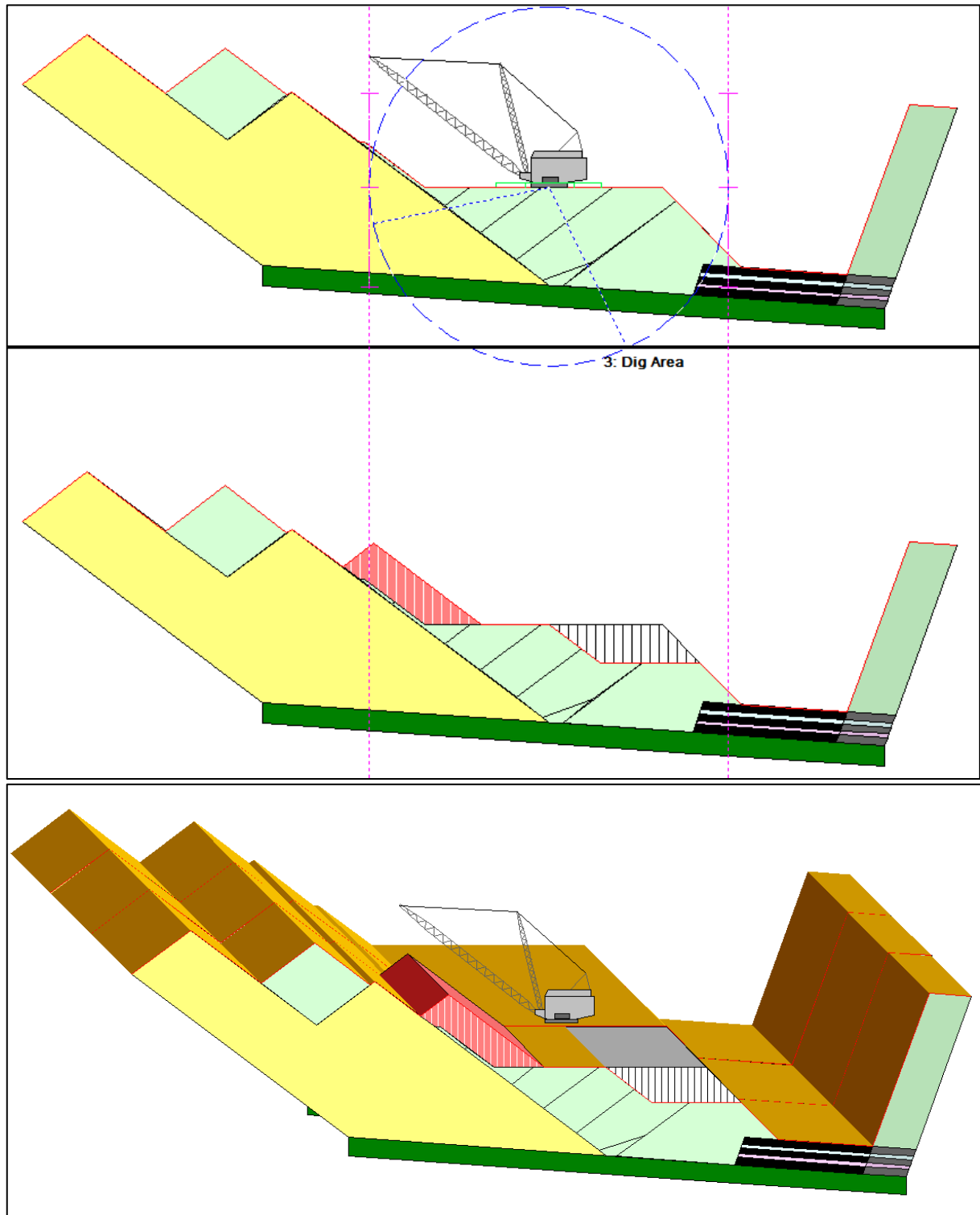
The dragline excavates the pullback material higher and back into the previous spoilpile. The lower bench is re-established ready for the final spoil pass.



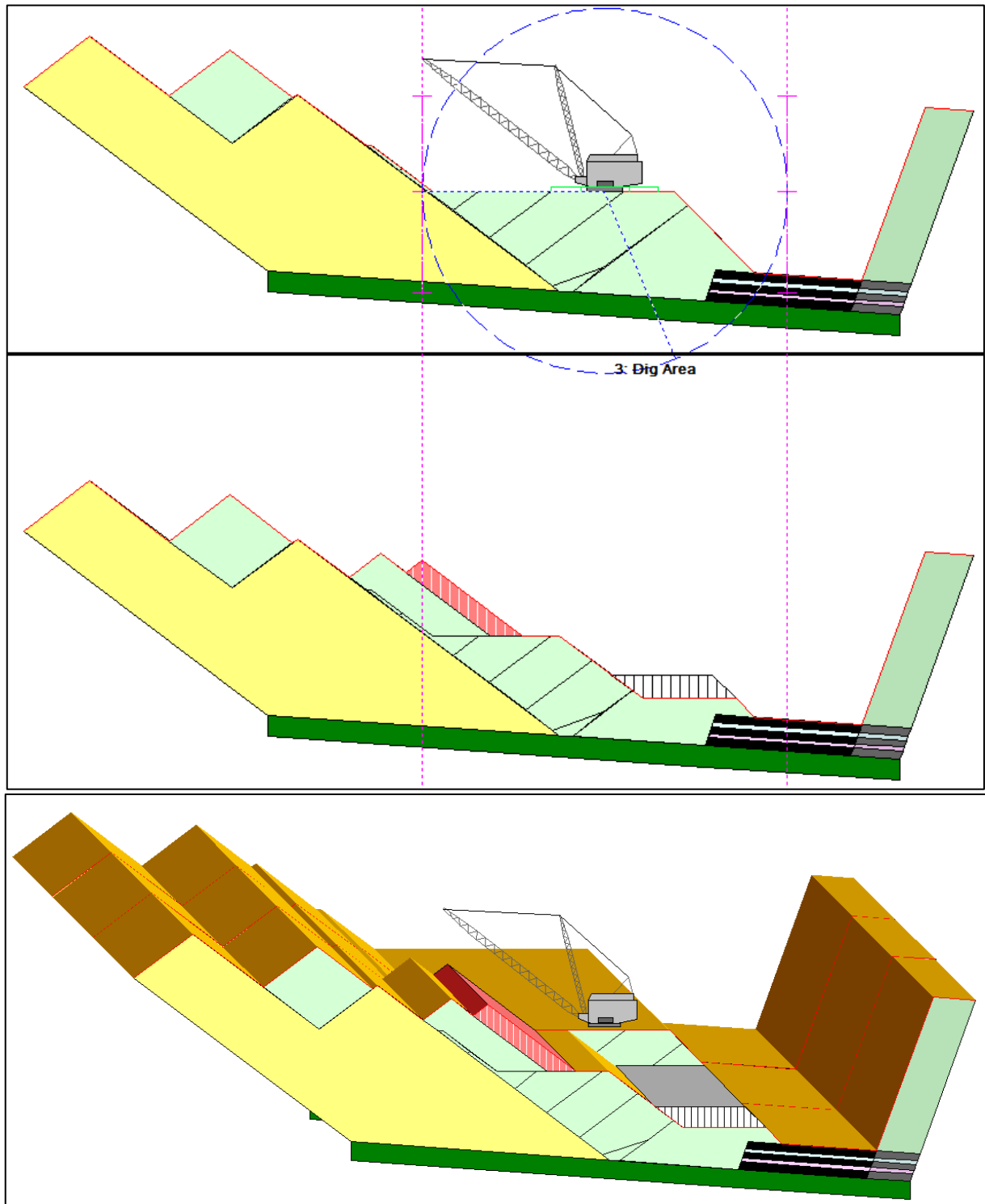
3: Dig Area



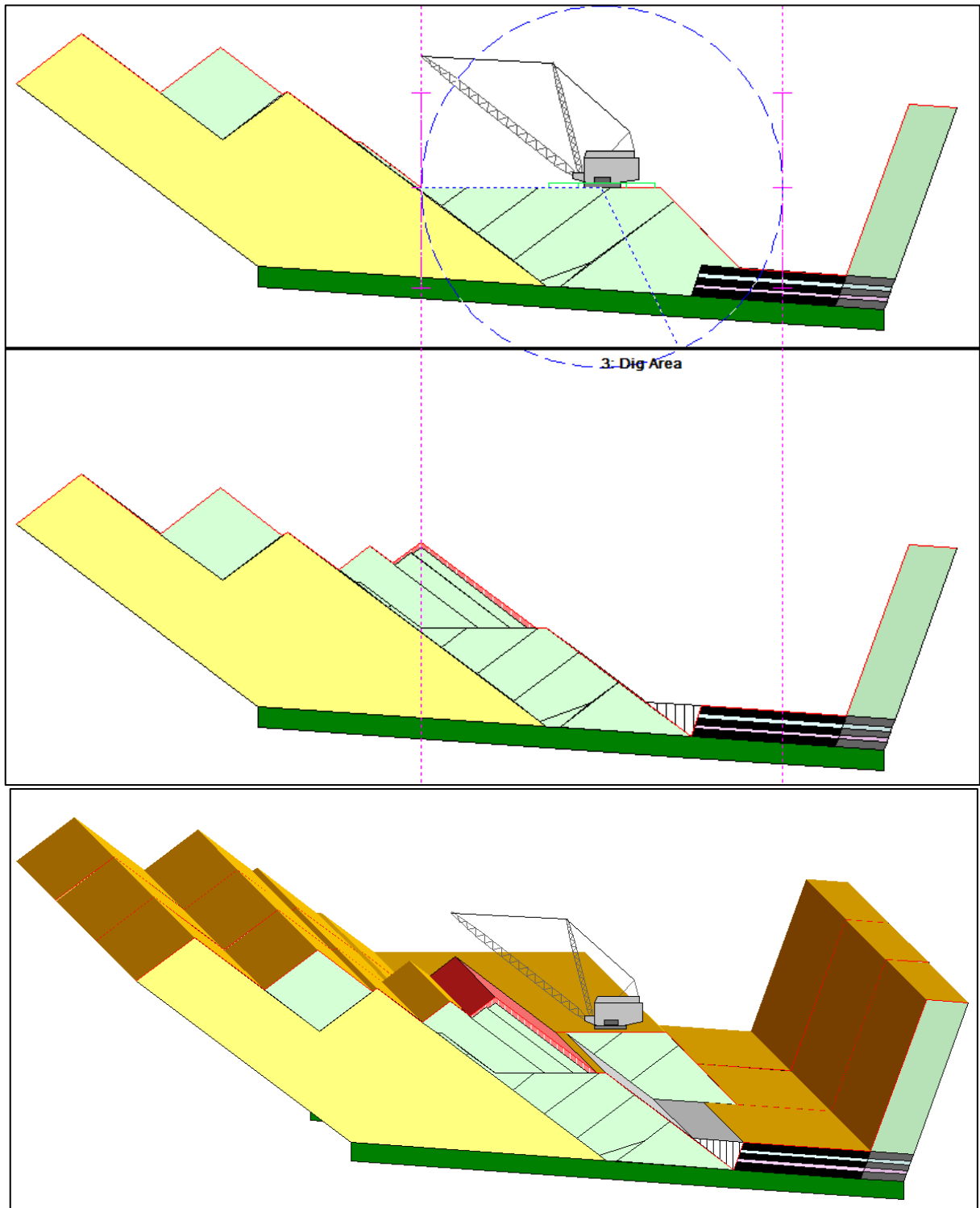
The dragline returns to the lower bench level, and commences removing the top of the remaining block. The material is dumped to the back of the final lower spoilpile.



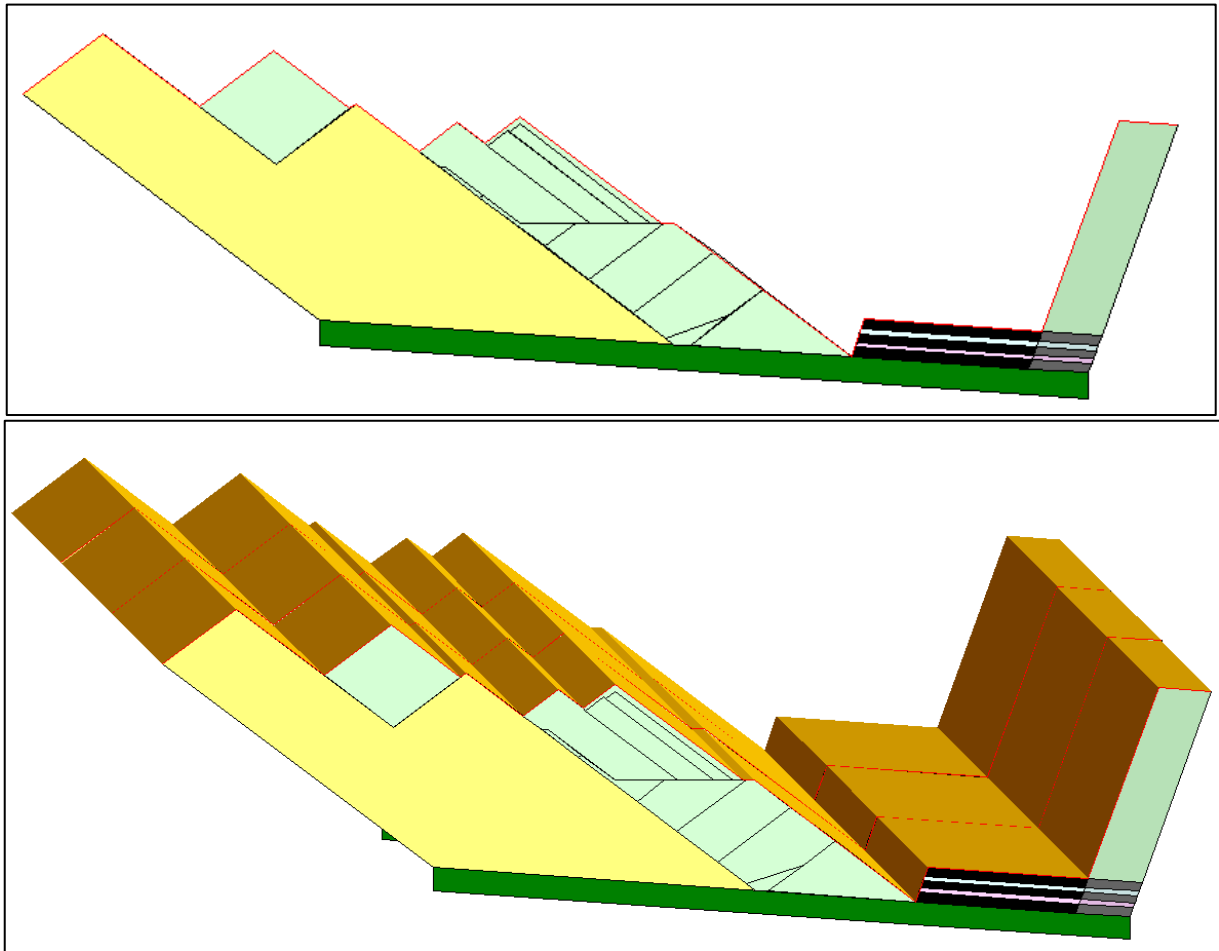
The remainder of the final block is successively removed, and used to build the final spoilpile.



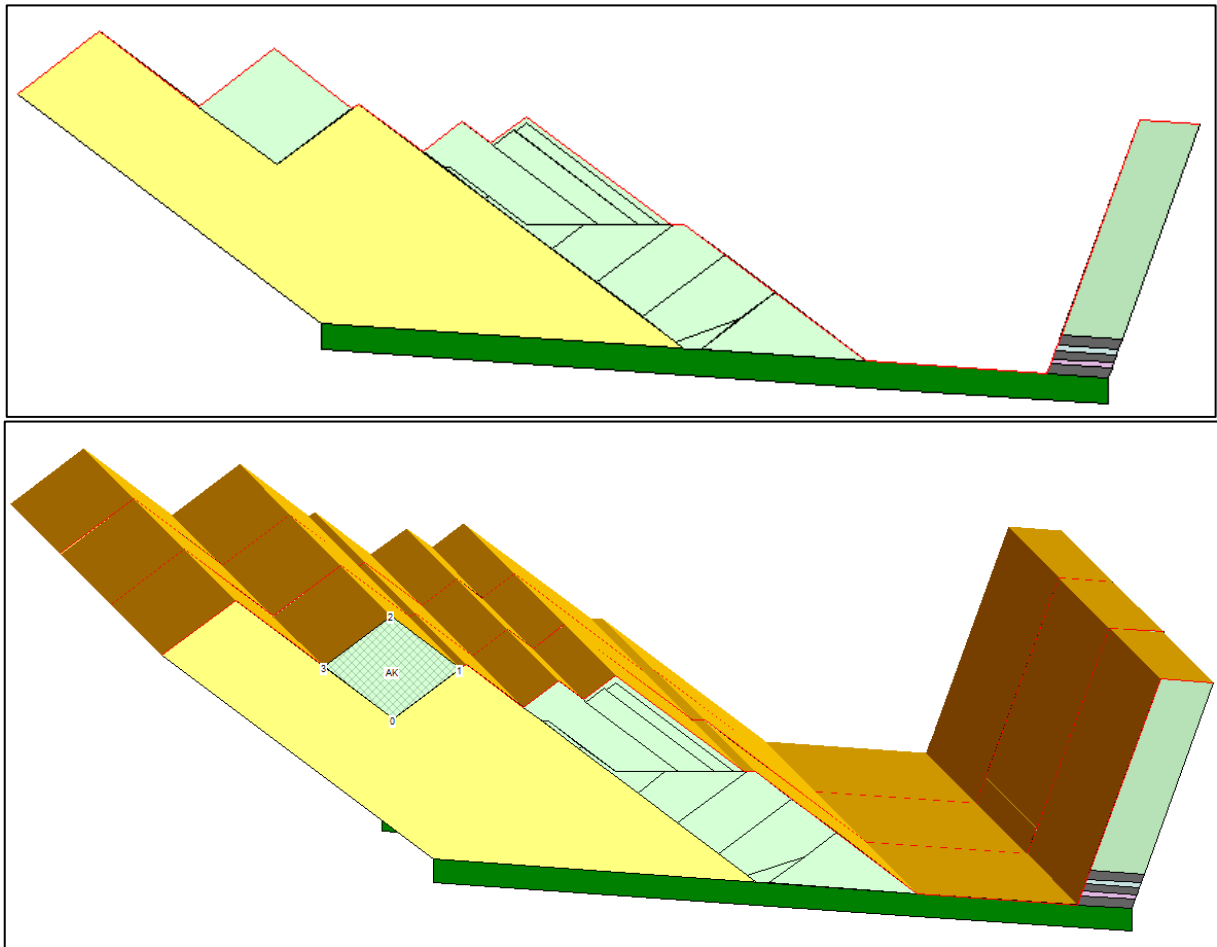
The coal edge and lowwall is cleaned up.



The coal is fully exposed by the end of the final pass.



The completed pit after coal mining is shown in the sections below. The completed spoilpile consists of a high pullback spoilpile, and a lower main spoilpile.

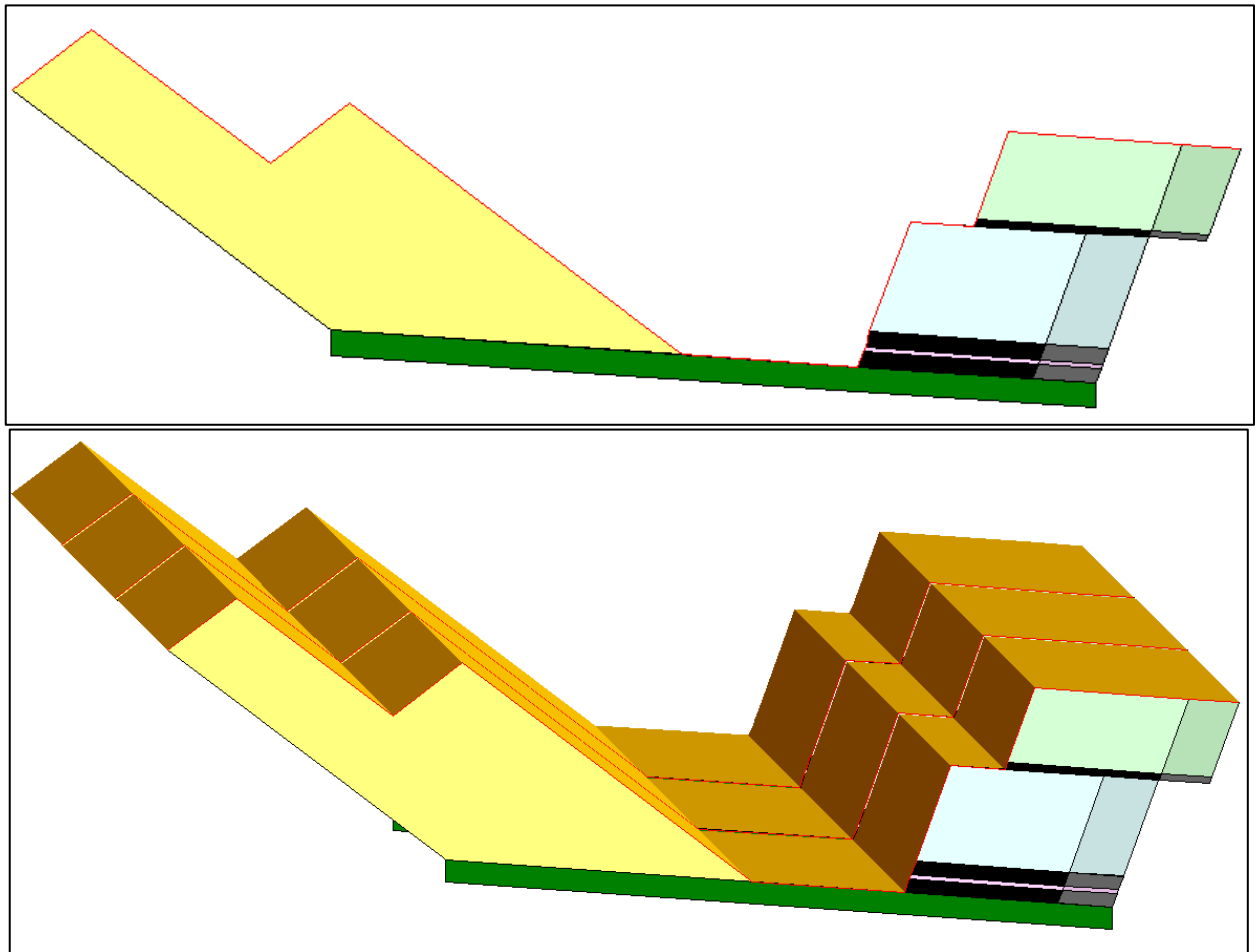




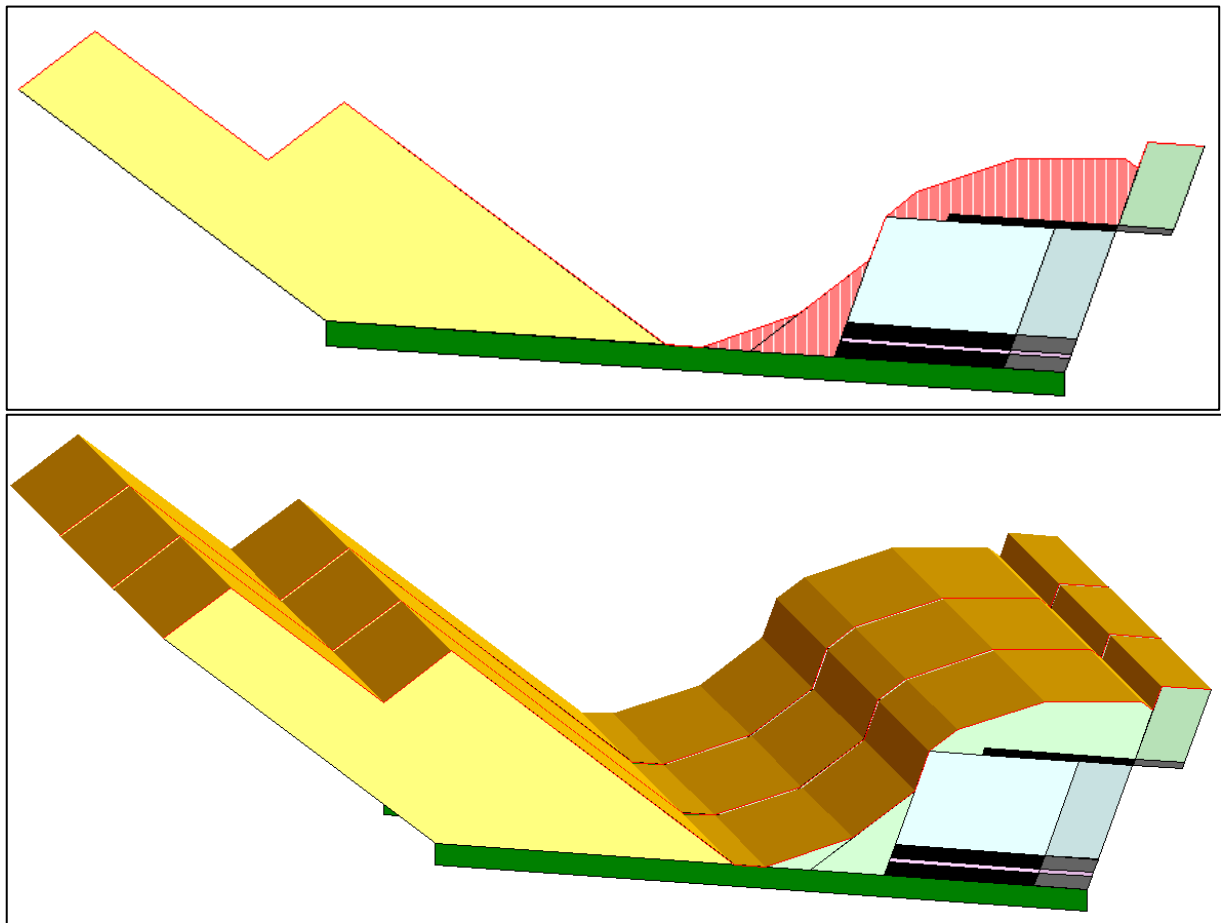
TWO SEAM ZONES, DEIB PULLBACK METHOD

The following series of cross sections show the Double Elevated Inpit Bench (DEIB) pullback dragline method simulated for a two coal seam zone area (stacked). The method involves the dragline working on two lowwall bench pads (one high and one low) in order for the dragline to stack the spoil higher, with an extra sidecast pass to expose the upper seam zone.

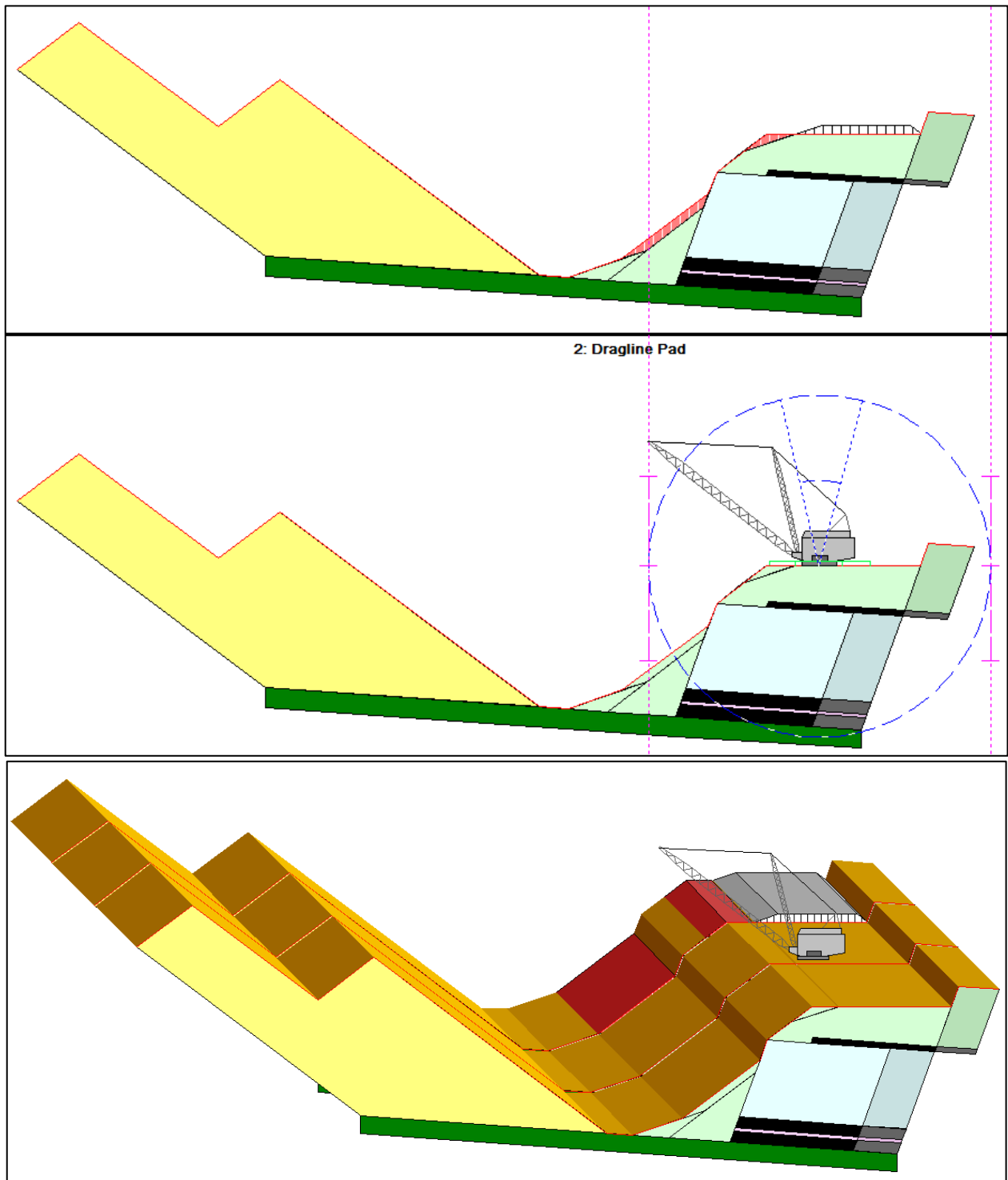
The following series of cross sections describes the method. The cross sections below show the unblasted pit.



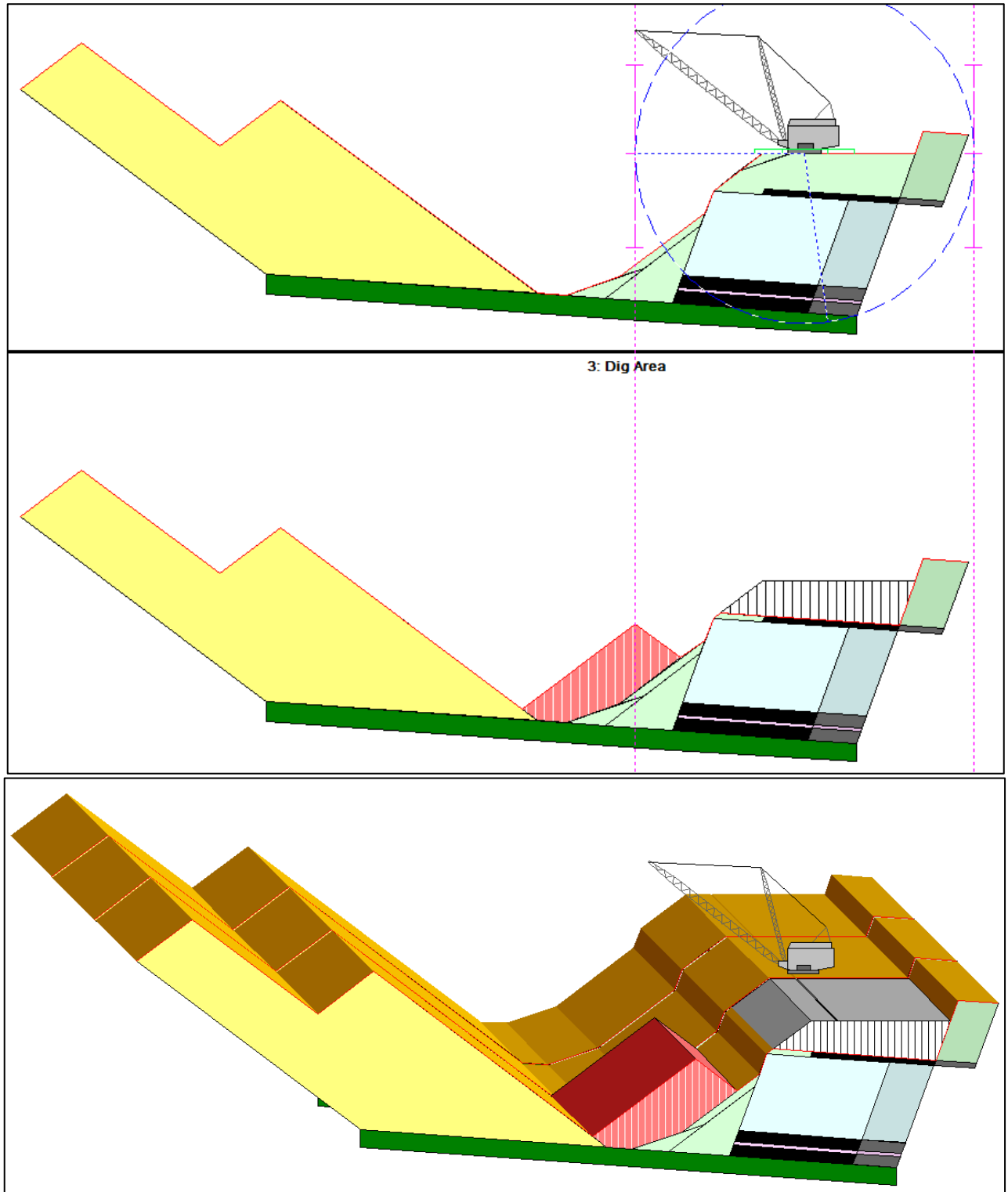
The overburden is blasted. A relatively conventional production blast has been assumed.



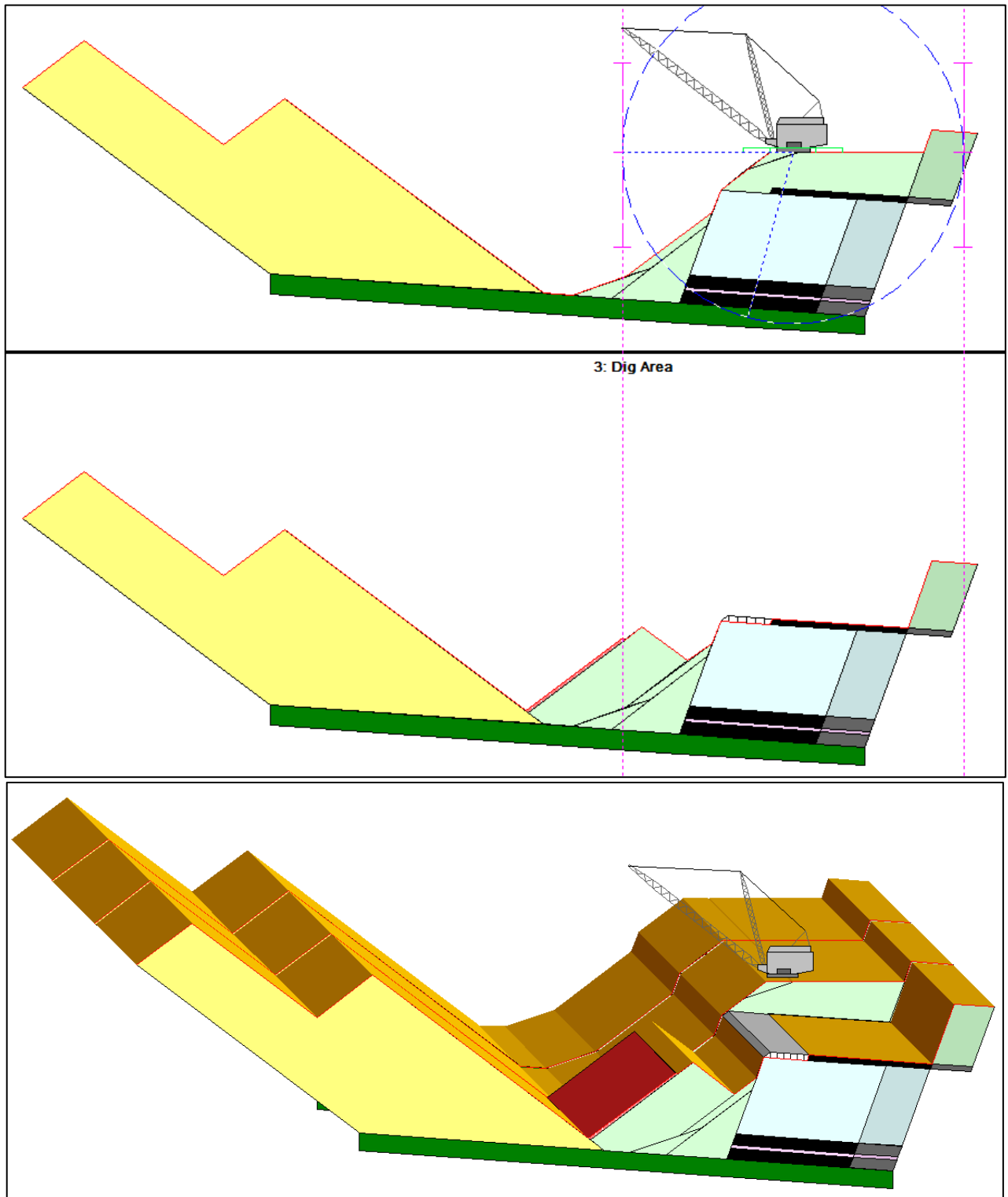
The initial dragline pad is prepared on front of the dragline by either the dragline in overhand mode, or by dozers.



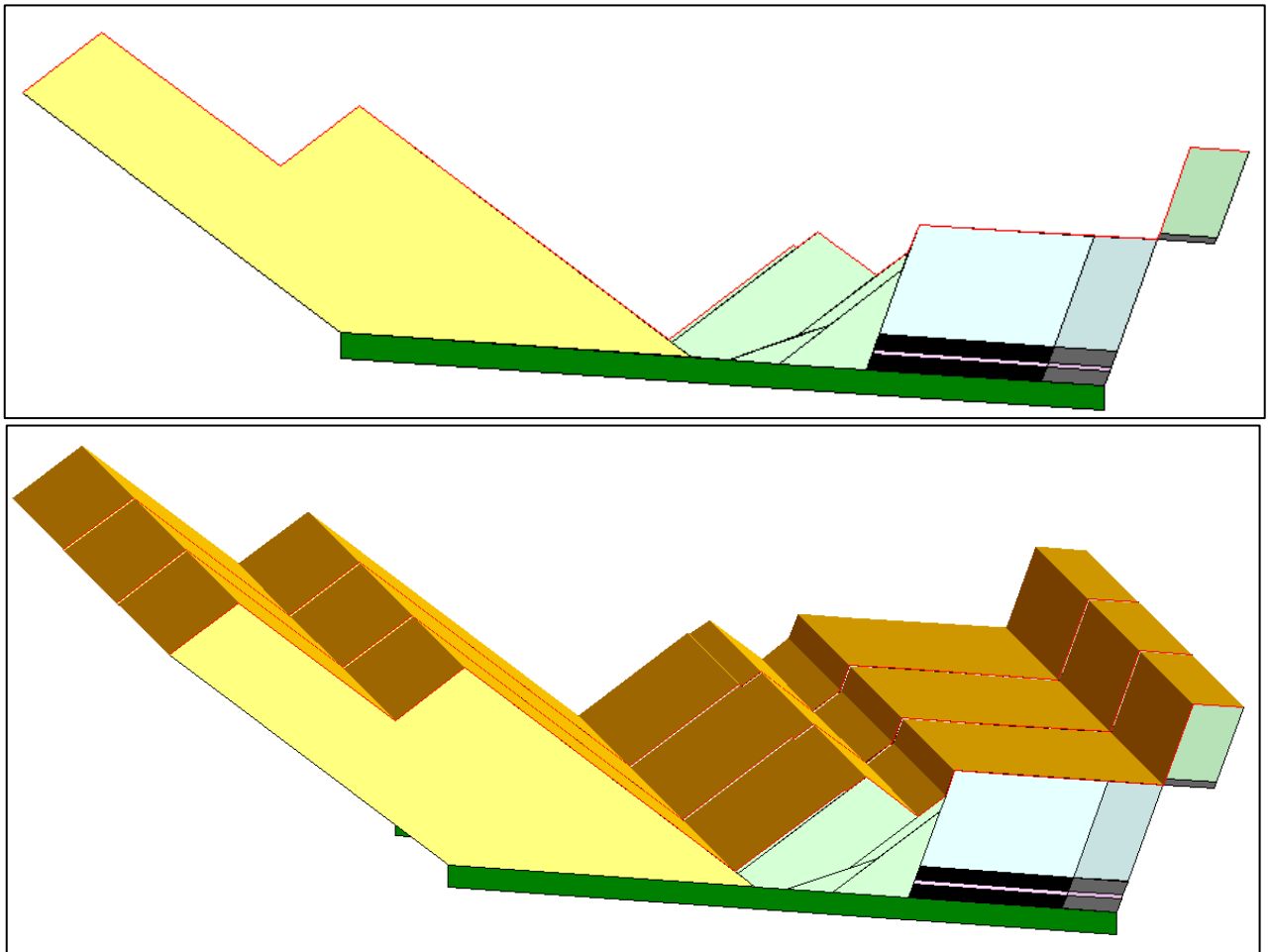
The dragline exposes the upper seam zone by offline key and simple sidecast. The material should be cast as far out into the pit as possible to allow minimal buffering of the lower interburden blast.



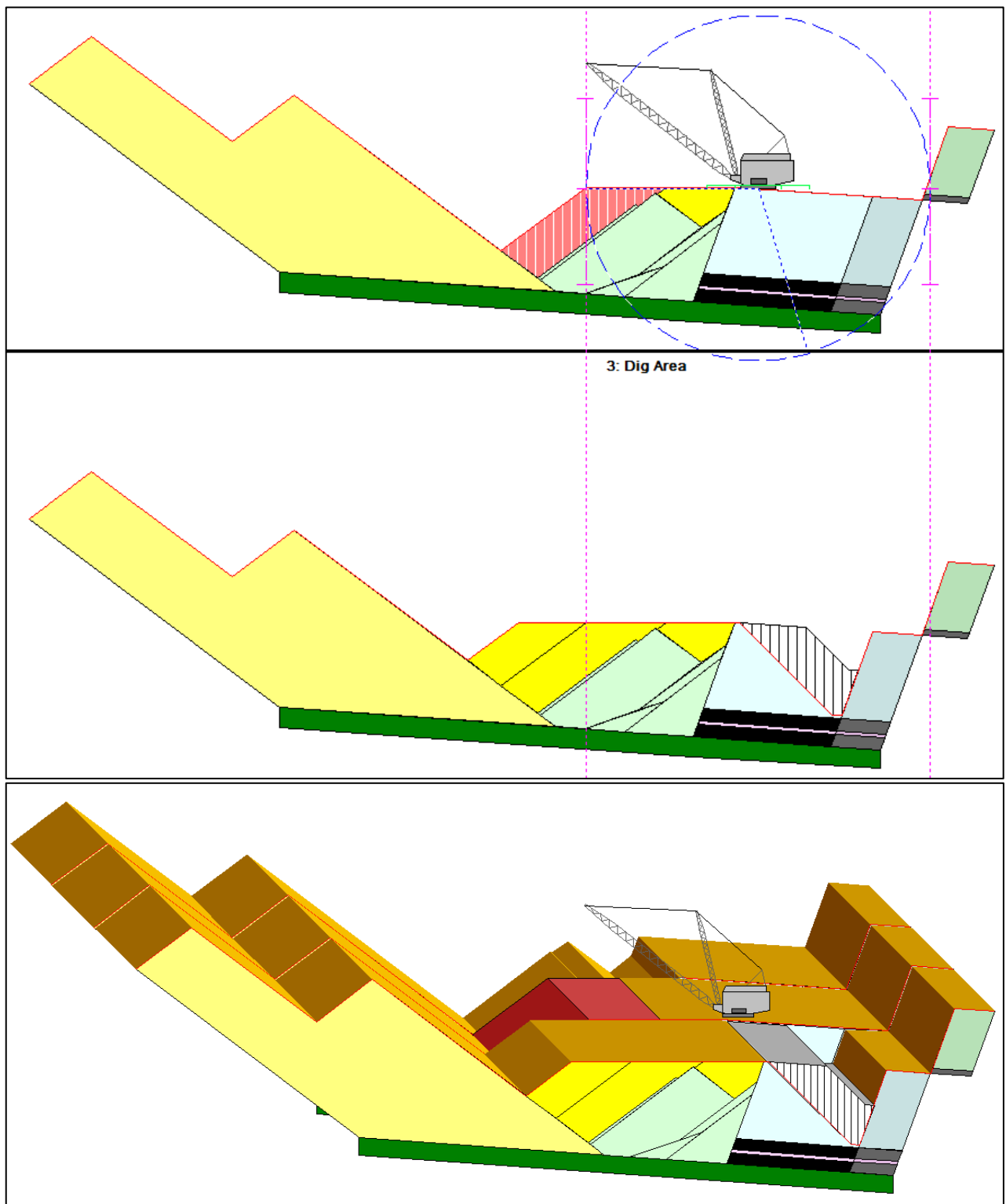
The bench edge is also cleaned up to allow for later drilling of the lower interburden.



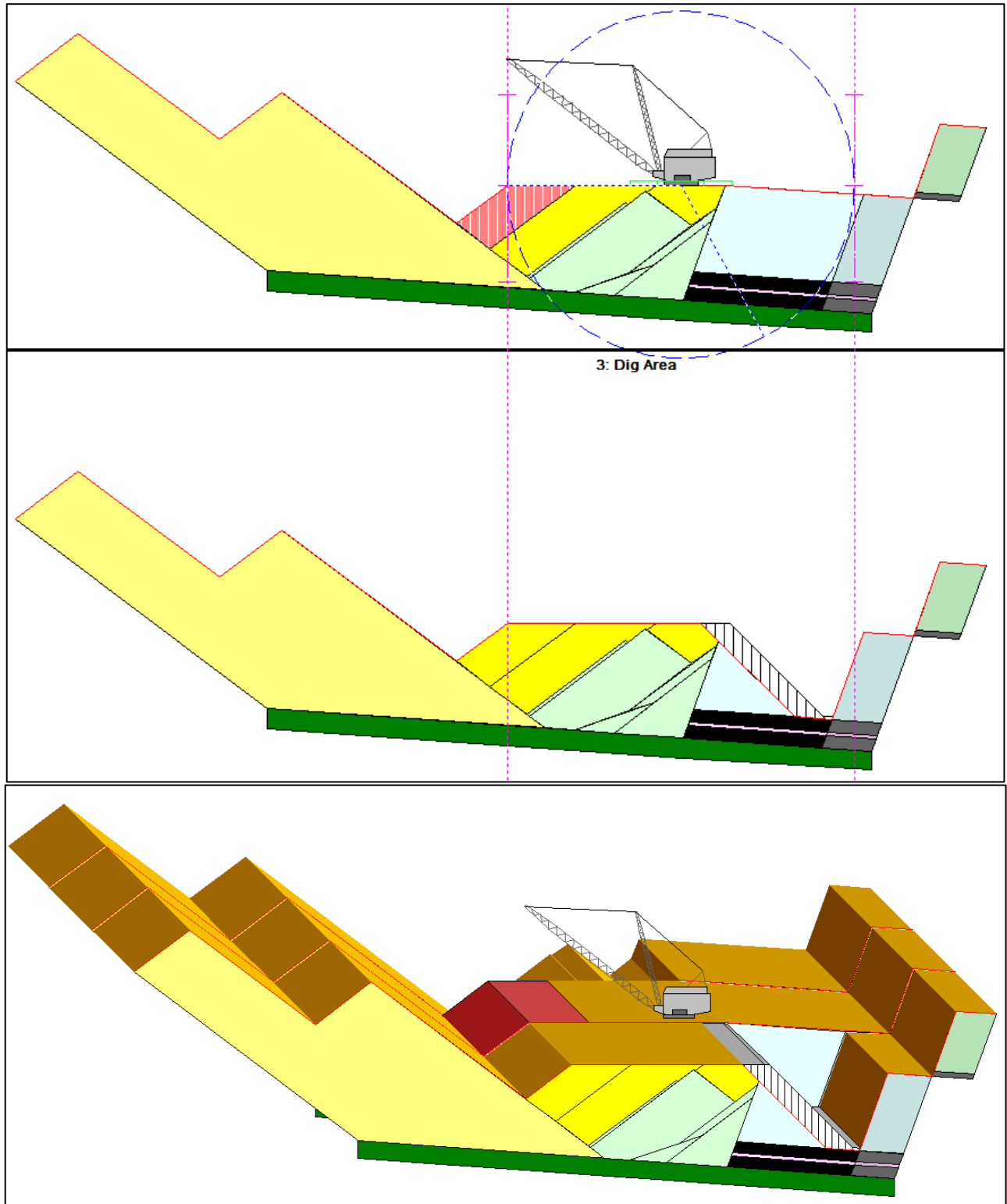
The sections below show the pit after the upper coal zone has been mined out. The interburden can then be buffer-blasted.



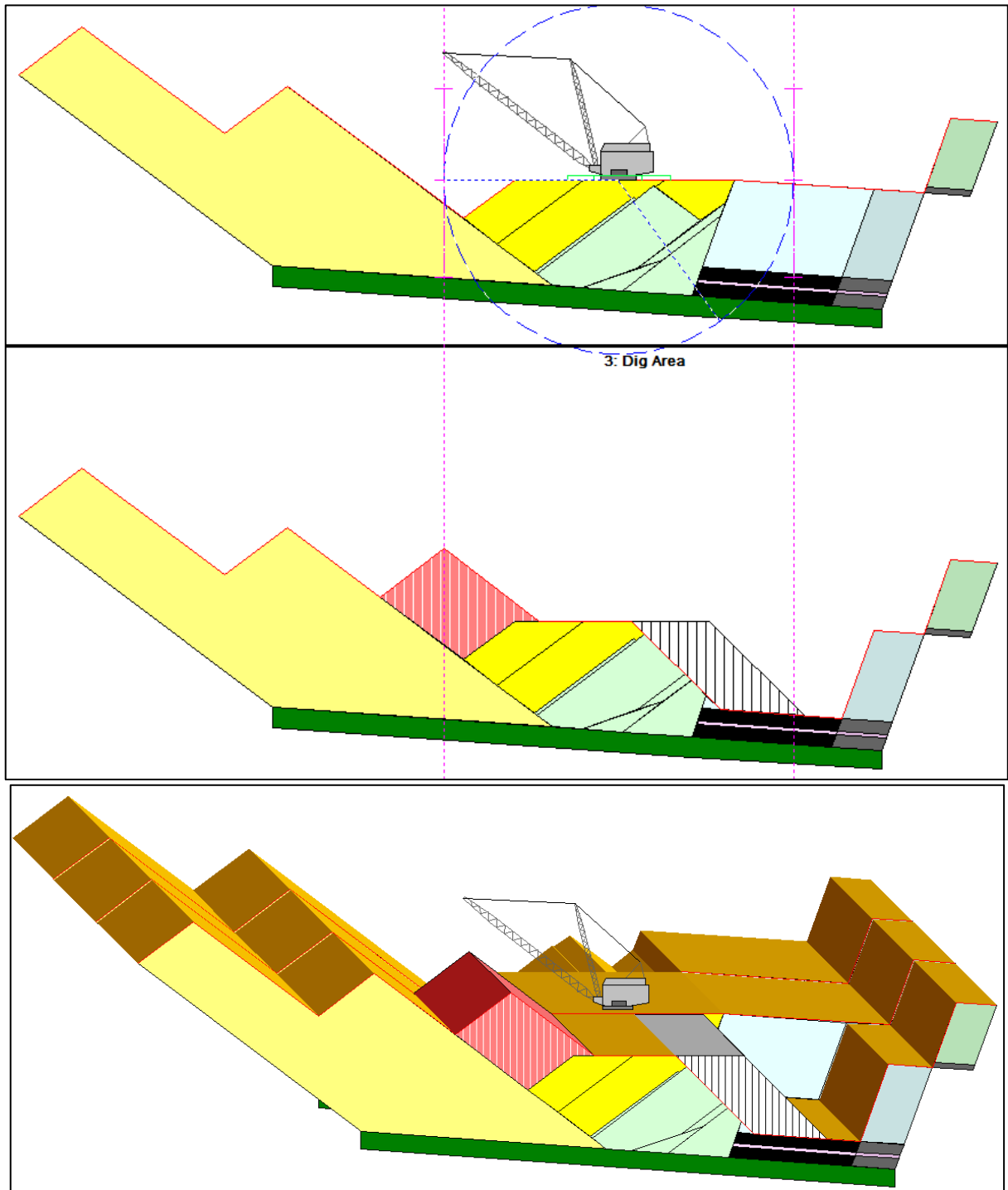
The dragline begins excavation of the lower interburden by first excavating the highwall key using an offline chop method. The material is used to widen the initial extended bench.



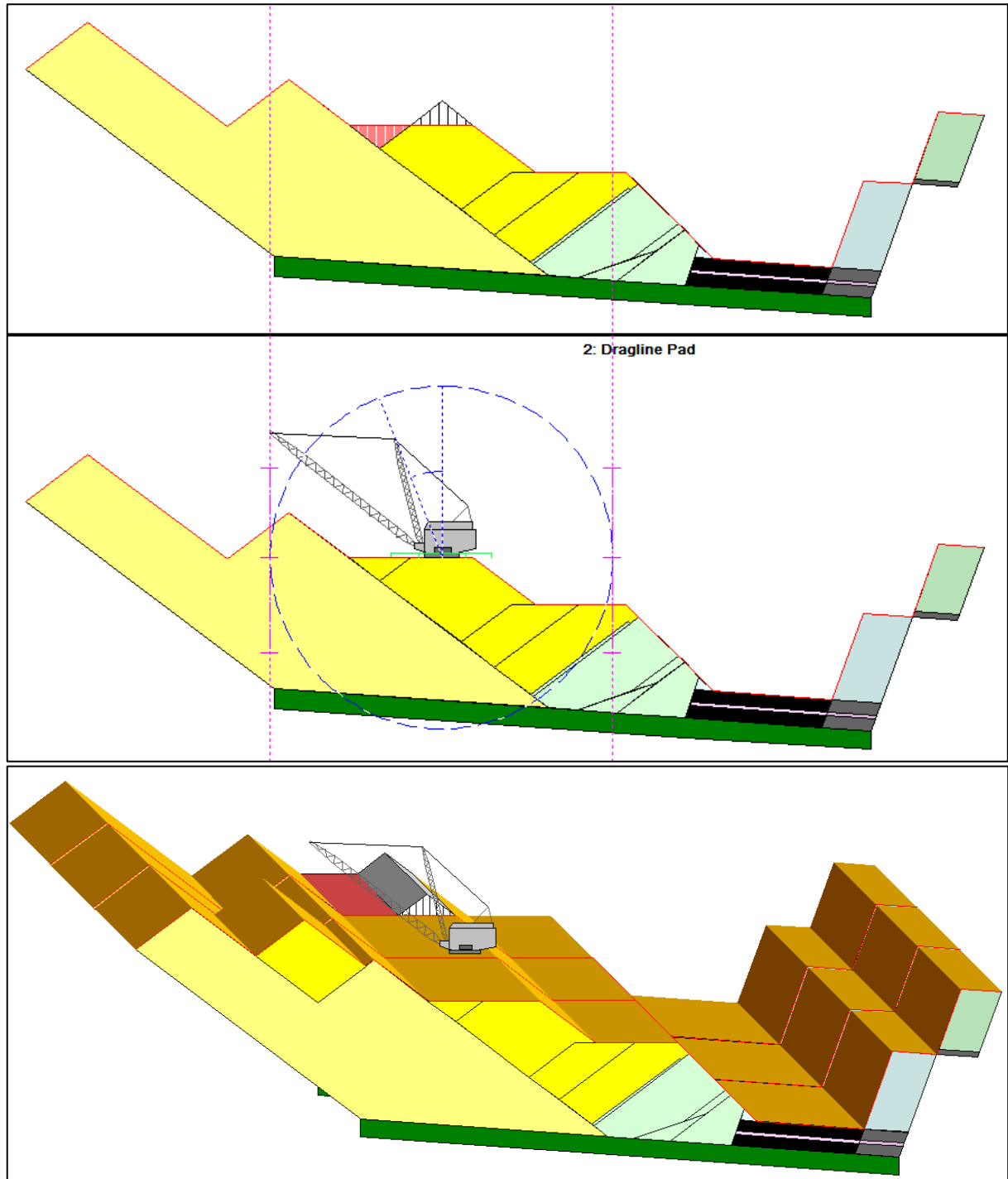
The key cut is successively widened until the extended bench is of adequate length. Excess material from the key area can be allowed to build up at the end of the bench if limited reach is an issue.



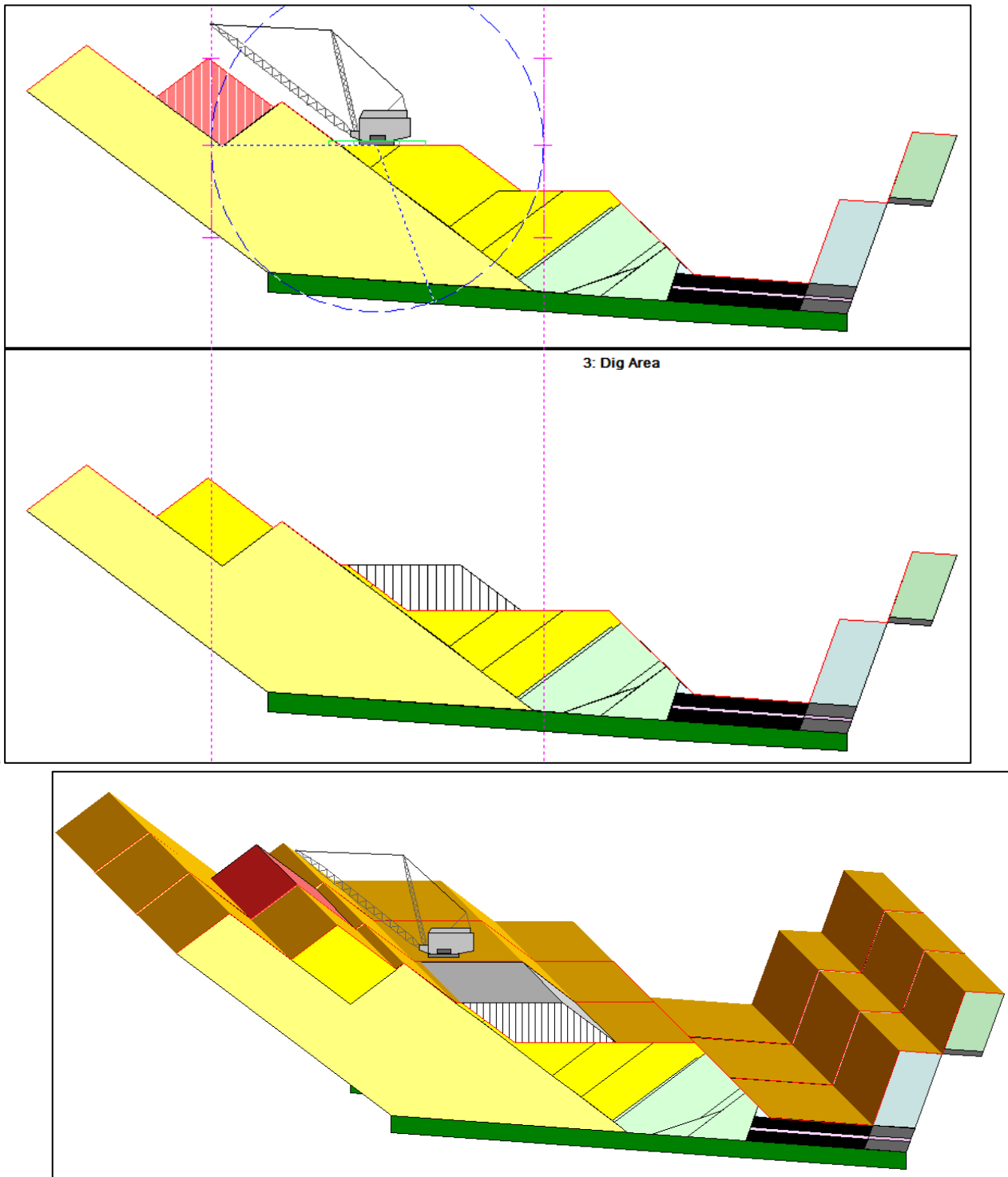
The cut is successively widened and the material is used to build the intermediate spoil pile to the correct height.



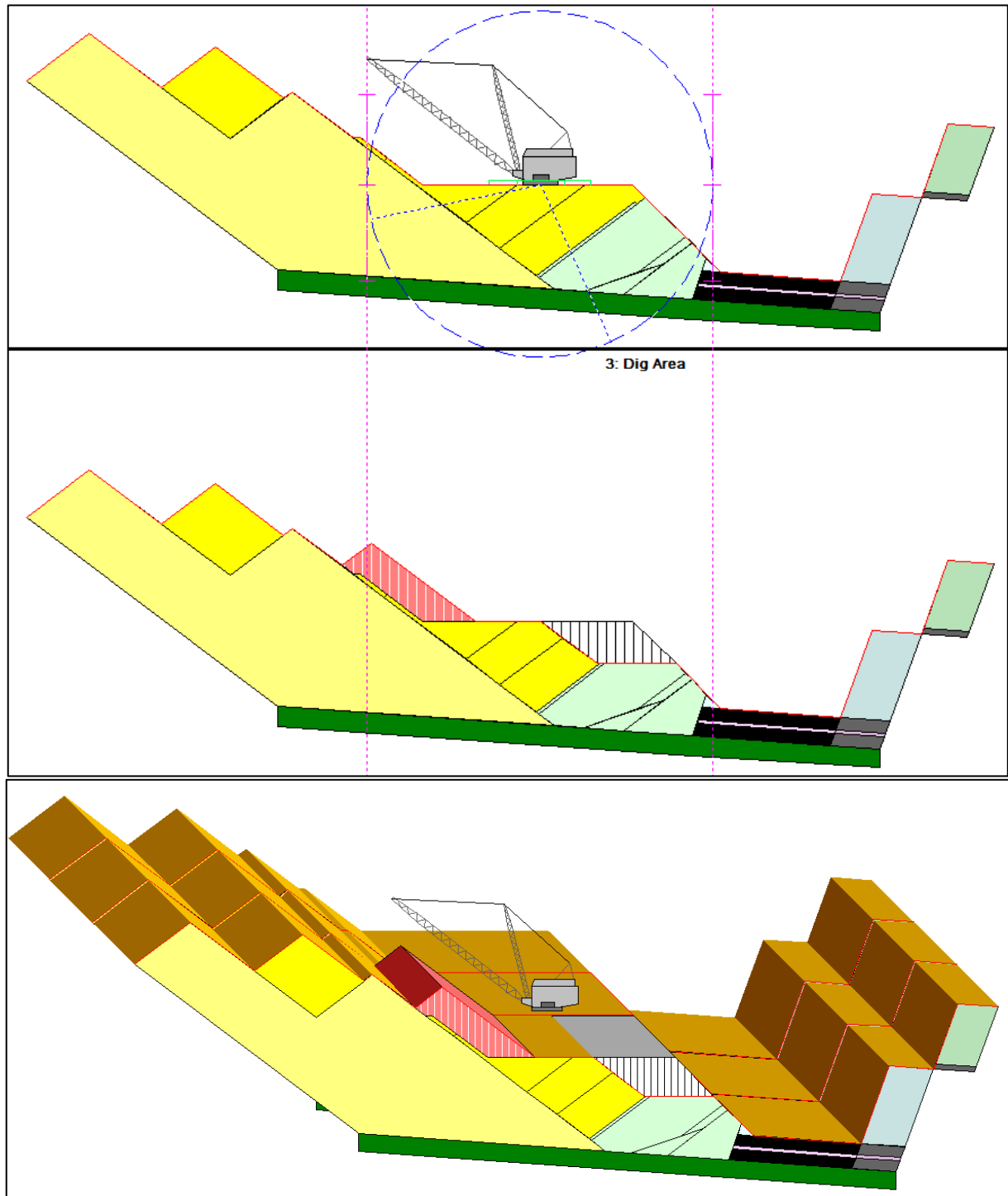
Now on the high pass, the dragline relocates to the high bench and levels the pullback pad. The simulations allow for the dragline to do this, but it is preferable if this is previously carried out by dozers.



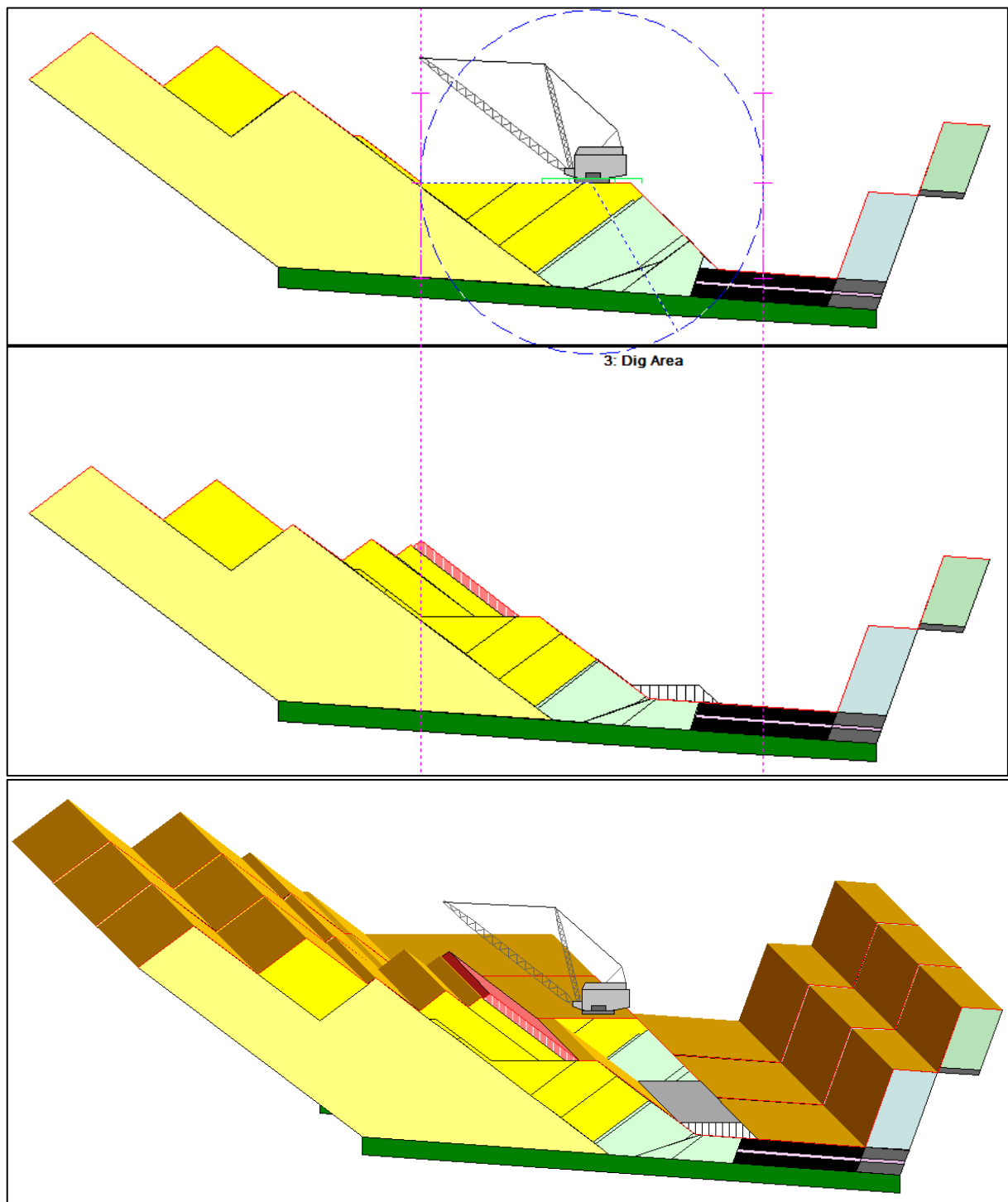
The dragline excavates the pullback material higher and back into the previous spoilpile. The low bench is re-established ready for the final spoil pass.



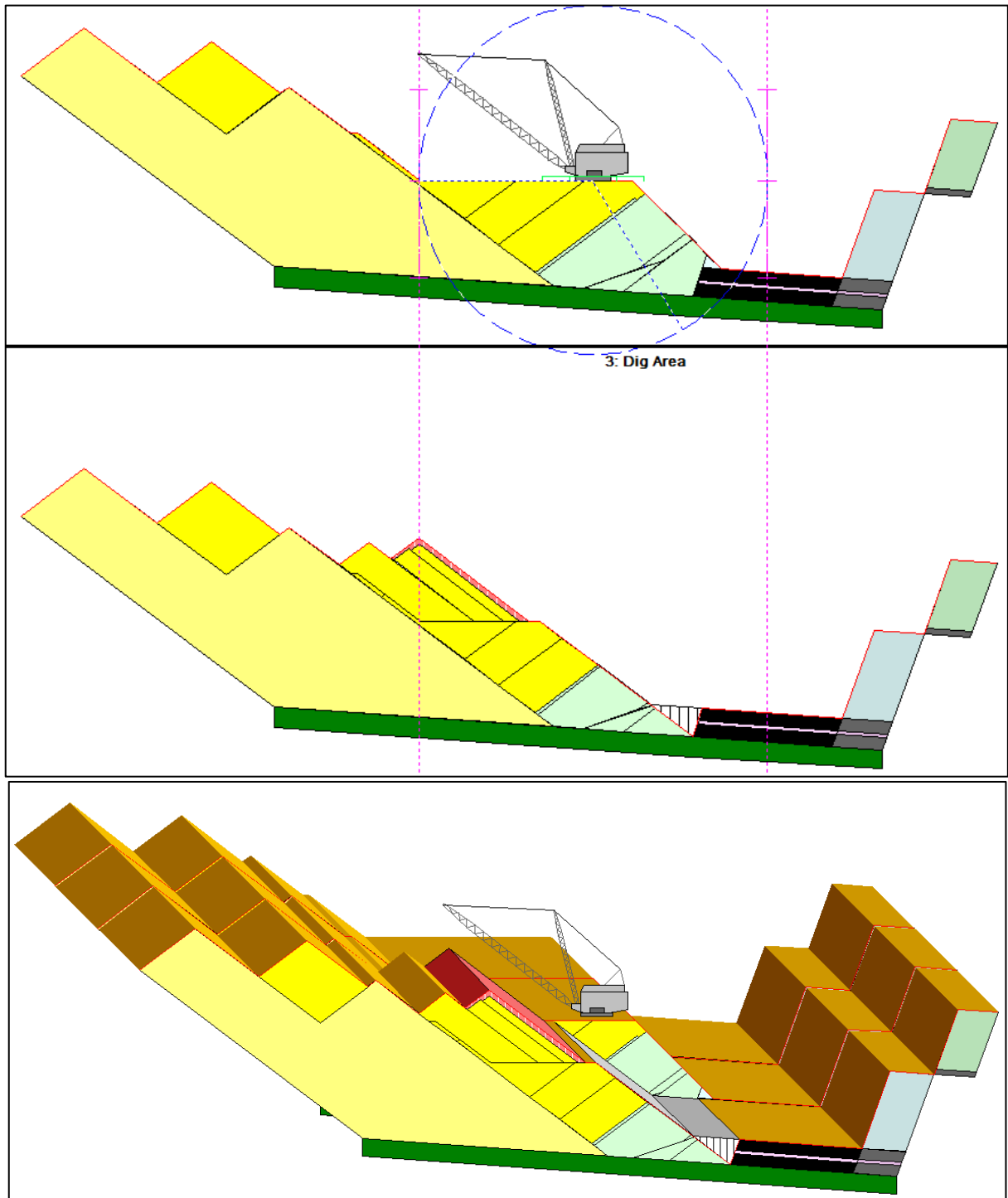
The dragline returns to the lower bench level, and commences removing the top of the remaining block. The material is dumped to the back of the final lower spoilpile.



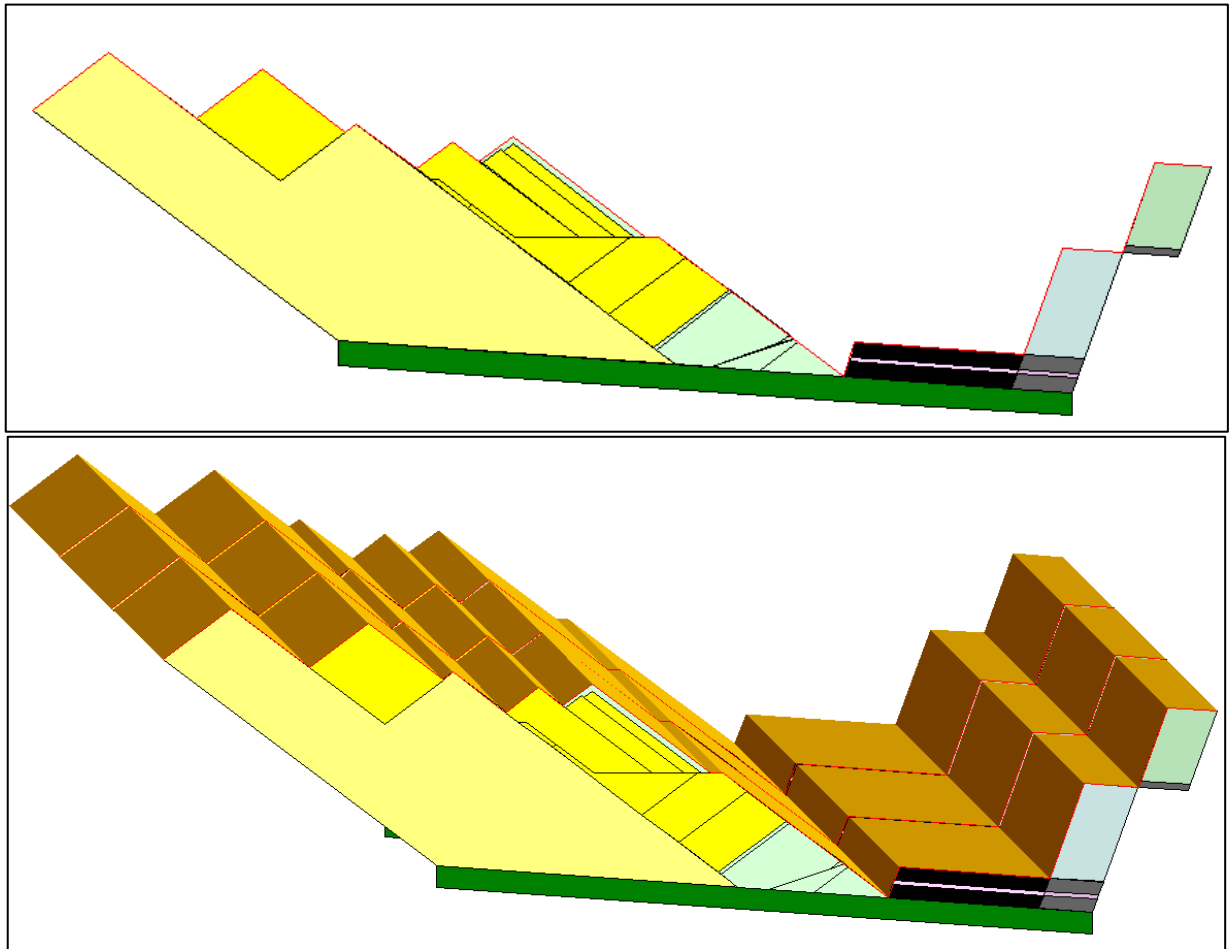
The remainder of the final block is successively removed, and used to build the final spoilpile.



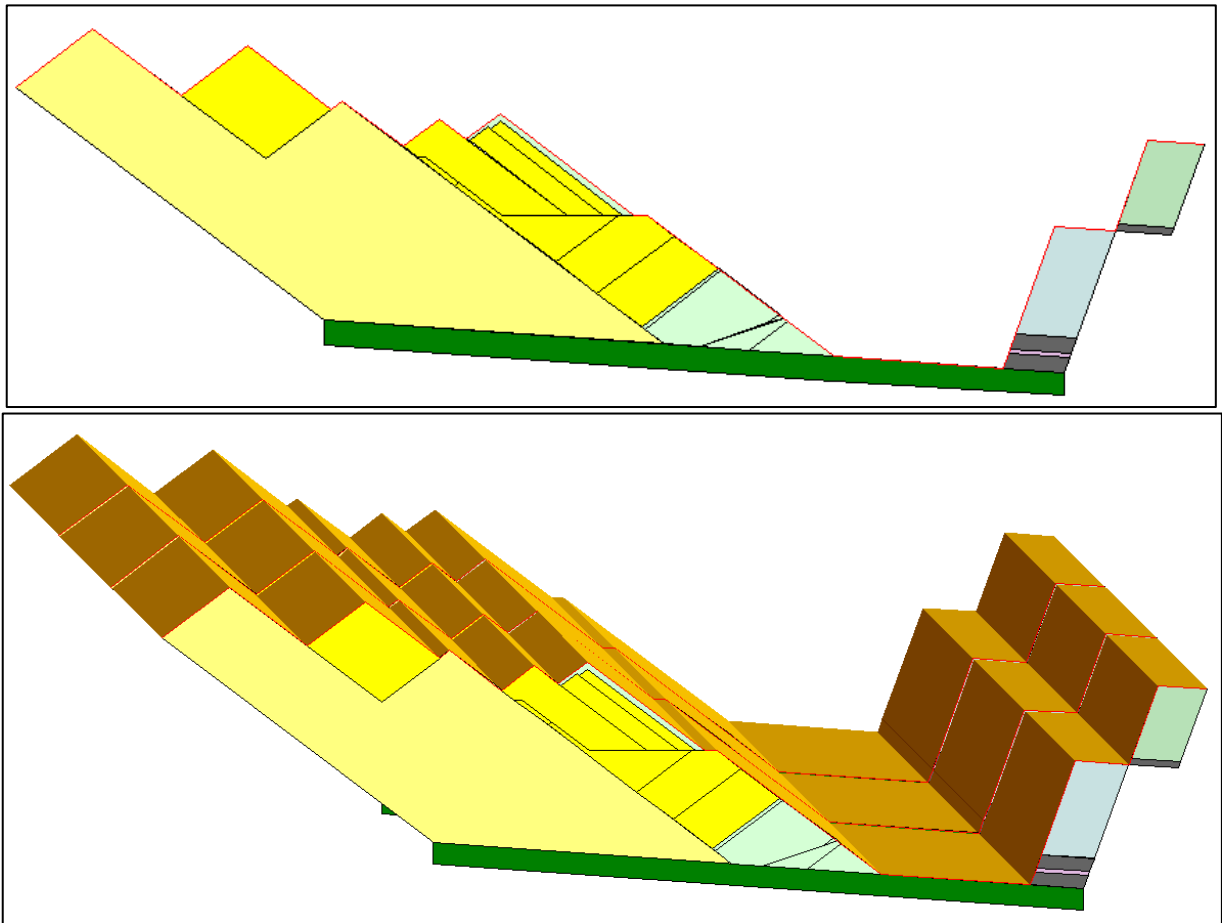
The coal edge and lowwall is cleaned up.



The lower coal is fully exposed by the end of the final pass.



The completed pit after coal mining is shown in the sections below. The completed spoilpile consists of a high pullback spoilpile, and a lower main spoilpile.



Appendix B. SCHEDULE STAGE PLANS

6Mtpa EEE Case

Figure 5.13 – 6Mtpa EEE Case - Start Jul 2017



Figure 5.14 - 6Mtpa EEE Case – FY18



Figure 5.15 - 6Mtpa EEE Case – FY19



Figure 5.16 - 6Mtpa EEE Case - FY20



Figure 5.17 - 6Mtpa EEE Case – FY22



Figure 5.18 - 6Mtpa EEE Case – FY24



Figure 5.19 - 6Mtpa EEE Case – FY27



Figure 5.20 - 6Mtpa EEE Case – FY29



Figure 5.21 - 6Mtpa EEE Case – FY32



Figure 5.22 - 6Mtpa EEE Case – FY37



Appendix C. MEANDU OVERBURDEN UNITS MEMO



JB Mining Services Pty Ltd

ABN 99 050 708 596

Geological and Mining Services for the Resources Industries

Phone 07 3229 5611

email greg.jones@jbms.com.au

MEANDU OVERBURDEN UNITS

SUMMARY RECOMMENDATIONS

The current OB model being used by Xenith (mea_1611) provides a basic framework to assign NAF/PAF categorisation for the four future mining areas with the following modifications:

K4S and K4E	TE plus UT as NAF rehabilitation resource Top 20m of CG as NAF secondary rehabilitation reserve SH as NAF primary rehabilitation reserve
K2E	TE plus top 10m UT as PAF Lower UT as NAF rehabilitation resource CG as NAF rehabilitation reserve
Central and Ramp 5	exclude all primary overburden from NAF rehabilitation resource at this stage. Central and Ramp 5 previously mined spoil is tested on site using field pH and EC as a preliminary screening tool; the chips samples from Central and Ramp 5 would need to be submitted for TS and ANC if a NAF classification is going to be applied to the samples.

Xenith will split the top 20m of the CG unit for use in K4S and K4E, and the top 10m of the UT unit in K2E using the GDCALC function of Vulcan.

BACKGROUND

The current geological model as used by Xenith (mea_1611) contains the following geological units which include the three OB units above the Ace seam.

Age	Code	Description
Tertiary	SO	Soil - 0.5m
	TE	undifferentiated Tertiary
	BA	fresh Basalt
Triassic	UT	Upper Triassic
	CG	Conglomerate
	SH	Shale
	ACE	coal

The current discussion is based on the results from five openholes holes drilled and analysed in 2015 as part of the EGi programme as shown in the following figure. These holes were drilled downdip of the K2E, K4E and K4S pits.

Analysis data from the three fully cored holes in the K2E area is yet to be completed.

BRISBANE OFFICE
AUSTRALIA

Level 2, 143 Charlotte Street
BRISBANE QLD 4000

GPO Box 2560
BRISBANE QLD 4001

APPENDIX

E

Mine Material Characterisation



Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Suitably qualified person

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. This Statutory Declaration must be completed by the person who conducted the environmental evaluation and accompany the environmental report submitted to the Department of Environment and Heritage Protection (the department).

Oaths Act 1867

**QUEENSLAND
TO WIT**

I Dr Greg Mddocks
Insert the name of the person making this declaration
of RGS Environmental Pty Ltd
Insert the street address of the person making this declaration
3 Elder Court Shailer Park

in the State of Queensland do solemnly and sincerely declare that:

- I am the suitably qualified person and author of an environmental report entitled
Meandu Mine Material Characterisation

Insert title of the environmental report

In accordance with the environmental evaluation issued by the department under the Act to:

TEC Coal Pty Ltd

21 December 2016

Insert name of recipient of the notice

Insert date of the notice

A copy of my report is attached to this statutory declaration and marked "A".

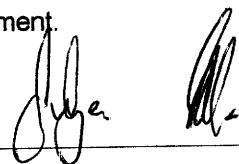
I possess the following qualifications and experience relevant to this environmental evaluation:

20 years industry and 14 years consulting experience. I have a PhD in Geochemical Engineering

I have not knowingly included any false, misleading or incomplete information in the report; and

I have not knowingly failed to reveal any relevant information or document to the department.

I certify that:



Statutory Declaration
Suitably qualified person

- The report addresses the relevant matters for the evaluation and is factually correct; and
- The opinions expressed in it are honestly and reasonably held.

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at

LOGAN CITY

Insert location

this

6TH

Insert day (e.g. 18th)

day of

SEPTEMBER

Insert month

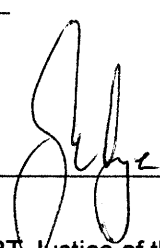
in the year

2018

Insert year


Signed

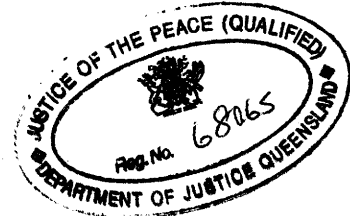
(Person making this declaration)


Signed

<INSERT Justice of the Peace / Commissioner
for Declarations / Lawyer>

Gerald Winston Dyer

Printed name and registration number (if
applicable)



EXECUTIVE SUMMARY REPORT

Mine Material Characterisation Overview

Meandu Mine

Prepared for: Stanwell Corporation



Mine Material Characterisation

Meandu Mine

Geochemical Assessment of Mine Waste, Process Waste and Rehabilitation Material

Prepared for: Stanwell Corporation Ltd.

DOCUMENT CONTROL

Report Title

Project Name	Meandu Coal Mine – Mine Material Characterisation
Job Number	2016017
Report Number	2016017_Rev3

Limitations and disclaimer:

This report documents the work undertaken by RGS Environmental Pty Ltd (RGS).

This report should be read in full. While the findings presented in this report are based on information that RGS considers reliable unless stated otherwise, the accuracy and completeness of source information cannot be guaranteed, although RGS has taken reasonable steps to verify the accuracy of such source data. RGS has made no independent verification of this information beyond the agreed scope of works and RGS assumes no responsibility for any inaccuracies or omissions outside of RGS's direct control. Furthermore, the information compiled in this report addresses the specific needs of the Client, so may not address the needs of third parties using this report for their own purposes. Thus, RGS and their employees accept no liability for any losses or damage for any action taken or not taken based on any part of the contents of this report. Those acting on information provided in this report do so entirely at their own risk.

This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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1 ES1 Introduction

On 21 December 2016, the former Department of Environment and Heritage Protection (EHP) (now Department of Environment and Science (DES)) issued TEC Coal Pty Ltd (a subsidiary of Stanwell Corporation Limited (Stanwell)) with a notice to conduct or commission an environmental evaluation under Section 326B of the *Environmental Protection Act 1994* (EP Act) (the Notice). The grounds for the environmental evaluation relate to the identification of acid and metalliferous drainage (AMD) at Meandu Mine and the potential for this AMD to cause environmental harm. As the full nature and extent of the AMD was unknown, EHP (now DES) required that an environmental investigation be undertaken to determine whether environmental harm has occurred as a result of AMD at the Meandu Mine.

AMD has been identified as reporting by overland flow to retention dam 7 (RD7) in the retention dam network on the western side of the mine, where it is mixing with other mine affected water. Water from RD7 flows to RD8 where it is either re-used for site purpose or reports to the Meandu Creek Dam via release (compliance) point 3 (CP3). AMD reporting to RD7 is believed to be originating from two closely associated seepage locations:

- 1 Bullgang Corner, located approximately 600 m south-east of RD7.
- 2 A covered (vegetated) coal rejects area between Ramp 7 and the western side of the North-West A tailings void. This coal rejects area is assumed to be rehabilitated in the current Plan of Operations for Meandu Mine. This area will need to be evaluated to determine if remedial works are necessary in the future.

Specifically, the Notice requires that investigations are undertaken to:

1. Determine whether environmental harm has occurred as a result of AMD at Meandu Mine.
2. Identify and characterise the AMD and material with potential to generate AMD in the North-West tailings void/ spoil dump and rehabilitated rejects to assess the extent of environmental harm likely to be caused by the AMD; and to determine the effects of AMD ingress to stored historical tailings (e.g. potential dissolution of metal contaminants in the tailings which may be transported to the receiving environment in the seepage).
- 3 Identify other locations at Meandu Mine where AMD is occurring; and to identify potential AMD source materials at Meandu Mine.
- 4 Determine the potential for AMD related environmental harm (acute and/or chronic impacts on the aquatic ecosystem and other relevant water quality objectives (WQO's)) that could occur from future (ongoing) activities at Meandu Mine, including potential impacts from:
 - build-up of metals in sediment downstream of Meandu Creek Dam
 - elevated metal concentrations in Meandu Creek waters
 - alteration of the pH of Meandu Creek Dam waters and release of sediment bound contaminants to the downstream environment
 - elevated salinity levels in Meandu Creek waters.

To address the requirements of the Notice, Stanwell has commissioned an Environmental and Engineering Evaluation into AMD at the Meandu Mine site. This investigation incorporates studies across of range of technical disciplines including:

- mine planning and life of mine (future) (Xenith Consulting)
- material classification assessments (geochemical) (RGS Environmental Pty Ltd) (this assessment)
- hydrogeological assessments (JBT Consulting)
- surface water quality, sediments and aquatic ecology investigations (Ecological Services Professionals Pty Ltd)
- water modelling and development of engineering solutions (Golders Associates Pty Ltd).

Based on the assessments undertaken it is currently understood that the most likely cause of historic AMD events and ongoing AMD from the North-West A and North-West B landform (known as Hitachi Hill) was oxidation of sulfide minerals and subsequent leaching of AMD weathering products from the rejects storage. Overall, based on the specialist studies undertaken up to May 2018, the AMD issues at Meandu Mine are considered relatively minor and can be managed through the implementation of changes to the mining and placement of mined materials. Stanwell is committed to proactive long-term resolution of the AMD issue and development of potential engineering options that may be implemented at Meandu Mine to mitigate any potential environmental impacts associated with AMD. Some initial measures have been implemented by Stanwell to manage AMD including interim lime dosing and changes to monitoring and operations. Further changes are potentially required to the way mining, mine waste, mine water, landform design and rehabilitation are managed at Meandu Mine subject to the outcomes from ongoing monitoring of the Bullgang Drain and RAMP 7 water as the North-West Backfilled Pit water level is lowered.

1.1 Scope of works and information sources

RGS Environmental Pty Ltd (RGS) was engaged from November 2016 through to August 2018 to implement a static and kinetic leach testing program to evaluate the geochemical properties of coal and mine waste materials including soil, overburden, interburden, coal rejects, tailings and coal ash (from Tarong and Tarong North power stations) that is emplaced into mined out pits at Meandu Mine. This testing program has informed the environmental evaluation into AMD at the Meandu Mine.

The purpose of the work completed by RGS was to qualify, and where possible quantify, the potential extent of AMD at Meandu Mine, in terms of both the spatial extent of the mine material that may contribute to AMD and the potential extent in terms of the concentration of sulfide bearing minerals that could oxidise and release AMD.

Specifically, the purpose of the RGS work program was to:

- characterise the geochemical and physical properties of all mined materials
- classify the materials into functional units
- assist Stanwell to produce material balances for mined materials
- define potential impacts associated with AMD and saline drainage from the materials
- provide recommendations to reduce potential impacts from AMD and saline drainage.

As part of this work, RGS implemented a static and kinetic leach testing program that commenced in November 2016 and that is continuing up to August 2018, reviewed historical water quality data and information relating to the historical placement of materials to assist with the determination of source and extent of AMD at Meandu Mine. A review of previous geochemical assessments for the Meandu Mine site from 1990 to 2016 was also undertaken.

Historic site water data was provided by Stanwell in the form of a water quality database which included all on-site water quality monitoring data from 25-10-78 up until 14-09-16. The continuation of water quality sampling and monitoring beyond this date range is acknowledged. Information relating to current and historical placement of materials has been supplied by Stanwell, sourced directly from Mine operators.

This report is an extended executive summary of the full report provided by RGS to Meandu Mine.

1.2 Notice requirements

An overview of the Notice requirements specific to geochemical investigations and how they have been actioned is provided in **Table 1-1**.

Table 1-1: Notice requirements specific to geochemical investigations

NOTICE REQUIREMENT	ACTION
<i>1. An appropriately qualified person(s) as defined in this notice must provide background and baseline information for the coal mining activity relevant to the environmental investigation including:</i>	
<i>iv) a summary of geochemical data relevant to the investigation</i>	RGS reviewed surface and groundwater quality data from 1978 to 2016 and site reports and documented the known occurrences of AMD.
<i>vi) a brief history and overview of the AMD at the site (from first known (historic) indicators to current awareness</i>	A summary of the known history of AMD is provided in ES2 of this report.
<i>3. An appropriately qualified person(s) as defined in the notice must undertake studies to determine the presence and extent of AMD at Meandu Mine, and to determine the acid generating potential of materials at Meandu Mine, the studies must include:</i>	
<i>i) geochemical assessments to characterise the chemical and physical properties of any materials at Meandu Mine (soil, overburden, in-pit side cast coal, product coal, rejects, tailings, ash etc) with potential to generate AMD so these materials can be classified and then managed appropriately</i>	RGS reviewed geochemical reports from 1990 through to a comprehensive static assessment by EGi in 2016 that included 1,018 samples from 9 drill holes. RGS added to the geochemical data by implementing additional static geochemical assessment of 1,418 samples and kinetic leach testing on 20 samples of ash, rejects and overburden samples that has been ongoing for 20 months.
<i>iii) studies to identify the extent and locations of potential AMD source materials at Meandu Mine</i>	The geochemical and physical analysis included analysis of coal, coarse rejects, fine rejects, tailings, ash and all major overburden units including the soil. Sampling and analysis was undertaken in all areas of the mine and included all major stratigraphic and lithological units.

NOTICE REQUIREMENT	ACTION
iv) <i>Investigations to identify physical and/or environmental influences relating to storage areas (coal rejects, overburden, waste rock, and topsoil) that may determine the occurrence, rate of progression, or volume of AMD generated at Meandu Mine for example: stockpile location, size, surface area, profile/geometry, water infiltration and drainage characteristics</i>	The role of RGS in aspect of the Notice was to characterise the physical properties of the materials, but not just the physical properties. For example, sampling and analysis was undertaken on coarse and fine grade rejects on a monthly basis for 15 months and also on as-placed rejects in Hitachi Hill to evaluate how the storage and placement of rejects may affect AMD production.
5. <i>An appropriately qualified person(s) as defined in the notice must develop a predictive model for Meandu Mine in relation to AMD impacts to provide information relevant to development of:</i> — <i>Mine material management plans</i> — <i>Mine water management plans</i> — <i>Landform and rehabilitation management plans</i> — <i>Closure plans</i> <i>The predictive model must include:</i>	
i) <i>a material model (based on geochemical characterisation)</i>	RGS utilised static and kinetic leach test data to develop source terms for the GoldSim water balance and water quality model.
iv) <i>capacity to predictively model acid production at Meandu Mine</i>	The kinetic leach testing data was used to forecast future acid production rates and saline and metalliferous drainage rates and these values were then incorporated into the GoldSim model.

2 ES2 History of AMD

Meandu Mine commenced operations in 1984 in the King 1 (K1) and King 2 (K2) open pits and then in the North-West A open pit. Tailings were initially placed into in-pit cells in the North-West A pit and then into a valley fill tailings dam in the Black Creek catchment (the King 2 tailings storage facility (K2TSF)). Coal rejects were initially placed into small cells and then into Reject Area Storage 1 (RSA1) to the west of the North-West A open pit. Rejects from the coal handling preparation plant (CHPP) were hauled from the reject stockpile and placed into RSA1. RSA1 was initially constructed on top of natural ground that allows surface runoff and seepage to report onto Ramp 7 haul road, into RD7 and into the upper ephemeral area of Meandu Creek. When the storage capacity on natural ground at RSA1 was reached, spoil and rejects were subsequently placed in-pit at North-West A.

In 1995 a period of above average rainfall events led to an acidic drainage event from RSA1. The pH of the seepage from RSA1 was approximately pH 3 to 3.5, with a measured acidity of 1,530 mg/L, and elevated concentrations of iron and zinc. Following this event, analysis of the water quality data from RD7 (and RD8) verified that acidic water was (mostly) associated with above average rainfall events. It is likely that the acid events recorded in RD7 and RD8 were other seepage events from RSA1. This is because analysis of water quality data from the open pits at that time confirms that the pit water was mostly circum-neutral.

The North-West B open pit was opened after North-West A had been mined and was then subsequently used to store spoil, rejects and tailings until December 2005. As tailings were placed into North-West A tailings storage dam, water within the tailings percolated into the adjacent spoil and rejects within the mined open pit. In about 2005, tailings placement in North-West A ceased and rehabilitation commenced in 2008 by placing spoil and rejects on top of the tailings. Due to low geotechnical stability and overloading, the tailings were displaced vertically by some 50 m over about 3 years. From 2005 to December 2017 tailings were placed into North-West B and water from the tailings continued percolating into adjacent spoil and into unsaturated spoil and rejects in North-West A.

In mid-2013 seepage from RSA1 rejects storage area was noted and this water was subsequently identified as AMD. The seepage continued, and this was attributed to water seeping from the backfilled North-West A open pit. The seepage is continuing at about 2 ML per day at two seepage locations known as Ramp 7 and Bullgang Drain. Initially the AMD seepage at these two locations was attributed to porewater being squeezed directly from the tailings. This was subsequently shown by RGS to be incorrect as static and kinetic leach cell testing of the tailings in 2007 by EGI (2007) over 12 months verified that the tailings continued to generate neutral pH drainage even after 12 months of exposure and leaching under fully oxidised, unsaturated leach testing. RGS expects that even though the tailings were displaced vertically, their inherent fine-grained, plastic texture and ability to retain moisture would maintain them at a high moisture content, reducing their potential for oxidation and generation of AMD.

Investigation of the historic incidents of AMD at the site by RGS, determined that the most probable cause of the historic AMD events and ongoing AMD from the North-West A and North-West B landform (known as Hitachi Hill) was oxidation of the sulfide minerals, and subsequent leaching of the AMD weathering products from the rejects stored in RSA1.

At RSA1, aerial imagery and the shape of the landform suggests that the rejects were end-tipped then pushed by dozer during construction and it is probable that the rejects were left exposed to atmospheric conditions for an extended time-period (months and possibly even years). This extended exposure is likely to have contributed to the production of AMD. Occurrences of AMD from RSA1 may not have been readily observed during operations until there was sufficient rain from a large or prolonged rainfall event to wash them onto the Ramp 7 haul road, or into the North-West A pit, or later, into the spoil and rejects in the North-West A backfilled pit. The range of the baseflow data for Ramp 7 and Bullgang Drain from July 2013 to February 2017 has the following characteristics:

- pH 3.4 to 6.3;
- EC (minimum 1,690 $\mu\text{S/cm}$, average 3,199 $\mu\text{S/cm}$ and maximum 4,500 $\mu\text{S/cm}$);

- Acidity (minimum 12 mg/L, average 277 mg/L and maximum 490 mg/L);
- SO_4^{2-} (minimum 223 mg/L, average 1113 mg/L and maximum 1,580 mg/L);
- Al (minimum 0.005 mg/L, average 0.84 mg/L and maximum 4.52 mg/L);
- Co (minimum 0.01 mg/L, average 0.7 mg/L and maximum 1.21 mg/L);
- Fe (minimum 0.33 mg/L, average 91.6 mg/L and maximum 181 mg/L);
- Mn (minimum 0.88 mg/L, average 32.9 mg/L and maximum 50.3 mg/L);
- Ni (minimum 0.03 mg/L, average 0.51 mg/L and maximum 0.92 mg/L); and
- Zn (minimum 0.01 mg/L, average 4.11 mg/L and maximum 12.3 mg/L)

3 ES3 Static mine waste material characterisation and classification

The presence of AMD and non-compliance events associated with salinity in water released from site triggered (amongst other technical studies) a drilling, sampling and static geochemical analytical program in 2015 (EGi, 2015) and a static and kinetic leach testing program by RGS from November 2016 to March 2018.

The purpose of the static geochemical test program was to characterise and classify the overburden and interburden in K2E, K4E, K4S and Central open pits into six geochemical classes ranging from acid consuming (AC) to potentially acid forming (PAF) waste classes (refer Table 2). The geochemical data was utilised with the geological understanding of the overburden and interburden to develop an inferred (first pass) geological model of these materials, so that a preliminary material balance for the overburden and interburden could be developed and then used in the 2017 Life of Mine plan developed by Xenith to ensure that any PAF material was not placed into a 6 m vertical or 50 m horizontal area of the 'as-designed' final reshaped landform.

The static geochemical test and classification program was also extended to coal rejects, tailings and coal ash materials and development and implementation of additional management strategies for coal rejects and tailings as part of the 2017 Life of Mine plan including placement of these materials into mined pits. This is also being applied to PAF overburden, interburden and mined spoil.

Standard Acid Base Accounting (ABA) methods used in the Australian mining industry (AMIRA, 2002; COA, 2016) and internationally (INAP, 2009) were used to characterise and classify the mined materials from the drilling and sampling programs. The analytical methods included using sulfur analysis by Leco analyser to measure the total sulfur (TS) concentration and converting this to a maximum potential acidity (MPA) value that assumes all sulfur is present as sulfide minerals and that all sulfur will produce acidity. This assumption is known to overestimate the actual MPA because not all sulfur is present as reactive pyrite (i.e. sulfide sulfur measurements completed by RGS confirmed that approximately 20 to 40 % of the total sulfur measured is likely to be present at either sulfate, sulfate minerals or organic sulfur). Chromium Reducible Sulfur (CRS) can be used to significantly improve estimates of sulfide sulfur.

Classification of mine waste materials using ABA analyses can be completed using a variety of standard methods, but the actual criteria are typically site dependent. In this study RGS has used the total sulfur content and the neutralisation potential ratio (NPR) to classify mined materials including soil, overburden, interburden, rejects, tailings and ash. The geochemical classification system used by RGS to classify the mine waste materials into different material types is summarised in **Table 3-1**.

Table 3-1: Geochemical classification system used by RGS for mine waste materials

Material Type	Classification Criteria
Acid Consuming (AC)	TS% < 0.05 and NPR > 10 & > 50 kg H ₂ SO ₄ /t
Non-Acid Forming (NAF)	TS% < 0.05 and NPR > 3
Non-Acid Forming Uncertain (NAF-UC)	TS% < 0.05 and NPR < 3
Potentially Acid Forming Uncertain (PAF-UC)	TS% > 0.05 and < 0.2% and NPR > 1 < 3
Potentially Acid Forming - Low Capacity (PAF-LC)	TS% > 0.05 and < 0.2% and NPR < 1
Potentially Acid Forming (PAF)	TS% > 0.2%

It should be noted that additional testing such as Net Acid Generation tests, can also be used in conjunction to ABA tests and could result in a reduction of PAF determinations and further that kinetic testing can result a more accurate determination as to whether a material has a significant potential to generate acid. The NPR values adopted for the criteria are very conservative, for example, for PAF-UC, RGS assumes that the ANC levels will at least equal (i.e. balance the MPA maximum potential acidity), that is no acid would be returned in the Net Acid Producing Potential (NAPP) test.

3.1 Coal, reject, tailings and ash

Analysis and plotting of the total sulfur content of all coal resource assay data in all coal seams within the mining lease by JB Mining Pty Ltd (2016) verified that the site wide total sulfur content is relatively low compared to other coal mines in Queensland (RGS, 2015). This was verified through a static testing program with the total sulfur results for coal, rejects, tailings and ash materials summarised in **Table 3-2**.

Table 3-2: Summary of total sulfur data from the AMD database developed by RGS

Material type	Number of samples	Minimum total sulfur %	Median total sulfur %	Average total sulfur %	Maximum total sulfur %
Coal	330	0.02	0.11	0.15	1.03
Rejects	14*	0.11	0.21	0.22	0.36
Tailings	15*	0.15	0.27	0.28	0.37
Ash	14*	0.01	0.02	0.02	0.02

* Obtained from consecutive monthly sample collection at the coal handling processing plant for rejects, the coal handling processing plant tailings underflow thickener, and the K2N ash storage area.

* The reject, tailings and ash data presented here does not comprise the entire data set for these materials, but the data is from as-produced fresh samples. The supplemental data for these materials is from samples collected during drilling programs.

Spatially plotted total sulfur (isopach) data verified that the total sulfur content was similar in all coal seams, although at least anecdotally, the total sulfur content appeared to be slightly higher in the earlier Ace and King seams mined to the north and west of the mine area. It was also determined that the total sulfur content of the coal roof and coal floor units is also not significantly different to the coal seams. On the other side of the ABA methodology, acid neutralising capacity (ANC) analysis and test data has confirmed that there is very little inherent ANC in most of the mine waste materials (**Table 3-3**), excluding basalt flows. The ANC method also has the potential to overestimate the actual ANC in mine waste materials. The low ANC means that even samples with little sulfide sulfur content have the potential to produce acidity. However, the limit of reporting (LOR) for ANC is higher than that for total sulfur, thus in some instances the number of samples classified in a PAF category will be overestimated when zero ANC is assumed for the NPR calculation.

Table 3-3: Summary of acid neutralising capacity (ANC) data from the AMD database developed by RGS

Material type	Number of samples	Minimum kg H ₂ SO ₄ /tonne	Median ANC kg H ₂ SO ₄ /tonne	Average kg H ₂ SO ₄ /tonne	Maximum kg H ₂ SO ₄ /tonne
Coal	247	<0.5	2.2	2.5	15
Rejects	14*	1.8	5.0	3.5	20.7
Tailings	15*	0.3	2.8	2.9	5.1
Ash	14*	0.3	1.1	0.7	5.0

3.2 Mine material classification summary

The data presented in **Figure 3-1** confirm that most coal, rejects and tailings were classified as PAF, due to the low ANC concentration in the samples. The data in **Figure 3-1** also provides the number of samples tested which fell within the waste classes by the logged major lithological units. The data verify of the 1,318 samples with total sulfur and ANC results (including coal, rejects and tailings) that:

- 51 % of the samples were NAF;
- 14% were PAF-UC; and
- 35 % were PAF.

When coal, rejects and tailings were removed from the dataset then:

- 67 % of the samples were NAF;
- 17% were PAF-UC; and

- 16 % were PAF.

The data showing the number of samples within each waste class in each of the major lithological units is presented for the overburden (**Figure 3-2**) and the interburden (**Figure 3-3**).

Lithology	AC	NAF	NAF-UC	PAF-UC	PAF-LC	PAF	# Check
Alluvium			3				3
Basalt	2	15	2	2	2		23
Carb.Siltstone	1	8	1	19	9	3	41
Clay		18	35	1	16		70
Claystone	1	15	30	11	12	2	71
Conglomerate	3	23	14	6			46
Lignite						2	2
Sand		3	6				9
Sandstone	3	124	159	25	55	1	367
Shale		48	1	41	3	1	94
Siltstone	1	75	37	37	32	3	185
Soil			1	25	1		27
Spoil		12	29	2	13		56
Coal		2		8	107	35	152
Rejects			2	12	71	34	119
Tailings					18	35	53
Total sample #	11	343	320	189	339	116	1318
% by waste class	0.8	26.0	24.3	14.3	25.7	8.8	
Major waste group	NAF		PAF-UC		PAF		
% by waste group	51		14		35		

Figure 3-1: Summary of the number of samples in each waste class by major lithological unit and mine waste type (coal, rejects and tailings)

Figure Legend:

The green bars within the cells are graphical representation of the values in table.

The pink bars within the cells are graphical presentation of the values in table corresponding to the number of samples within the lithological or waste types.

	AC	NAF	NAF-UC	PAF-UC	PAF-LC	PAF	Sample # by lithology
Alluvium			3				3
Basalt	2	15	2	2	2		23
Carb.Siltstone				10	4	1	15
Clay		18	35	1	16		70
Claystone		6	25	8	9	2	50
Conglomerate		14	9	4			27
Lignite						2	2
Sand		3	6				9
Sandstone		33	105	8	31		177
Shale		48	41	1	3	1	94
Siltstone		10	19	9	7		45
Soil			1	25	1		27
Spoil		2	46	1	48	4	101
Total sample #	2	149	292	69	121	10	643
% by waste class	0.3	23.2	45.4	10.7	18.8	1.6	
Major waste group	NAF		PAF-UC		PAF		
% by waste group	68.9		10.7		20.4		

Figure 3-2: Summary of the number of samples in each waste class by major lithological unit in the overburden above the Ace coal seam

Figure Legend:

The green bars within the cells are graphical representation of the values in table.

The pink bars within the cells are graphical presentation of the values in table corresponding to the number of samples within the lithological or waste types.

	AC	NAF	NAF-LC	PAF-LC	PAF	PAF-HC	Sample # by lithology
Carb.Siltstone	1	7	1	9	5	2	25
Claystone	1	9	5	3	3		21
Sandstone	3	91	54	17	20	1	186
Siltstone	1	65	18	28	25	3	140
Conglomerate	3	9	5	2			19
Coal (Roof & Floor)		2		6	21	42	71
Total sample #	9	183	83	65	74	48	462
% by waste class	1.9	39.6	18.0	14.1	16.0	10.4	
Major waste group	NAF			PAF-LC	PAF		
% by waste group	59.5			14.1	26.4		

Figure 3-3: Summary of the number of samples in each waste class by major lithological unit in the interburden below the Ace coal seam

Figure Legend:

The green bars within the cells are graphical representation of the values in table.

The pink bars within the cells are graphical presentation of the values in table corresponding to the number of samples within the lithological or waste types.

As explained above the static geochemical data for total sulfur and total ANC are used to calculate the maximum or net acid producing potential but do not consider the reaction rates that are measured using kinetic leach cell testing. The static geochemical results using the total sulfur data and the NPR indicate that:

- coal, rejects and tailings are generally classified as PAF;
- coal roof, coal floor and coal partings are generally classified as PAF;
- basalt and conglomerate are predominantly NAF;
- there is no clear relationship between the lithological units and PAF mine waste, meaning that:
 - o it is currently not possible to classify mine waste using lithological coding unless spatial relationships can be derived with ongoing work to determine if the PAF samples within lithological units are constrained to a particular location or zone in the deposit;
 - o ongoing sampling and analyses will be required to remove uncertainty around the location of PAF mine waste; and
- From a materials management perspective, RGS finds that the bulk of the samples in the overburden and interburden are within the NAF mine waste class and this is typical of most coal mines.

In addition to the drilling and sampling program for the AMD assessment described above, RGS also completed coal reject sampling (15 samples) from Hitachi Hill, which had previously been subjected to progressive co-mingling and emplacement with mined spoil from Central pit. The 15 reject samples were collected in March 2016, whilst Hitachi Hill was being reshaped and a 4.5 ha area of previously covered rejects was exposed. The samples were analysed for pH and electrical conductivity in the field and had neutral pH. However, after exposure to atmospheric conditions in sample containers at the site for six months, the samples were found to have a pH of < 3. This suggests that if rejects are co-mingled and progressively encapsulated they are unlikely to oxidise and produce acidity. In contrast, if rejects are left exposed to atmospheric conditions (in the range 3 to 6 months) they will oxidise and produce acidity.

4 ES4 Kinetic mine waste material characterisation

Static testing provides chemical or physical data of a sample that is essentially a “snap shot” in time. Static chemical analysis provide data such as pH, salinity, total sulfur, ANC, cation exchange capacity, nutrient content or the water soluble or total elemental content of the sample.

In contrast, kinetic leach column (KLC) tests provide dynamic data such as the **rate** at which the minerals in the sample will oxidise, dissolve or precipitate over time. KLC data are used on their own to evaluate the risk associated with a material and are a key input (source term) for water quality modelling.

KLC testing can also be used to **confirm the static classification** of the samples using total sulfur, ANC and NPR or alternatively prove that some materials classified as PAF using static tests can be treated as NAF materials). For example, the tailings, fine-grade and coarse-grade rejects are all classified as PAF. However, after 14 months of leach testing the tailings and fine-grade rejects have retained neutral pH drainage. Long-term KLC tests will verify if the samples remain NAF or become PAF (i.e. quantify the lag-period required for the sample to turn from NAF to PAF).

The KLC program used samples obtained from the K4E pit for coarse-grade reject samples, fine-grade rejects collected from the CHPP belt, tailings from the CHPP underflow thickener, ash from the K2N ash pit and overburden samples from drill core samples collected from K2E. The samples were evaluated as individual samples (grey shaded samples in **Table 4-1** and in a variety of mixtures to simulate potential management strategies such as:

- co-disposal of tailings and rejects;
- co-disposal of tailings, rejects and ash;
- co-mingling of rejects and overburden samples; and
- the addition of agricultural lime to increase the sample ANC.

Table 4-1: Summary of the KLC samples evaluated in this study

KLC # 2	Ash (100%)	Ash slurry deposited into K2N and K2W from Tarong and Tarong North power stations
KLC # 23	Rejects from Hitachi Hill (100%)	Medium-grade rejects from Hitachi Hill (nominally < 50 mm PSD)
KLC # 12	Coarse-Grade Rejects (100%) - Simulate End Tip Placement	Coarse-grade rejects collected from K4E (> 75 mm PSD) and crushed to pass 19 mm PSD in KLC
KLC # 5	Fine-Grade Rejects (100%) - Simulate End Tip Placement	Fine-grade rejects from the CHPP (nominally < 10 mm PSD) collected from reject belts and used as provided
KLC # 3	Tailings (100%)	Tailings from the CHPP underflow thickener (< 0.075 mm) and used as provided after drying
KLC # 9	Weathered Basalt (100%)	Weathered basalt - heavily weathered oxidised basalt / clay from 5 to 7.6 m bgl in K2E that was used as provided
KLC # 20	Conglomerate (Weathered Coarse Sandstone) (100%)	Conglomerate from 40.1 to 44.3 m bgl in K2E crushed to pass 10 mm PSD in KLC
KLC # 22	Sandstone (100%)	Sandstone from 75 to 82.7 m bgl in K2E crushed to pass 10 mm PSD in KLC
KLC # 10	Shale (100%)	Shale from 87 to 92.4 m bgl in K2E crushed to pass 19 mm PSD in KLC
KLC # 21	Volcanic Transition (Base of Tertiary) (100%)	Weathered basalt (base of tertiary) (from 45.8 to 52.9 m bgl in K2E) - Impermeable and did not leach
KLC # 1	Ash (90%) + Tailings (10%)	Testing co-disposal of tailings and ash
KLC # 6	Fine-Grade Rejects (75%) + Tailings (25%)	Testing co-disposal of reject and tailings
KLC # 15	Coarse-Grade Rejects (75%) + Tailings (25%)	Testing co-disposal of reject and tailings

KLC # 8	Fine-Grade Rejects (60%) + Tailings (5%) + Ash (35%) - Simulate Co-disposal	Testing co-disposal of rejects, tailings and ash
KLC # 11	Coarse-Grade Rejects (60%) + Tailings (5%) + Ash (35%) - Simulating Co-disposal	Testing co-disposal of rejects, tailings and ash
KLC # 7	Fine-Grade Rejects (75%) + Weathered Basalt (25%) - Simulate End Tip Placement	Testing co-disposal of fine-grade rejects with overburden / interburden
KLC # 4	Fine-Grade Rejects (75%) + Weathered Sedimentary (25%)	Testing co-disposal of fine-grade rejects with overburden / interburden
KLC # 13	Coarse-Grade Rejects (100%) - Simulate Traffic Compaction	Coarse grade rejects collected from K4E (> 75 mm PSD) and crushed to pass 19 mm PSD in KLC and attempted compaction
KLC # 16	Coarse-Grade Rejects (75%) + Weathered Basalt (25%) - Simulate End Tip Placement	Testing co-disposal of coarse-grade rejects with weathered basalt
KLC # 17	Coarse-Grade Rejects (75%) + Weathered Basalt at the base of the Tertiary Unit (25%)- Simulate End Tip Placement	Testing co-disposal of coarse-grade rejects with weathered basalt
KLC # 18	Fine-Grade Rejects (75%) + Sandstone (25%) - Simulate End Tip Placement	Testing co-disposal of fine-grade rejects with sandstone
KLC # 14	Coarse-Grade Rejects (100%) + Limestone - Simulate End Tip Placement	Testing supplemental addition of calcium carbonate
KLC # 19	Fine-Grade Rejects (100%) + Limestone (450g) - Simulate End Tip Placement	Testing supplemental addition of calcium carbonate

The KLC method included:

- using 20 L capacity cells;
- measuring the particle size distribution of the sample used in the cell;
- using 15 kg of sample in each cell;
- adding 1.4 L of water to each sample every month and leaving the water in the cell for 24 hours to maximise leachant (laboratory grade distilled water) contact with the sample;
- opening the column at 24 hours and letting the leachate drain from the cell;
- measurement of the pH and EC at 4, 8 and 24 hours;
- measuring the total volume of water recovered at 24 hours;
- closing the cells off to retain any residual water; and,
- sending sampling of the leachate (recovered sample) for analysis of pH, EC, acidity, alkalinity, major cations and anions and 39 metal(oids).

The KLC program has been ongoing for 85 weeks and includes conducting leach cycles each month. It is important to understand that the KLC results presented in this report as pH, EC and mg/L concentrations are derived from the water / rock ratios used in the laboratory and do not reflect actual water quality that would occur in the field. The

The key results from the KLC program are in:

- **Figure 4-1 and 4-2** for reject, ash and tailings samples
- **Figure 4-3 and 4-4** for samples mixed with tailings
- **Figure 4-5 and 4-6** for overburden samples
- **Figure 4-7a and 4-8** for samples mixed with overburden.

The major findings of the KLC program include the following.

- **Hitachi Hill Rejects:** KLC testing on the oxidised acidic reject sample was undertaken and while the pH has been consistent at 3.14 to 2.92 over 12 months the magnitude of the acidity decreased from 258 mg/L to 72 mg/L and the sulfate concentrations decreased from 1,190 to 105 mg/L. These data suggest that this particular reject sample was pH neutral during its placement and encapsulation, but following surface exposure, there was a period of oxidation and accumulation of AMD weathering products, that were subsequently rapidly leached from the sample during the KLC program. These data suggest that if the PAF rejects are emplaced and co-mingled with NAF spoil within four to eight weeks of being placed onto the reject stockpile they have a low potential to produce acid drainage.

- Coarse-Grade Rejects:** Sample (KLC12) had a static PAF classification with 0.13% total sulfate, 0.047% sulfide sulfate, ANC 2.1 kg H₂SO₄/tonne and NPR 0.5. This reject sample initially leached neutral drainage but became acidic (below pH 5) within six months. The sample had low but increasing acidity and was obtained from in-pit coal rejects in K4E by Meandu Mine geologists was then crushed to pass 19 mm sieve. It was dominated by coarse gravel size material with a high porosity and was free draining. After 14 months it leached drainage with a pH of 3 to 4. The acidity in the leachate of this sample has increased slowly from 1 mg/L to 31 mg/L and sulfate is less than 100 mg/L after 14 months. This sample has a lag period of less than six months to produce acidic drainage under unsaturated atmospheric conditions. The addition of 500 g of < 2mm agricultural lime to the coarse grade rejects (sample KLC 15) (equivalent to 30 kg / tonne) had a substantial positive effect on maintaining the sample at neutral pH over 14 months. The initial pH was 8.2 and the final pH was 7.7. The sulfate concentration was maintained at about 150 mg/L over the 14 months. The addition of agricultural lime will ensure that the PAF-LC rejects will not become acidic (i.e. the PAF rejects become NAF through the addition of more ANC). The coarse-grade rejects had relatively low concentrations of all metal(oids), however the concentration of copper and lead increased over 14 months up to 0.042 mg/L and 0.088 mg/L.
- Fine-Grade Rejects:** Sample (KCL 5) had a static PAF-LC classification with 0.15% total sulfate, 0.13% sulfide sulfate, ANC 1.9 kg H₂SO₄/tonne and NPR 0.4. The sample was sourced from fine-grade rejects off the CHPP belts, was dominated by material less than 1 mm particle size and was not free draining. The sample initially leached neutral drainage and retains a pH of 7.19 after 14 months of leaching. The sample has had low acidity over the program starting at 26 mg/L and ending with 11 mg/L. Compared to the coarse-grade reject samples, the sulfate concentration was initially elevated (1,970 mg/L), but decreased rapidly to 154 mg/L after 14 months. Material represented by this sample therefore has a lag period of more than 14 months to produce acidic drainage under unsaturated atmospheric conditions. The fine-grade, low permeability of the material encourages moisture retention and limits sulfide oxidation. The initially elevated sulfate concentration is attributed to entrained sulfate from the process water circuit in the CHPP and the high surface area of this sample. The addition of 450 g of < 2mm agricultural lime to the fine-grade rejects (KLC19) (equivalent to 30 kg / tonne) had a substantial positive effect on maintaining this fine reject sample at neutral pH over 14 months. The initial pH was 8.1 and the final pH was 8.2. The sulfate concentration was initially elevated at 3,030 mg/L, but decreased rapidly over 14 months to 289 mg/L. The addition of agricultural lime will ensure that the PAF-LC rejects will not become acidic (i.e. the PAF rejects are rendered NAF through the addition of more ANC).
- Tailings:** Sample KLC 3 had a static PAF-LC classification with 0.14% total sulfur, 0.048% sulfide sulfur, ANC 3.3 kg H₂SO₄/tonne and NPR 0.7. This sample was sourced from a combined composite of tailings collected from the CHPP underflow thickener. The tailings sample is dominated by material less than 0.075 mm and was not free draining. The sample initially leached neutral drainage and retains a pH of 6.2 after 14 months of leaching. The sample had had low and consistent acidity and sulfate concentration over the test program of approximately 4 mg/L and 350 mg/L, respectively. Material represented by this sample therefore has a lag period of more than 14 months if it were capable of producing acidic drainage under unsaturated atmospheric conditions. The fine-grained and low permeability nature of the material encouraged moisture retention and limits sulfide oxidation. It is noted that lime [Ca(OH)₂] is added to the tailings stream to maintain the pH of the tailings at about pH 7, because there are times when the tailings has the potential to generate acidity at the CHPP.
- Ash:** Sample KLC 2 had a static PAF-LC classification with 0.02% total sulfur, < 0.005% sulfide sulfur, ANC 1.1 kg H₂SO₄/tonne and NPR 0.6. This sample was sourced from a combined composite of ash collected from the K4N ash pit. The ash is dominated by material less than 0.075 mm particle size, but was free draining. The sample initially leached pH 6.7 drainage and retained a pH of 7.4 after 14 months leaching. The sample had low and decreasing acidity that

reduced from 24 mg/L to 2 mg/L. The concentration of dissolved sulfate also decreased rapidly from 1,910 mg/L to 10 mg/L over 14 months. This sample has a static NAF classification due to the very low sulfur content and non-detectable sulfide content and it has no potential to produce acidic drainage. It is noted that lime ($\text{Ca}(\text{OH})_2$) is added to the ash stream to increase the pH of the ash slurry to about pH 7 because there are times when the ash (like the coal and tailings) may produce some acidity. This process neutralises any actual acid in the ash. The initially elevated sulfate concentration is most likely due to entrained water in the process circuit more so than sulfate released from sulfate dissolution. Elevated but declining levels of trace elements were measured in the KCL leachate although vanadium levels remained consistent.

- Clay - highly weathered basalt:** Sample KLC 9 was sourced from a combined composite of drill core obtained from diamond hole 8029C from 5 to 7.6 m bgl. The overburden was dominated by material less than 2 mm particle size and had low permeability. This sample had a static PAF-LC classification with 0.18% total sulfur, < 0.008% sulfide sulfur, ANC 0.3 kg H_2SO_4 /tonne and NPR 0.1. The very low sulfide sulfur concentration, coupled with its position in the upper fully oxidised and weathered regolith in the stratigraphic profile at the site, infers that this material is highly unlikely to produce acidic drainage due to sulfide oxidation. The sample initially leached pH 4.5 drainage and retained a pH of 5.5 after 14 months. This is normal for weathered volcanic soils and the acidity in this instance is attributed to soluble aluminium (Al^{3+}) and manganese (Mn^{2+}). The sample has had low and decreasing acidity that reduced from 33 mg/L to 6 mg/L over the 14-month test period. The dissolved sulfate concentration also reduced from 212 mg/L to 115 mg/L over 14 months. The electrical conductivity was initially elevated at 3,660 $\mu\text{S}/\text{cm}$, but this is due to the presence of dissolved sodium chloride (NaCl) and not sulfate. This is important as it shows that weathered overburden contains sodium chloride, which contributes to salinity in drainage at the site.
- Conglomerate / coarse sandstone:** Sample KLC 20 was sourced from a combined composite of drill core obtained from diamond hole 8071C from 40.1 to 44.3 m bgl. The overburden was dominated by material in the gravel fraction and was free draining. This sample was assumed to have a static PAF-UC classification with 0.005% total sulfur, ANC 0.25 kg H_2SO_4 /tonne and NPR 1.6, although it is noted that the sample lies at the intersection of NAF-UC / PAF-UC as total sulfur is neither below or above 0.05%. KLC 20 initially leached pH 7.7 drainage and retained a pH of 8.3 after 14 months of leaching. The electrical conductivity was initially elevated at 2,400 $\mu\text{S}/\text{cm}$ and decreased to 184 $\mu\text{S}/\text{cm}$ at the end of the test period. The electrical conductivity was again dominated by sodium chloride rather than sulfate, again indicating that the overburden is a source of salinity. Elevated levels but declining of the metal selenium was measured in the KCL leachate.
- Sandstone:** Sample KLC 22 was sourced from a combined composite of drill core obtained from diamond hole 8071C from 75 to 82.7 m bgl. The overburden was dominated by material in the gravel fraction and was free draining. This sample has a static PAF-LC classification with 0.08% total sulfur, < 0.06% CRS, ANC 0.25 kg H_2SO_4 /tonne and NPR 0.1. The sample initially leached pH 4.16 drainage and returned a pH of 2.65 after 14 months of testing. Over the test period, the acidity concentration increased from 48 mg/L to 232 mg/L and the sulfate concentration decreased progressively from 1,860 to 762 mg/L. Elevated levels of metalloids were measured in the KCL leachate.

KLC leachate from the sandstone sample had elevated concentrations of:

- aluminium (range of 0.58 to 7.54 mg/L)
- cobalt (range of 0.2 to 0.56 mg/L)
- iron (range of 0.4 to 11.8 mg/L)
- nickel (range of 1.43 to 2.58 mg/L)
- selenium (initially at 0.36 mg/L but reducing concentration trend)
- uranium (range of 0.001 mg/L to 0.24 mg/L)
- zinc (range of 0.306 mg/L to 0.668 mg/L).

- **Shale:** Sample KLC 10 was sourced from a combined composite of drill core obtained from diamond hole 8071C from 87 to 92.4 m bgl. The shale was dominated by material in the gravel fraction and was free draining. This sample had a static PAF-UC classification with 0.05% total sulfur, < 0.025% CRS, ANC 0.03 kg H₂SO₄/tonne, NPR 0.1. The static classification and KCL tests results are consistent. KLC 10 initially leached pH 7.1 drainage and returned a pH of 5.4 after 14 months. Over the KLC test period, there was no substantial change in the acidity (approximately 4 mg/L) and sulfate (approximately 600 mg/L) concentrations. The shale had relatively low concentrations of metal(oids).

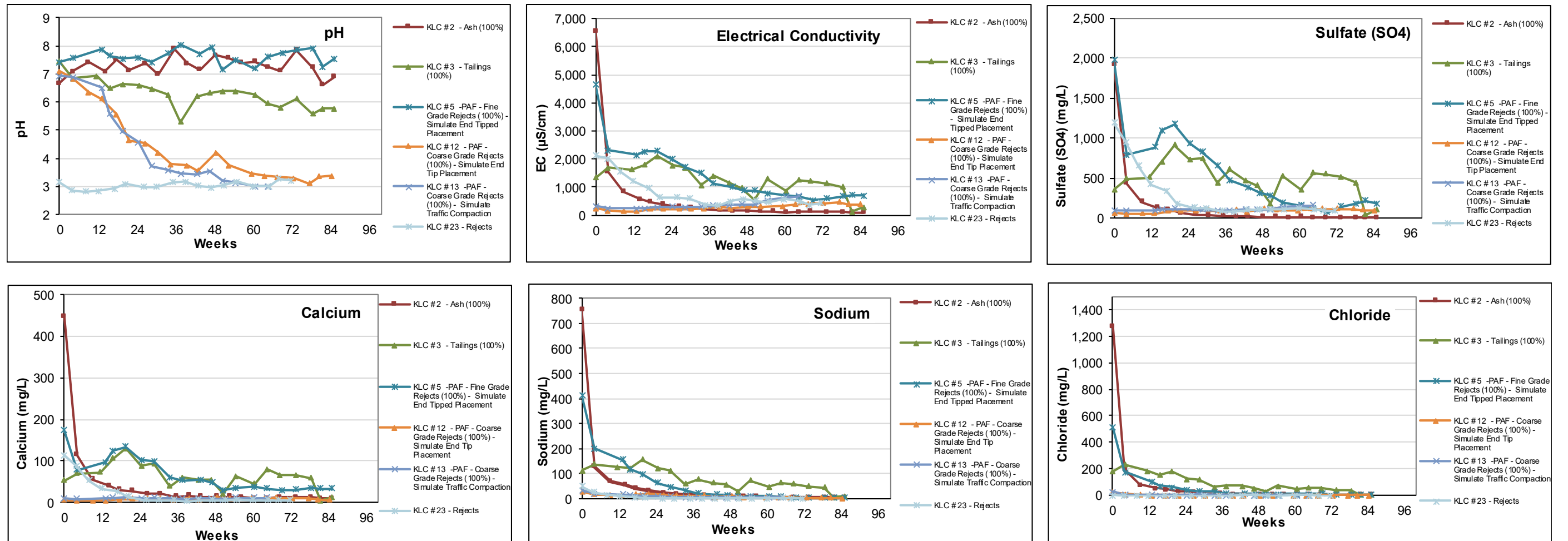


Figure 4-1: KLC results for reject, ash and tailings samples

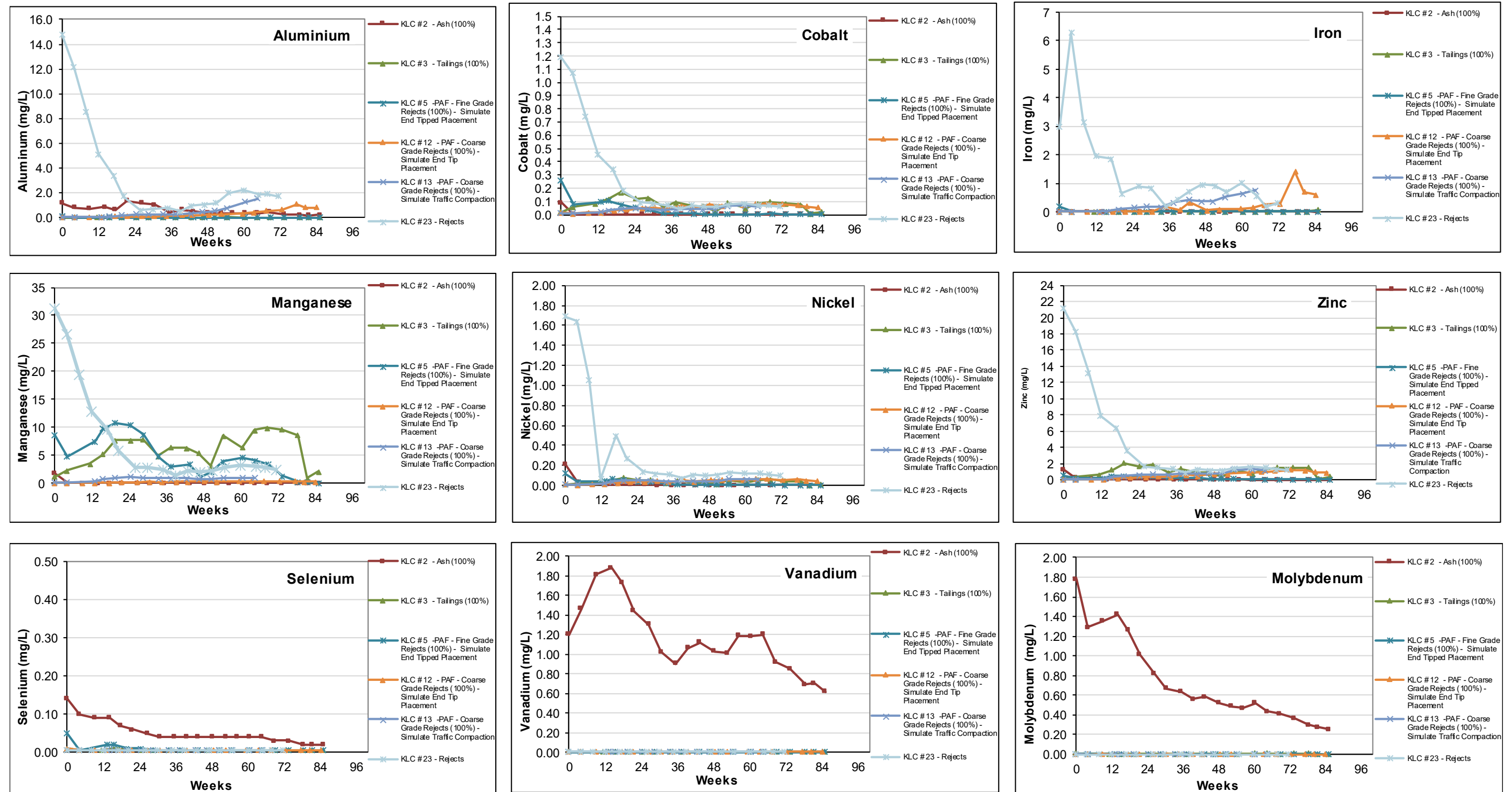


Figure 4-2: KLC results for reject, ash and tailings samples

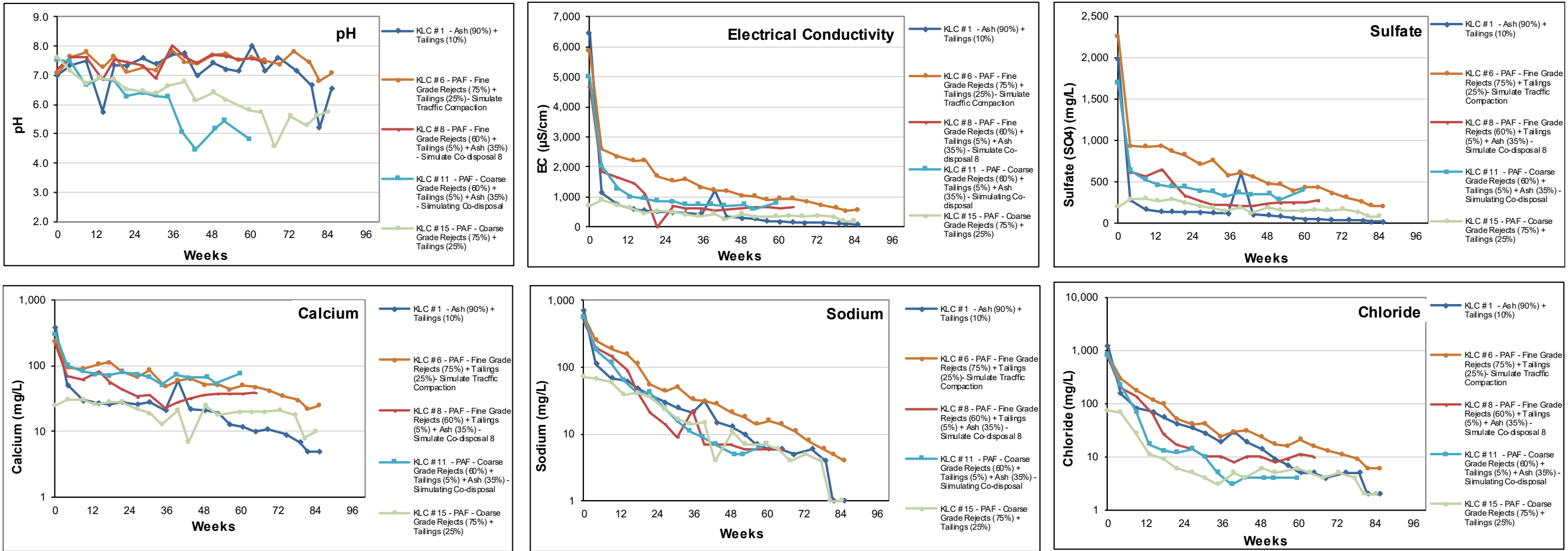


Figure 4-3: KLC results for tailings and tailings bearing samples



Figure 4-4: KLC results for tailings and tailings bearing samples

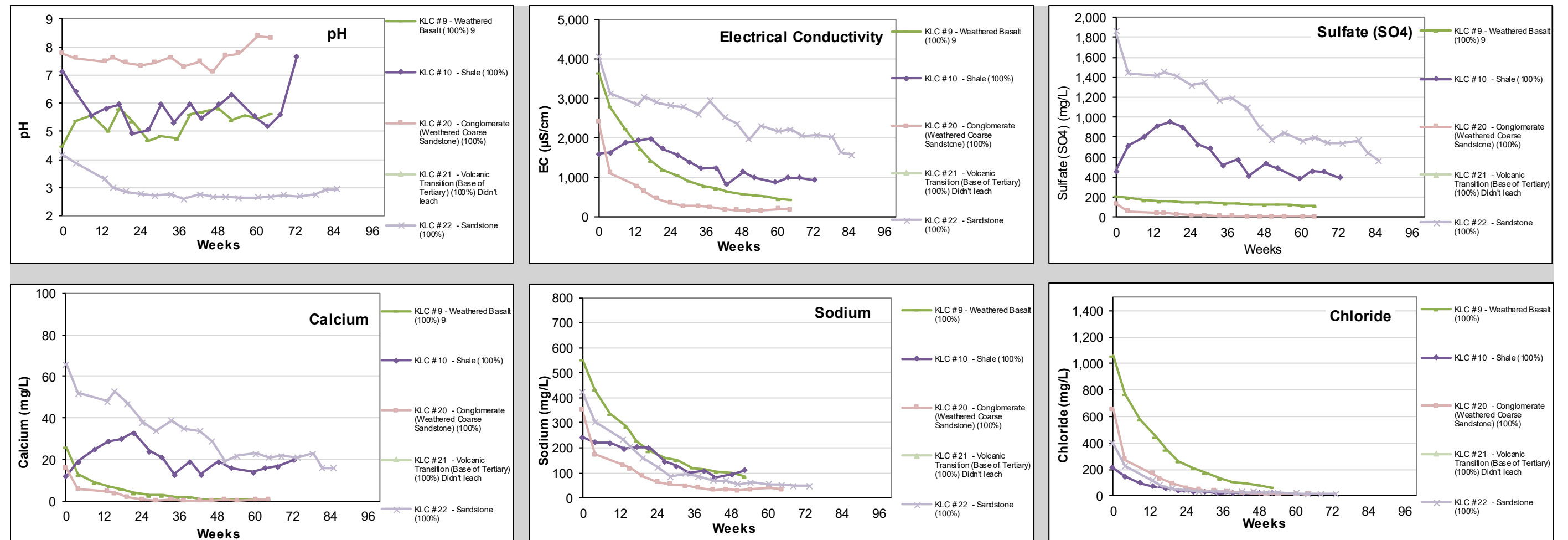


Figure 4-5: KLC results for overburden samples

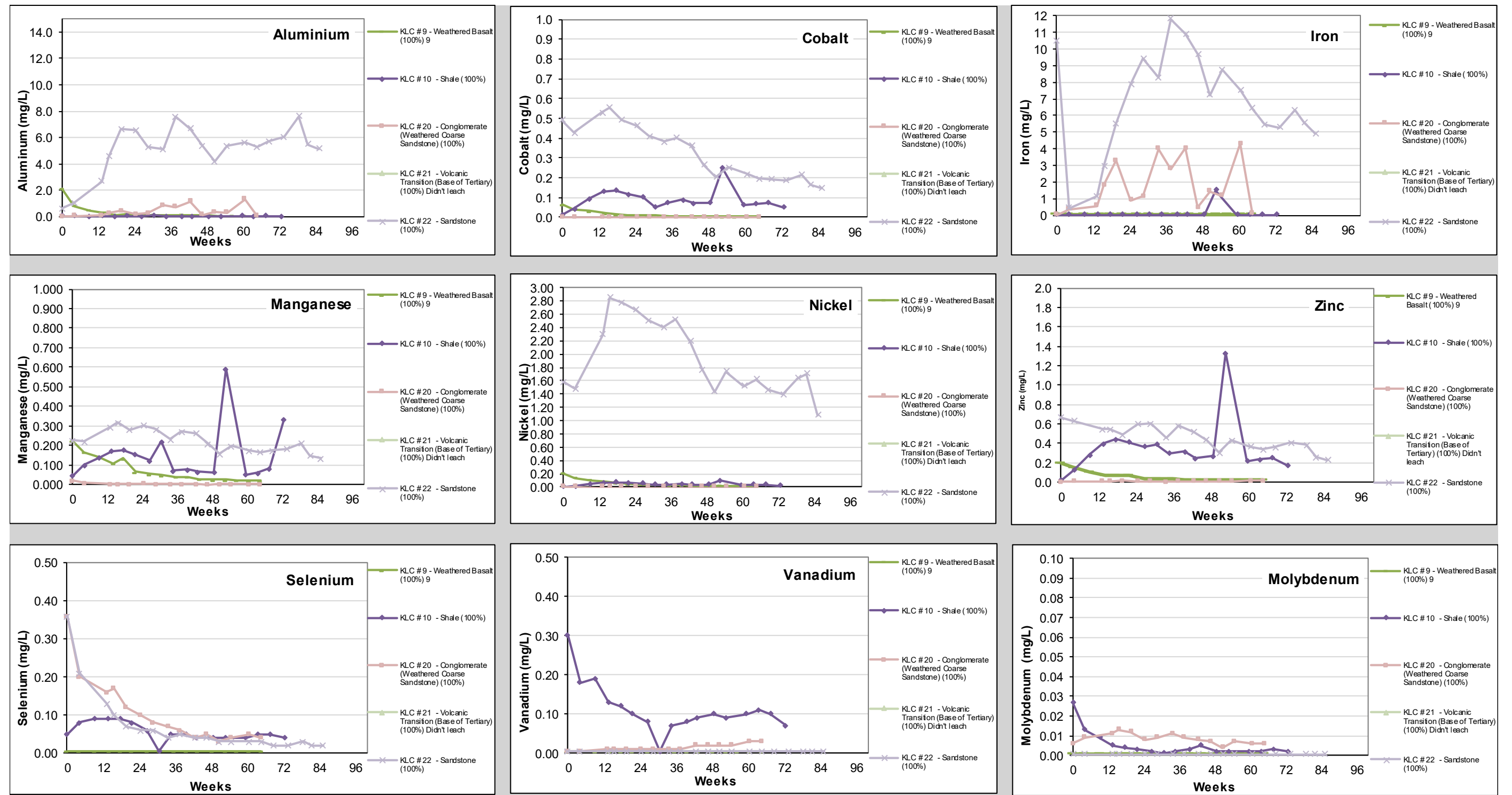


Figure 4-6: KLC results for overburden samples

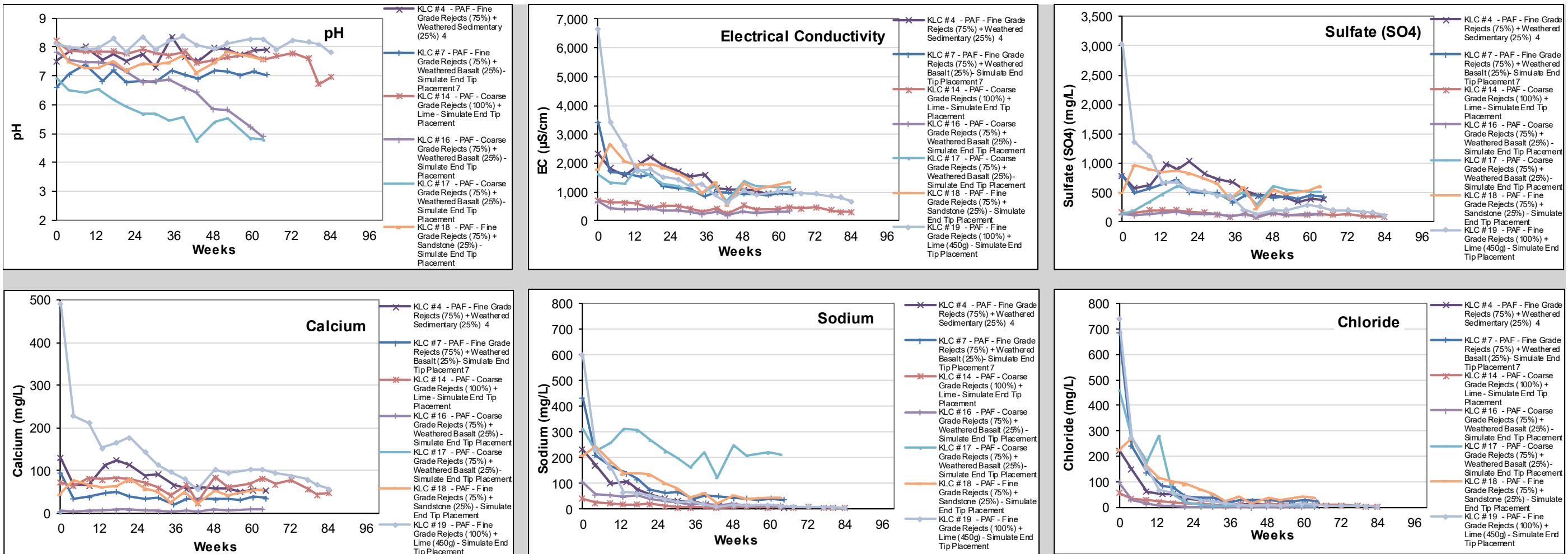


Figure 4-7: KLC results for overburden bearing samples mixed with reject

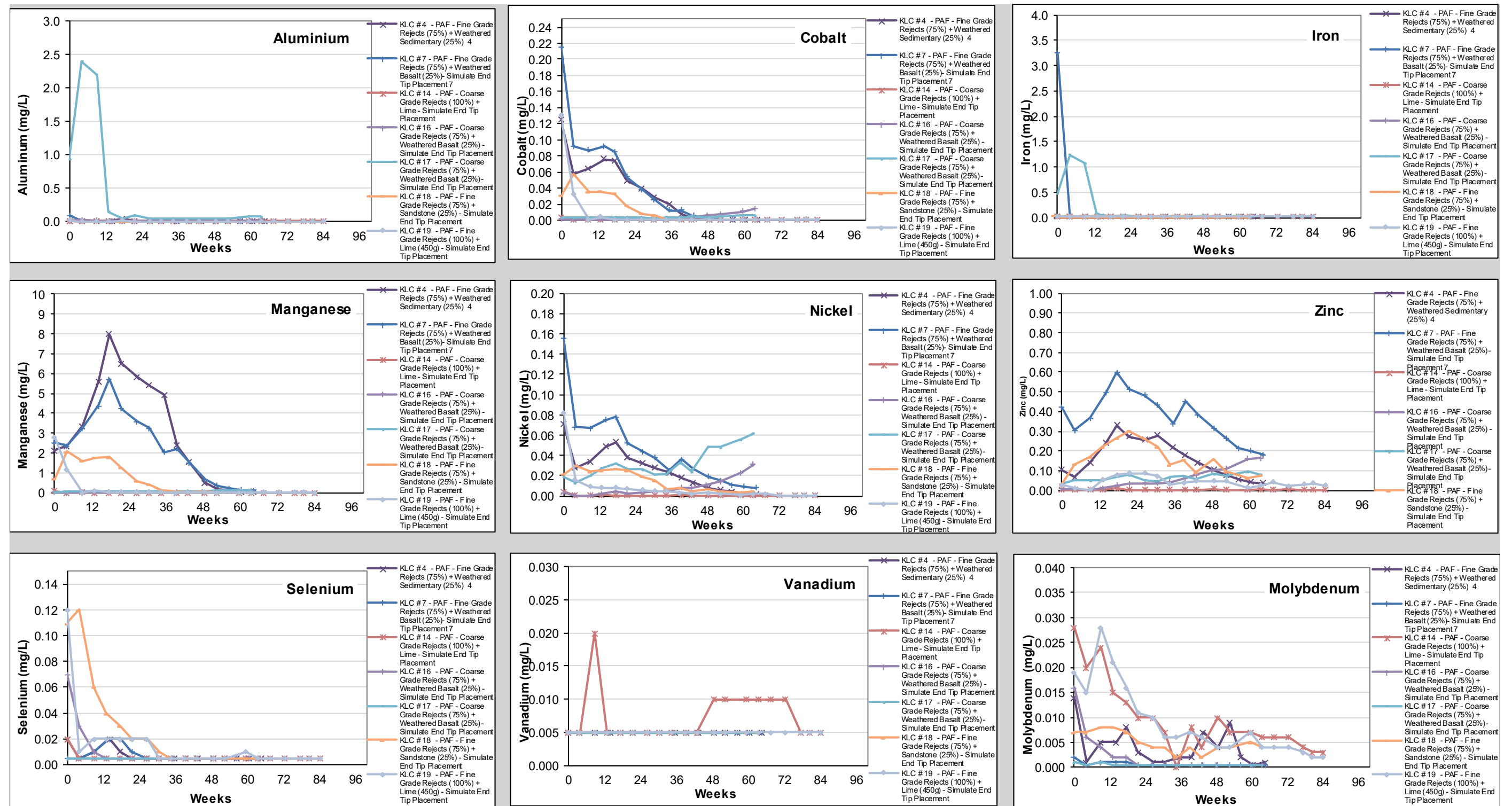


Figure 4-8: KLC results for overburden bearing samples mixed with reject

5 ES5 WATER QUALITY MODELLING

Golder Associates (Golder) was engaged by TEC Coal in 2016 to develop a mass balance integrated water model using Goldsim (herein referred to as the IWM) to evaluate future water quality aspects. A mass balance model is a simplistic numerical simulation of a highly complex (and mostly unknown) bio-geo-chemical system and by its very nature can only be used to infer potential environmental situations.

Aqueous phase inputs to the model were derived by RGS and Golder from average measured water quality data. For example, the average water quality data from the samples collected from Ramp 7 and Bullgang Drain were used as the numerical input in the IWM for AMD entering the system at this location. In addition to the aqueous inputs, geochemical source terms were derived using KLC data.

The source terms utilised data derived from the KLC testing, presented in units of mg/kg/day. The density of the mine waste material is accounted for in the model. The assumptions in the derivation of the geochemical source terms for ash, coarse-grade rejects, fine-grade rejects, tailings, conglomerate, sandstone, weathered regolith (clay) and shale include the following.

- All mined materials are present in-situ under the same oxidised unsaturated conditions tested under laboratory conditions. This assumption will overestimate AMD production because under field conditions AMD producing material is progressively encapsulated and oxidation is therefore limited. Under field conditions tailings are maintained under saturated conditions and they are also subjected to reduced oxidation. Backfilled material placed into mined pits can be saturated as groundwater and surface infiltration or addition of process water are added to the system. Under these conditions the oxidising environment will revert naturally to anoxic and reducing conditions whereby a range of chemical conditions change the speciation and fractionation of the major ions and metal(oids): for example, under reducing conditions sulfate can be reduced to sulfide.
- In the application of source terms each day, a sample assumed to be present under oxidising conditions in a waste dump has the potential to oxidise and release a given mass (g) of soluble weathering products (eg. acidity, salt or metals) from each tonne of material. This approach can overestimate solute mobility from the solid phase to the aqueous phase for a number of reasons including:
 - o The release of major cations (eg. sodium, calcium, potassium and magnesium) from the solid phase is governed by cation exchange processes, which mean that these cations are adsorbed or desorbed between the solid and aqueous phases to maintain equilibrium in the porewater. As such, sodium will not in effect be released from the solid phase at a fixed rate unless some of the sodium has been removed from the system in the aqueous phase. This requires contact between the solid phase and aqueous phase and this only occurs when there is above average rainfall that provides sufficient movement of rain into the regolith. This process is further limited by the fact that water does not percolate evenly through the natural regolith or constructed mine waste dumps.
 - o Sulfide minerals undergo a complex series of reactions due to oxidation around the surface of the minerals including the formation of secondary soluble and sparingly soluble minerals (e.g. Jarosite) that are subsequently released to the aqueous phase if the minerals come into contact with water. The assumption in the source terms is that sulfur is released at a given rate based on KLC data, but this assumption is likely to overestimate the solute inputs to the mass balance model.
- There are no geochemical reactions such as precipitation, hydrolysis or cation exchange taking place within the solid/aqueous matrix. Because of this the concentration in the mass balance may be overestimated.
- The hydraulic process in the mass balance model utilise the AWBM model (refer to Golder, 2018). The primary mechanism of recharge to groundwater within backfilled pits is via percolation of rain via preferential flow. Other hydro-geochemical assumptions include the following.
 - Within each cubic metre of material 20% are pore voids that represent active surface area within the matrix.
 - Of the 25% of pore voids 5% is reactive at any stage.

6 ES6 FINDINGS FOR MINE AREAS

6.1 North-West Backfilled Pit (NWBFP)

The data trends of the AMD from Bullgang Drain and Ramp 7 suggest that the magnitude of the acidity and dissolved metals concentrations is decreasing, although longer data measurement of the water as close as possible to the actual seepage sources is needed to confirm this trend. RGS expects that the acidity and metal concentrations in seepage will continue to decrease over time. Notwithstanding, the pH of the seepage water is likely to continue to be in the pH range of 3 to 4 for many years (but the acidity and associated metals will decrease) before the AMD is leached from the system, unless active management is implemented in this area of the mine.

The NWBFP began seeping AMD at Ramp 7 and Bullgang Drain at about 2 ML per day from mid-2013, which is when the water level in the pit reached pre-mine topographic low points around the rim of the pit (refer to JBT, 2018). A source of the water in the NWBFP is due to the addition of entrained water in the tailings that was emplaced into the North-West A and North-West B pits from about 1995 to December 2017. Without the addition of the tailings water to the NWBFP the water level in the pit is likely to have been lower than the topographic spill points and there may not have been a continual release of water at Ramp 7 and Bullgang Drain: evaluation of the IWM would verify this assumption by determining the volume of water that was pumped to the NW pits from the tailings stream over the life of the mine.

When RGS commenced work at this site, it was thought by Meandu Mine personnel that the AMD may be due to water being squeezed out of the tailings that had been deformed vertically during backfilling of North-West A pit. This has been discounted by RGS because:

- There is no evidence of acidic drainage in tailings from the K2TSF that operated early in the mine life.
- KLC testing of tailings, that had been exposed for at least two years, collected from North-West A by EGi over 12 months in 2007 proved that the tailings retained neutral pH over 12 months.
- There is no evidence from KLC testing undertaken by RGS over 14 months that acidic drainage is likely from tailings within this time period under laboratory-controlled conditions.
- The low sulfide content and fine-grained physical nature of the tailings encouraged moisture retention and limits oxidation.

RGS expects that the acidic drainage at Ramp 7 and Bullgang Drain is from the oxidation of sulfide minerals placed (predominantly) into RSA1 from circa 1986 to 1995 and may also be attributed to the oxidation of sulfide minerals in rejects that have been emplaced (and left open to atmospheric conditions for more than six months) into the NWBFP. Within the NWBFP water percolating through the spoil is contained within the backfilled void, and if the water level in the NWBFP is decreased, there would not be ongoing seepage from the pit. Nevertheless, because rejects in RSA1 were placed onto natural ground in between Ramp 7 and the edge of the North-West A open pit, there have been acidic discharges from RSA1 to Ramp 7 over the life of mine: in 1995 there was a documented AMD event at this location. Further mitigation in RSA1 may be required to either neutralise the acidity in-situ or reduce entry of water to the rejects to reduce seepage from the area.

6.2 Central Pit

There is a large amount of spoil in Central pit that has been mined (in some instances) up to three times, as the depth of the coal mine is extended over time. Some of the previously mined spoil is therefore up to 30 years old. The spoil from Central pit has been placed into the NWBFP and the area in the NWBFP known as Hitachi Hill. RGS advised Stanwell to implement a site field-based pH and electrical conductivity screening method to test spoil and classify it as 'Indicative NAF' or 'Indicative PAF' spoil. The requirement for a field-based screening method is that the mining and placement of the spoil was and continues to be done in a rapid way that does not provide the long lead time to drill, sample and undertake complete ABA measurements. It was also assumed by RGS that if the spoil was 20 or 30 years old and had been rehandled several times over that period, that any sulfide minerals contained in the spoil would have oxidised and potentially generated reduce pH and elevated electrical conductivity values. Over 1,000 samples were collected and analysed using this

screening method. Several areas of low pH and or saline spoil were identified. This material was zoned in the mine plan and excluded from placement into the rehabilitation zone of the NWBFP.

In order to verify that this indicative screening method was working, RGS had nine test pits excavated to 4 to 5 m bgl on Hitachi Hill and collected three bulk samples from each test pit. The 27 samples were submitted for complete static test work and the results verified the veracity of the indicative screening method for rehandled spoil and confirmed that there is no PAF spoil placed into the rehabilitation zone of the NWBFP that is nominally a 6 m vertical 50 m horizontal zone of the cover system.

6.3 Queen West backfilled pit (QWBFP) and King 2 North (K2N) ash pit

In the QWBFP there is circum-neutral pH groundwater with elevated salinity. There is no acidic drainage issue in these pits. The nature and source of the elevated salinity that occurs in the region of the QW void/ spoil dump has yet to be confirmed. In the groundwater assessment undertaken by JBT Consulting a connection exists between the K2W ash disposal void and the QW void via a low point in the ridge between the two voids, which is at a RL of approximately 472 mAHD has been noted. In mid-2012, the level of ash in the K2W void rose above 472 mAHD, allowing for the possibility of seepage from the K2W void to the spoil within the QW void after this date. The salinity of the contained ash in the pit however is typically low but does vary depending on the water management measures being implemented at the power station.

In addition, JBT has also noted that the bores where the high electrical conductivity are recorded are all screened with regolith material rather than spoil. Given the relatively low electrical conductivity recorded in the spoil bores within the QW void, it is concluded that the QW spoil, at least in the location of the bores shown on Figure 50 (GW54A, GW54B, GW66) is not the source of the high electrical conductivity seepage.

Further, a review of aerial photos from 1999 (prior to development of the QW void) to 2016 undertaken as part of the groundwater investigations does not reveal a potential source of the high electrical conductivity seepage. This assessment noted that given the relatively rapid development of the QW void (a review of historic aerial photos indicates that the QW pit was absent in August 2002 (i.e. extraction of coal had not occurred), visible in June 2003 and dumped over by July 2004) it is possible that material with the capacity to generate high electrical conductivity seepage (e.g. coal rejects) was dumped within the out-of-pit spoil at a location that was not recorded and/or visible in available aerial photographs. A review of available data has not confirmed the exact location and nature of the source material for the high electrical conductivity EC water that occurs in the region of the QW void/ spoil dump. Further analysis and recommended monitoring of the high EC area has been documented in JBT (2018) as part of this environmental investigation.

6.4 King 2 East (K2E)

This pit will become a final residual void that will contain water beyond closure. There has been extensive static and kinetic geochemical testing of material from the highwall in this pit. The static testing verifies that at least two thirds of the samples, including the coal are NAF and that the majority of the PAF material is present in the coal (**Figure 8**). There is an extensive history of water present in this pit and the data verifies that the water body has retained circum-neutral pH and low to moderate salinity. The water model provides the end of mine life water balance and water quality (Golder, 2018).

6.5 King 4 East (K4E) and King 4 South (K4S)

The static geochemical testing verifies that half to two thirds of the samples including the coal are NAF and that the majority the PAF material is present in the coal (**Figure 9**). The breakdown in the material balance is consistent with K2E. There is an extensive history of water present in this pit and the data verifies that the water body has retained circum-neutral pH and low to moderate salinity.

K2E	Waste Class						
Lithology	AC	NAF	NAF-UC	PAF-UC	PAF-LC	PAF	# Check
Basalt		5	1				6
Carb.Siltstone	1	1		1	2		5
Clay		2	14	1	15		32
Claystone	1	5	16	1	7		30
Coal		1		4	5	22	32
Conglomerate	3	10	6	1			20
Sand		1	5				6
Sandstone	2	45	37	2	12		98
Shale			1	2			3
Siltstone	1	44	13	14	11	2	85
Soil			3				3
	8	114	96	26	52	24	320
	NAF Summary			PAF Summary			
	218			102			

Figure 8: K2E static geochemical analyses

K4E	Waste Class						
Lithology	AC	NAF	NAF-UC	PAF-UC	PAF-LC	PAF	# Check
Basalt			1				1
Carb.Siltstone		4		18	5	1	28
Coal							0
Claystone			9	9	1		19
Conglomerate		10	3				13
Sandstone		18	48	3	9		78
Shale		33		32	1	1	67
Siltstone		16	14	17	8		55
Soil				2			2
	NAF Summary			PAF Summary			
	156			107			

K4S	Waste Class						
Lithology	AC	NAF	NAF-UC	PAF-UC	PAF-LC	PAF	# Check
Basalt	2	10		2			14
Carb.Siltstone			1	1			2
Coal				1	8	8	17
Lignite						2	2
Clay		7	14		1		22
Claystone		4	5			1	10
Conglomerate		1	1				2
Sand		1					1
Sandstone		25	17	11	7		60
Shale		17		7	2		26
Siltstone		8	3	2	7	1	21
Soil				1			1
	NAF Summary			PAF Summary			
	116			62			

Figure 9: K4E and K4S static geochemical analyses

7 ES7 Conclusions

7.1 Acid drainage potential

The production of acidic drainage from mine waste materials is a function of the sulfide content and sulfide mineral morphology, the particle size distribution (and associated porosity) of the material, and the way the materials are mined, stored and managed.

The static analytical program has verified that in general terms the coal, overburden and interburden has very little acid neutralising capacity and therefore some sample within even minor sulfide content have the potential to oxidise and produce acidic drainage. The sulfide content of coal from Meandu Mine was plotted using isopachs and was confirmed to be low with most coal samples having less than 0.3% total sulfur. The static geochemical analysis results also verified that some potentially acid forming samples are present within the major lithological units (e.g. sandstone).

It was originally thought that AMD seepage from Ramp 7 and Bullgang Drain may have been due to porewater being squeezed directly from the tailings. RGS have shown however that this is not the case with over 14 months of static and kinetic leach cell testing of tailings verifying that tailings continue to generate neutral pH drainage.

RGS have determined that the most probable cause of historic and ongoing AMD events from North-West A and North-West B landform (known as Hitachi Hill) was oxidation of sulfide minerals and subsequent leaching of AMD weathering products from the reject storage. Reject materials collected from the re-exposed area in Hitachi Hill were initially pH neutral but become acidic within six months of exposure to oxidising conditions. KLC testing of this material confirmed that after oxidation, solute concentrations decrease rapidly. Hence, under free draining conditions it is expected that the weathering products from this material will be removed from the system quite rapidly.

Fresh coarse reject material had a six-month lag period until the onset of acid production. The fine-grade rejects, tailings and ash maintained neutral pH over the test period of 14 months. The weathered clay samples had acid leachate from the first leach cycle but this acidity is due to soluble aluminium and manganese not sulfide oxidation processes. The PAF sandstone material used in the KLC testing program produced acid leachate within one month. This sample selected for the KLC program is not representative of sandstone in general (refer to **Figure 1** that clearly shows sandstone is predominantly NAF or AC) but does provide an example of how some PAF material could behave.

The current Meandu Mine management practice of limiting storage/exposure time of coarse reject materials at the reject stockpile to less than two weeks appears to be an effective way of controlling the risk of acidic drainage generation. The potential for oxidation will be further reduced through the incorporation of fine-grade rejects and tailings when the dewatering process is implemented at site, whereby pore voids within the coarse rejects will be filled with highly plastic low permeability tailings limiting oxidation and permeability. The combined reject and tailings stream will be placed into the spoil dumps and progressively co-mingled or encapsulated with NAF overburden and interburden. The PAF overburden units identified in the highwall during mining will be segregated and placed at least 6 metres under the final landform and covered by PAF material by truck and shovel mining methods. If acidic drainage is perceived as an ongoing issue, then supplemental liming could be considered, but in is unlikely to be required. Ongoing drilling, sampling and analysis will be continued to improve the reliability of the overburden model so that PAF units can be identified ahead of mining and managed appropriately. Sampling of reject, tailings and ash streams should be continued into the future for basic geochemical test parameters to ensure the geochemical nature of the mine waste is tracked over time.

7.2 Saline drainage potential

Saline drainage can be attributed to sulfate released from the oxidation of sulfur bearing mine waste and overburden units but can also be from the mobilisation of sodium chloride from Tertiary and Triassic overburden and interburden. Saline drainage will continue in the absence of acidic drainage and acid bearing minerals. Whilst acidic drainage can be neutralised, saline drainage can only be managed through dilution or concentration. The potential for the concentration of the salts (dominated by sodium, calcium, sulfate and chloride) in seepage to significantly contribute to environmental harm should be evaluated, before serious consideration is given to whether the implementation of water treatment solutions is required.

7.3 Metalliferous drainage potential

Metalliferous drainage is mostly associated with acidic sulfide bearing minerals. However, the ash data verifies that some materials with neutral pH can leach anionic elements such as lithium, molybdenum and vanadium. The primary metals and ions in the AMD at Ramp 7 and Bullgang Drain include:

- aluminium (n=33 and avg. 0.56 mg/L)
- cobalt (n=31 and avg. 0.699 mg/L)
- iron (n=33 and avg. 98.79 mg/L)
- manganese (n=33 and avg. 31.19 mg/L)
- nickel (n=31 and avg. 0.512 mg/L)
- zinc (n=31 and avg. 4.26 mg/L)
- sulfate (n=37 and avg. 1,156 mg/L)
- sodium (n=37 and avg. 360 mg/L)
- chloride (n=37 and avg. 303 mg/L).

The KLC data reflect the parameters contained in the AMD at Ramp 7 and Bullgang Drain, with the exception of Li, Mo and V present at low concentrations in the ash, and the presence of uranium that has increased from 0.010 mg/L to 0.191 mg/L in the PAF sandstone sample (KLC 22). Uranium was not present in other materials and is considered anomalous within the mine materials.

7.4 Closing recommendations

In the opinion of RGS, the AMD issues at Meandu Mine are relatively minor and can be managed through the implementation of changes to the mining and placement of mined materials. The removal and treatment of water from the NWBFP with lime will reduce the water level at this location and remove the accumulated weathering products from the groundwater. Because tailings water will no longer be placed into the NWBTSEF, recharge to the groundwater system in this pit will be limited to surface infiltration of rain through the backfilled spoil.

The RSA1 area may need further work to reduce the potential for intermittent above average rainfall events to leach AMD from this area. Recommended actions could include liming the dump and re-instating a deeper soil cover system subjecting to the results of monitoring of the Bullgang Drain and Ramp 7 water as the North-West Backfilled Pit water level is lowered.

The residual water void that will be present at Meandu mine will be the K2E pit. This pit will become a final residual void that will contain water beyond closure. There has been extensive static and kinetic geochemical testing of material from the highwall in this pit. The static testing verifies that at least two thirds of the samples, including the coal are NAF and that the majority of the PAF material is present in the coal (**Figure 8**). There is an extensive history of water present in this pit and the data verifies that the water body has retained circum-neutral pH and low to moderate salinity. The water model provides the end of mine life water balance and water quality (Golder, 2018). Further geological modelling and geochemical characterisation work could be undertaken on what will be the final pit wall at the end of the mine life to ensure that the inputs to the residual water void are understood (in detail). This can be accommodated through defining the final extent of the pit shell and drilling, sampling and analysis of the samples to verify the geochemical and physical properties of the final pit wall.

8 References

RGS (2015). *Understanding mine waste geochemistry in the Bowen Basin: from exploration to mine closure*. In proceedings of the Bowen Basin Symposium, Ed. JW Beeston, pp473-480, 7-9 October.

RGSG



LEADERS IN MINING
GEOCHEMISTRY

APPENDIX

F

Contaminant Hydrogeological Assessment



Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Suitably qualified person

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. This Statutory Declaration must be completed by the person who conducted the environmental evaluation and accompany the environmental report submitted to the Department of Environment and Heritage Protection (the department).

Oaths Act 1867

**QUEENSLAND
TO WIT**

I John Bradley
Insert the name of the person making this declaration
of 5/12 Greendale Way Carindale QLD 4152
Insert the street address of the person making this declaration

in the State of Queensland do solemnly and sincerely declare that:

- I am the suitably qualified person and author of an environmental report entitled
Stanwell Corporation, Meandu Mine - Environmental & Engineering Evaluation Project – Groundwater
Data Review and Conceptual Groundwater Model

Insert title of the environmental report

In accordance with the environmental evaluation issued by the department under the Act to:

TEC Coal Pty Ltd

21 December 2016

Insert name of recipient of the notice

Insert date of the notice

A copy of my report is attached to this statutory declaration and marked "A".

I possess the following qualifications and experience relevant to this environmental evaluation:

B App. Sci (Geology Hons), MSc. (Hydrogeology and Groundwater Management)

Principal Hydrogeologist – JBT Consulting Pty Ltd

JB

GE Rose 10/9/18

Statutory Declaration
Suitably qualified person

I have not knowingly included any false, misleading or incomplete information in the report; and

I have not knowingly failed to reveal any relevant information or document to the department.

I certify that:

- The report addresses the relevant matters for the evaluation and is factually correct; and
- The opinions expressed in it are honestly and reasonably held.

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at

BRISBANE

Insert location

this

10th

day of

SEPTEMBER

in the year

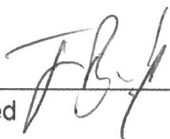
2018

Insert day (e.g. 18th)

Insert month

Insert year

Signed



(Person making this declaration)

Signed



C/- Justices of the Peace Branch
Level 6/154 Melbourne Street
South Brisbane QLD 4101
Ph: 1300 301 147
E: jp@justice.qld.gov.au

GERALDINE
ELIZABETH
ROSE

Printed name and registration number (if applicable)



STANWELL CORPORATION

MEANDU MINE

**ENVIRONMENTAL & ENGINEERING
EVALUATION PROJECT**

**GROUNDWATER DATA REVIEW
AND
CONCEPTUAL GROUNDWATER MODEL**

September 2018



JBT01-012-059

RECORD OF ISSUE

File Name	Description	Issued to:	Date Issued	Method of Delivery
JBT-012-059	Final	A. O'Kane	7 September 2018	email

JBT Consulting Pty Ltd

John Bradley
PRINCIPAL HYDROGEOLOGIST

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1.0 INTRODUCTION

1.1 Background

On 21 December 2016, the former Department of Environment and Heritage Protection (EHP) (now Department of Environment and Science (DES)) issued TEC Coal Pty Ltd (a subsidiary of Stanwell) with a notice to conduct or commission an environmental evaluation under Section 326B of the *Environmental Protection Act 1994* (EP Act) (the Notice).

The grounds for the environmental evaluation relate to the identification of acid and metalliferous drainage (AMD) at Meandu Mine (refer to Figure 1 for location) and the potential for this AMD to cause environmental harm. As the full nature and extent of the AMD was unknown, EHP (now DES) required that an environmental investigation be undertaken to determine whether environmental harm has occurred as a result of AMD at the Meandu Mine. AMD was identified as reporting by overland flow to retention dam 7 (RD7) in the retention dam network on the western side of the mine, where it was mixing with other mine affected water. Water from RD7 flows to RD8 where it is either re-used for site purposes or reports to the Meandu Creek Dam via release (compliance) point CP3. AMD reporting to RD7 is believed to be originating from two closely associated seepage locations:

1. Bullgang Corner, located approximately 600 m south-east of RD7; and
2. a covered (vegetated) coal rejects area between Ramp 7 and the western side of the North West (NW) A tailings void (NWA tailings).

Specifically, the Notice requires that investigations are undertaken to:

1. Determine whether environmental harm has occurred as a result of AMD at Meandu Mine.
2. Identify and characterise the AMD and material with potential to generate AMD in the North-West tailings void/ spoil dump and rehabilitated rejects to assess the extent of environmental harm likely to be caused by the AMD; and to determine the effects of AMD ingress to stored historical tailings (e.g. potential dissolution of metal contaminants in the tailings which may be transported to the receiving environment in the seepage).
3. Identify other locations at Meandu Mine where AMD is occurring; and to identify potential AMD source materials at Meandu Mine.
4. Determine the potential for AMD related environmental harm (acute and/or chronic impacts on the aquatic ecosystem and other relevant water quality objectives (WQO's)) that could occur from future (ongoing) activities at Meandu Mine, including potential impacts from:
 - build-up of metals in sediment downstream of Meandu Creek Dam
 - elevated metal concentrations in Meandu Creek waters
 - alteration of the pH of Meandu Creek Dam waters and release of sediment bound contaminants to the downstream environment
 - elevated salinity levels in Meandu Creek waters.

To address the requirements of the Notice, Stanwell has commissioned an Environmental and Engineering Evaluation (the EEE Project) into AMD at the Meandu Mine site. This investigation incorporates studies across of range of technical disciplines including:

- mine planning and life of mine (future) (Xenith Consulting)
- material classification assessments (geochemical) (RGS Environmental Pty Ltd)
- hydrogeological assessments (JBT Consulting) (this assessment)

- surface water quality, sediments and aquatic ecology investigations (Ecological Services Professionals Pty Ltd)
- water modelling and development of engineering solutions (Golders Associates Pty Ltd).

1.2 Environmental Evaluation Notice Requirements

Stanwell commissioned John Bradley of JBT Consulting (JBT) in December 2016 as the appropriately qualified person (as per the requirements of the Notice) in matters relating to groundwater for the EEE Project. The requirements of the Notice that relate to groundwater are outlined in Table 1-1. Table 1-1 also contains reference to where the Notice requirements are addressed in this report, or identifies the technical studies that have been undertaken by other consultants to address the requirements.

Table 1-1: Environmental Evaluation Notice Requirements

Environmental Evaluation notice requirements	Report Section
1. A summary of groundwater quality data relevant to the investigation.	• Section 5.4 presents and discusses the general and AMD chemistry of groundwater and selected surface water sites.
2. Identification and characterisation of the groundwater environmental values (EV's) for Meandu Creek that may be impacted by AMD from Meandu Mine.	• Section 4 of this report discusses the environmental values for groundwater • Detailed discussion of the environmental values for Meandu Creek is contained within the Ecological Services Professionals (ESP) report.
3. Studies to determine the presence and extent of AMD at Meandu Mine, which must include: • contaminant hydrogeological investigations inclusive of drilling and installation of monitoring bores (if required); • investigations to identify physical and/or environmental influences relating to storage areas (coal rejects, overburden, waste rock and topsoil) that may determine the occurrence, rate of progression or volume of AMD generated at Meandu Mine, for example ...water infiltration and drainage characteristics; • a dedicated site plan showing the location and extent of AMD at Meandu Mine, including existing seepage flow paths.	• Section 3 discusses the groundwater monitoring network, including the installation of an additional 11 bores to support the AMD investigation) • Section 5.5 presents the results of geophysics investigations, which were undertaken to provide additional information on site hydrogeology, including identification of seepage pathways. • Section 6.0 presents a discussion of mechanisms for seepage, including identification of seepage pathways for AMD from the NW void. • The characterisation and classification of material types (rejects, overburden, waste rock etc.) is discussed in the RGS Environmental report.
4. Studies to determine whether AMD at Meandu Mine has impacted on or has the potential to impact on the environmental values of groundwaters including Meandu Creek. These studies must include: • water quality investigations to determine any impacts on environmental values of groundwater and surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine; • water quality investigations to determine future impacts on environmental values of groundwater and surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine; and • identify short-term and long-term measures including (if relevant) further lines of investigation, monitoring requirements and operational or mine planning measures that should be developed and/or implemented to prevent environmental harm occurring from AMD at Meandu Mine.	• Section 5.4 presents and discusses water quality data (surface water, AMD seepage water and groundwater) and to establish the extent of existing and potential future impacts. • Section 9.0 presents and discusses short-term and long-term mitigation measures to prevent environmental harm from AMD via the groundwater system.

Environmental Evaluation notice requirements	Report Section
5. A predictive model for Meandu Mine in relation to potential AMD impacts ... which must include ... • mine water modelling that takes into account ... groundwater and in-pit and in-mine spoil water; • potential contaminant pathways; • ... model the dissolution and transport of metals to the receiving environment from Meandu Mine; • capacity to predictively model water quality impacts from AMD on groundwater and Meandu Creek.	• JBT has provided groundwater-related liaison, input and review to the Goldsim model that was prepared for the EEE Project by Golder Associates (Golder).

1.3 Report Structure

The report has been structured as follows:

- Section 2.0 presents a summary the regional and mine-scale geology and hydrogeology.
- Section 3.0 presents a summary of the groundwater monitoring network at Meandu Mine.
- Section 4.0 discusses the environmental values for groundwater within the Meandu Creek and Black Creek catchments.
- Section 5.0 presents and discusses available data for the review, including:
 - Section 5.1 – Available data;
 - Section 5.2 - Rainfall data;
 - Section 5.3 - Groundwater level data;
 - Section 5.4 - Groundwater chemistry data; and,
 - Section 5.5 - Geophysics data.
- Section 6.0 presents an analysis of seepage pathways and/or areas of potential groundwater contamination from the NW void to areas such as Bullgang Corner and Ramp 7. This AMD seepage, which ultimately reports to RD7 then RD8 via Bullgang Drain, is the main focus of the EEE Project and this report;
- Section 7.0 presents a summary of two other groundwater areas that have been identified during the process of analysis for the EEE Project, including:
 - A high electrical conductivity (EC) groundwater plume that occurs down-gradient of the QW void; and,
 - An area of potential groundwater contamination within the Black Creek catchment.

It should be noted that both of the areas above have been assessed as being unrelated to AMD processes and separate monitoring requirements have been recommended for each area (discussed in Section 11).

- Section 8.0 presents the conceptual groundwater model for the site,
- Section 9.0 presents and discusses short-term and long-term measures for control of groundwater seepage as well as recommendations for further investigations and monitoring.
- Section 10.0 presents a summary and conclusions from the groundwater investigation; and,
- Section 11.0 presents recommendations for further work arising from the study.

2.0 GEOLOGY AND HYDROGEOLOGY

2.1 Regional Geology

2.1.1 Surface Geology and Structure

Figure 2 shows the surface geology (at 1:100,000 scale) of the project area. Observations from Figure 2 include:

- The Meandu Mine is located within an area where the Tarong beds (the host unit for the coal seams that are mined at Meandu) occur at surface.
- In the southern area and central-eastern area of Meandu Mine, deposits of Tertiary basalt occur at surface. In the central-eastern area of the Meandu lease the basalt occurs as remnant ridge-top deposits, with the basalt tending to be dry (i.e. containing no groundwater). To the south the basalt thickens, and groundwater is known to occur within isolated fractures that are exploited at some locations for landholder groundwater supply.
- Quaternary alluvial deposits are associated with ephemeral creeks including Barker Creek and Meandu Creek (which are part of the Burnett River catchment) and Rocky Creek and Yarraman Creek (which are part of the Brisbane River catchment). The divide between the two catchments is defined by the line of ridge-top basalt that can be seen extending from south-west to north-east through the central-east area of the Meandu Mine (as described above).
- The approximate western and eastern limits of the Tarong Basin (the host basin for the Meandu Mine) are shown on Figure 2. These limits are based on interpretation of the boundary between the Boondooma Igneous Complex (Permo-Triassic intrusives) to the west, the Maronghi Creek beds to the east, and sediments of the Tarong beds in the Meandu Mine area (formation of the Tarong Basin is discussed below in Section 2.1.2).
- The location of mapped faults (from the mine geological model) are shown within the Meandu Mine area. The strike of the faults is generally north-west/ south-east, consistent with the margins of the Tarong Basin. The faults significantly disrupt the west-east continuity of the coal seams at Meandu Mine, as shown in the cross sections that are presented as Figures 6 to 9 and discussed below in Section 2.2.

2.1.2 Formation of the Tarong Basin

As noted above, the Meandu Mine is located within the Tarong Basin, a Triassic-age pull-apart basin. An appreciation of the extent of the Tarong Basin, especially the western and eastern extents, is deemed important for this study as the basin margins provide a limit to the western and eastern extent of groundwater flow within the groundwater units that occur at Meandu Mine and assist in understanding the regional groundwater flow directions. Three stages in development of the Tarong Basin have been described in Flood and Garces (1986) and are shown on Figure 3. The stages comprise:

- Stage 1 – a strike-slip fault is developed with a north-west/south-east orientation. The fault has a regional kink shown in the area where the Tarong Basin will later develop. To the west are located granitic rocks of the Boondooma Igneous Complex, while to the east are developed meta-sediments of the Maronghi Creek beds. The direction of paleo-drainage is from west to east.
- Stage 2 – The Tarong Basin starts to open up due to movement along the strike-slip fault. On the western side of the fault, rocks of the Boondooma Igneous Complex moved in a relative north-west direction, while to the east of the fault, metasediments of the Maronghi Creek beds moved in a relative south-east direction. As the basin started to open up, the central area of the Basin

began to subside and the deposition of sediments, which were derived from the basin margins, commenced. The dominant direction of sedimentation was from the west.

- Stage 3 – Increasing sedimentation from the west resulted in deposition of an alluvial fan complex that is known as the Tanduringie Fan (Flood and Garces 1986). Peat swamp depressions formed to the north and the south of the Tanduringie Fan, with coal deposits forming within the swamp environments as the basin widened and subsided further and sedimentation continued. The coal deposits to the south of the Tanduringie Fan are currently mined at Meandu Mine (i.e. the Tarong beds, which are up to 450 m thick at Meandu Mine (Pegrem 1986)), while the coal deposits to the north of the Tanduringie Fan are located within the area of the Kunioon deposit. There are no known coal deposits within the Tanduringie Fan between Meandu Mine and the Kunioon deposit and fan deposits can be seen at surface in road cuttings along the Tarong-Nanango Road (Pegrem 1986).

The maximum dimensions of the Tarong Basin are given by Pegrem (1986) as 30 km (wide) x 80 km (long), though in the Meandu Mine area the maximum width of the Tarong Basin is interpreted (by JBT for this report) to be in the order of 9 to 10 km.

2.1.3 Regional and Mine-Scale Hydrostratigraphy

The regional geological units shown on Figure 2 have been summarised in Table 2-1. The comments column of Table 2-1 includes a description of each geological unit, including a summary of known groundwater occurrence within that unit.

The mine-scale geology at Meandu Mine comprises, from surface downwards:

- Quaternary alluvium, including:
 - The Meandu Creek Alluvium, which comprises sand, silt and clay and is present in the south-west and west of the mining area beneath and immediately adjacent to Meandu Creek. Meandu Creek is ephemeral upstream of Meandu Creek Dam and has been diverted around the mining area.
 - The Rocky Creek Alluvium, which comprises sand, silt and clay and is present in the south-west and west of the mining area beneath and immediately adjacent to Rocky Creek. The unit is generally unsaturated within the Meandu Mine area as groundwater monitoring data indicates that the regional water table is below the base of alluvium.
- Tertiary basalt, which occurs as remnant ridge-top deposits in the Meandu Mine area. Water within the Tertiary basalt occurs within fractures and isolated sediments between basalt flows, but is generally unsaturated within the Meandu Mine lease area.
- Spoil, which comprises reworked material from coal mining. The spoil is variably saturated, containing perched water tables resulting from variable rates of recharge through the spoil material, as well as saturated zones at the interface between the base of spoil and underlying lower-permeability material. The thickness of mined spoil at Meandu Mine is shown on Figure 4.
- Regolith, which comprises the upper 20-30 m of Tarong beds and includes sandstone, siltstone, shale and conglomerate that have been weathered during the Tertiary. The regolith is generally unsaturated at site but may present a pathway for groundwater flow once adjacent areas (e.g. mined voids that have been filled with spoil or ash) become saturated to an extent that allows for exit from the voids via the regolith. An assessment of seepage pathways from the NW void is presented in Section 6.0.
- Upper Triassic coal measures (Tarong beds) comprising:

- Coal seams, which dip at approximately 5° to the south-east, and comprise (from upper to lower):
 - Ace Seam, which is typically oxidised and dry.
 - King Seam, approximately 60 m below the Ace Seam. This seam generally contains groundwater though the unit may be dry depending on the RL of the strata.
 - Queen Seam, a further 30 to 40 m below the King Seam, and generally containing groundwater.
 - Coal seams below the Queen Seam, which are not mined at site, but which occur beneath Meandu Creek in the western area of Meandu Mine in areas where the Queen Seam (and seams above) are absent due to the dip of the strata.

The sandstone/siltstone interburden between coal seams, which is generally described as being hydraulically “tight” and which is of lower permeability than the coal seams. Groundwater flow within the coal measures tends to occur within the coal seams rather than the interburden.

Table 2-1: Summary of Regional Geology and Hydrogeology

Geological Period	Geological Unit	Comment
Quaternary	Alluvium	• Within the Meandu Mine area, alluvial sediments of the Meandu Creek and Rocky Creek systems comprise clay, silt, sand and gravel. • The aquifers are variable in extent (width and thickness). Permeable zones are often discontinuous and the degree of hydraulic connection throughout the alluvium is variable. • Within Meandu Creek the aquifers are generally less than 5 m thick, but thickness of up to 35 m have been observed from drilling along Barkers Creek (Pegrem 1986). The alluvial plain is more extensive near the confluence between Barkers and Meandu creeks and the alluvium in this area is up to 30 m thick. • Within the Meandu Mine area, the alluvium within Rocky Creek is relatively thin and unsaturated, with a regional water table below the base of the creek. • The coarser materials (sands and gravels) within the alluvial sediments form aquifers which are exploited for irrigation supply and town water supply, particularly within the Barkers Creek alluvium and downstream of the confluence of Barkers Creek and Meandu Creek. • DNRM bore logs indicate that the alluvium upstream of the confluence between Meandu and Barkers creeks is more extensive than is shown by geological mapping (Figure 2), which was based largely on aerial photographic interpretation.
Tertiary	Basalt (Main Range Volcanics)	• The Main Range Volcanics comprise olivine basaltic flows and lesser pyroclastics. Basaltic flows are interbedded with minor siltstones, shales, sandstone, silcrete. The basalts tend to occur as ridge-cap deposits which tend to be deeply weathered. • Groundwater occurs within the secondary porosity of fractures, or between and beneath flows where minor strikes of water may occur within interflow sediments. It is noted that all groundwater monitoring bores within the adjacent Meandu Mine which monitor the basalt have historically been dry.
Tertiary	Laterite, residual soils and slope wash deposits	• This unit is used to broadly categorise Tertiary-age colluvial deposits, alluvial fans, pediment slope wash, clay, silt, scree, pebbles and cobbles, and regolith. • At Meandu Mine the Tertiary unit comprises a unit that is known locally as the regolith; the regolith comprises the upper 20-30 m of Tarong beds that have been weathered during the Tertiary and consists of weathered sandstone, shale and conglomerate. The regolith is generally dry, though the unit may become variably saturated following recharge.
Triassic	Tarong beds	• Regionally the Tarong beds comprise: ○ A main lithology of labile (arkosic to sub-arkosic), fine to very coarse grained, poorly sorted sandstones and matrix supported conglomerates. The conglomerates tend to be dominant towards the basin margins and the lower parts of the sequence (Pegrem 1986). ○ Minor lithologies that include shale, siltstone, mudstone and coal. At Meandu Mine the coal deposits are developed to an extent that is economic for mining, with mining undertaken of the: ▪ Ace Seam, which is typically oxidised and dry; ▪ King Seam, approximately 60 m below the Ace Seam. This seam generally contains groundwater though the unit may be dry depending on the reduced level (RL) of the strata; and ▪ Queen Seam, a further 30 to 40 m below the King Seam, and generally containing groundwater. ○ Located between the coal seams is the interburden, which comprises sandstone, siltstone and shale. The interburden is generally hydraulically "tight" and is of lower permeability than the coal seams; therefore, the coal seams are generally the water-bearing units at site.

Geological Period	Geological Unit	Comment
Permian-Triassic	Boondooma Igneous Complex	• The Boondooma Igneous Complex comprises pink medium to coarse-grained biotite-hornblende granite, minor quartz diorite. • The granite may provide useable volumes of water to private bores where the unit is weathered or fractured, though the unit is regarded as a basement unit of the Tarong Basin (Flood & Garces 1986).
Devonian-Carboniferous	Maronghi Creek beds	• The Maronghi Creek beds comprise mudstone, shale, arenite, chert, jasper, acid to basic metavolcanics. • Groundwater within the Maronghi Creek beds occurs within fractures that are interpreted to be discontinuous and hydraulically isolated. • Regionally, a number of private groundwater bores are developed within this unit, which has the potential to provide low yielding supplies of groundwater suitable for stock watering (based on salinity).
Devonian-Carboniferous	Sugarloaf Metamorphics	• The Sugarloaf Metamorphics comprise slate, spotted hornfelsed slate, phyllite, quartzite, schist, amphibolite. • A number of private groundwater bores are developed within this unit, which has the potential to provide low yielding supplies of groundwater suitable for stock watering (based on salinity). This unit is regarded as a basement unit of the Tarong Basin (Flood & Garces 1986).

2.2 Hydrogeological Cross Sections

Hydrogeological long sections and cross sections, presented as Figures 5 to 9, have been prepared to show the relationship between features of the Tarong Basin (such as the basin margins and the Tanduringie Fan) and the Meandu Mine area.

Figure 5 is a long section that extends from south of Meandu Mine to north of the Kunioon deposit, with the location of the section shown on Figure 2. Figure 5 includes two sections, which are described as follows:

- The upper cross section shows the pre-mining geology. The geology in the area of the Meandu Mine and the Kunioon Project is based on cross sections derived from the respective geological models, with the extent of each model shown on the figure. In areas that are beyond the extent of the geological models, the section information is based on interpretation by JBT of available topographic data, 1:100,000-scale geological mapping and information provided in Pegrem (1986) and Flood & Garces (1986) with respect to the location and nature of the Tanduringie Fan.
- The lower cross section shows the same information as the upper cross section, but includes the current (early-2017) extent of mining and deposition of spoil at Meandu Mine.

The following features are evident from review of Figure 5:

- In the Meandu Mine area, the Tarong beds extend to the south beneath Yarraman Creek. It is interpreted that recharge to the deeper coal seams such as the Queen Seam is likely to occur in this area.
- The topography reduces in elevation from south to north and the bedrock elevation also decreases from south to north (based on the base of coal measures modelled at both the Meandu Mine and Kunioon deposit). It is stated in publications such as Pegrem (1986) that the coal seams dip at shallow angles towards the south and south-east, away from the central area of the alluvial fan (Tanduringie Fan); however, due to local and regional-scale faulting and folding, the overall dip of the coal measures is to the north in the sections shown on Figure 5.

Figures 6 to 9 show west-east cross sections through the Meandu Mine area, from the northern area of the Meandu Mine lease (Figure 6 – West East Section 1) to the southern area of the mining lease (Figure 9 – West East Section 4). The section locations are shown on Figure 2. Figures 6 to 9 include three sections per figure, which are described as follows:

- The upper cross section shows the pre-mining geology. Included on the top section are:
 - the original topographic surface;
 - the original (pre-mining) geology;
 - the deepest mined surface (at early-2017);
 - The extent of data obtained from the Meandu Mine geological model. For areas that are beyond the extent of the geological model, the geology is based on interpretation by JBT of 1:100,000 scale geological mapping, with the location of the faulted margins of the Tarong Basin based on information provided in Pegrem (1986) and Flood & Garces (1986); and,
 - the current topography; this line may be above the original topographic surface in areas where spoil has been dumped, or below the original topographic surface in active mining pits or in pits that are only partially filled with spoil.
- The middle cross section shows the current (early-2017) natural and mined geology and includes:
 - lines as above showing the deepest mined surface and current topography;

- the current geology, which is a combination of pre-mining geology (in unmined areas) as well as post mining geology (i.e. in areas where there is a difference between the deepest mined surface and the current topography, the deepest mined surface has been infilled by either spoil, tailings, or ash disposal);
- the groundwater level in bores that are located along the section line (water levels at early-2017). It is noted that the water level in the spoil is relatively low, indicating that the spoil does not contain a significant mounded aquifer system to drive groundwater flow. Groundwater flow from areas of spoil is interpreted to occur in situations where the water level in the spoil rises above the elevation of areas that are relatively low in the landscape and from which outflow from the mined void may occur, such as haul roads or areas of prior drainage.
- The lower cross section shows the final landform, that is, the full extent of mining along each section and the areas that contain spoil (being the difference between the final deepest mined surface and the final topographic surface).

Observations from review of the west-east cross sections (Figures 6 to 9) are as follows:

- A series of north-west/south-east trending faults (as shown on Figure 2) significantly disrupt the lateral continuity of the coal measures. These faults have the potential to disrupt groundwater flow in cases where the throw of the fault is greater than the thickness of the coal seam resulting in, for example, the abrupt termination of a transmissive coal seam against lower permeability interburden.
- The overall dip of the coal seams is towards the east (away from the central area of the Tanduringie Fan, as noted in Pegrem 1986). However, the faulting has, in many cases, resulted in the western side of the fault dropping relative to the eastern side of the fault; therefore, while the coal seams may dip locally to the east, the throw on the faults tends to result in a situation where the RL of the coal seams are higher in the east relative to the west. This results in a potential for groundwater flow from east to west (i.e. towards Meandu Creek), which is against the general dip of the coal seams.

2.3 Groundwater Occurrence and Flow Direction

From review of available geological data, the following conclusions are made with respect to groundwater movement and flow direction:

- At Meandu Mine the dip of the coal seams is to the south and south-east (Pegrem 1986). However, as noted above the overall groundwater flow direction in the coal measures is interpreted to be towards the north-west (i.e. towards Meandu Creek). This is interpreted to be related to:
 - The overall reduction in topography from south to north within the Meandu Creek catchment, with topography exerting a control on groundwater flow.
 - The overall reduction in bedrock elevation from south to north within the section of the Tarong Basin where Meandu Mine, the Tanduringie Fan and the Kunioon deposit are located. The RL of the bedrock and topographic surface therefore also control the RL of the coal measures, with an overall reduction in the elevation of the base of coal measures from south to north.
 - The north-west/south-east trending faults that are present at Meandu Mine create a situation where, in some areas of the mine, the western side of the fault is downthrown relative to the eastern side, creating a potential for groundwater to flow in the opposite direction to dip.

- Based on the observations above it is concluded that groundwater flow direction within the coal measures is extremely complex and will be impacted by a number of factors including:
 - regional recharge patterns and localised (preferential) zones of recharge;
 - the dip of the coal seams;
 - faulting, which acts to:
 - locally alter the groundwater flow direction, with groundwater flow potentially occurring contrary to the direction of the dip of the coal seams; and
 - compartmentalise groundwater occurrence and perturb groundwater flow, due to the truncation of coal seams (the conduits for groundwater flow) against low-permeability interburden.
- The overall groundwater flow direction in shallow groundwater units (e.g. regolith, basalt, alluvium) is interpreted to be in the direction of topography. Therefore, it is interpreted that the overall groundwater flow direction is as follows:
 - For the shallow Tertiary units (Tertiary basalt and regolith) the groundwater flow direction is assessed to be in the direction of topography (i.e. from topographically elevated areas towards topographically lower areas and surface water drainage lines). It is also interpreted that the groundwater and surface water divides will be the same for the Tertiary units, i.e. the surface water and groundwater flow direction will tend to be to either side of the catchment divide that is shown on Figure 2.
 - For the Meandu Creek alluvium, it is noted that Meandu Creek is a naturally ephemeral system and remains ephemeral upstream of the Meandu Creek dam (below the Meandu Creek Dam the creek is perennial due to regular dam discharges). Upstream of Meandu Creek Dam, groundwater within the alluvium, which may be present due to seasonal recharge or mine seepage, will flow in a downstream direction within the alluvial channel but may also seep downwards in areas where the regional water table is below the base of the creek;
 - For the Triassic coal measures, the overall groundwater flow direction is towards Meandu Creek. It should be noted that, for the coal measures, the groundwater divide is not the same as the surface water divide. For example:
 - Figure 5 shows a long section from south to north through Meandu Mine. The surface water divide is shown at the top of the basalt ridge and the groundwater flow direction within the basalt could be expected to be to either side of the divide that is formed by the basalt ridge. However, the underlying coal measures are interpreted to be recharged further south (i.e. in the vicinity of Yarraman Creek) with groundwater flow occurring to the north; therefore, the groundwater divide is further south than the surface water divide.
 - For the cross sections shown as Figures 6 to 9, the groundwater divide occurs to the east of the surface water divide and it is interpreted that groundwater within the coal measures to the east of the surface water divide will flow either to the west or to the north-west and ultimately towards Meandu Creek.

3.0 GROUNDWATER MONITORING BORE NETWORK

The current groundwater monitoring bore network at Meandu Mine comprises 63 bores at 50 sites (i.e., at a number of sites there are a shallow and deep bore that each monitor different groundwater units). The network has been developed on an ongoing basis since 1993 and includes:

- Historic bores - bores that were drilled in 1993 following a recommendation on the development and siting of a groundwater monitoring bore network (AGC Woodward-Clyde 1993). Bores that were drilled under this program were designated GW1 to GW22, though not all bores in the series were drilled, and bore construction logs have not been located to date. However, the AGC Woodward-Clyde (1993) report contained specifications for bore construction that included gravel packing and sealing of the annulus, therefore it is assumed that the bores were constructed in accordance with the specifications provided. These bores were sampled for water level and water quality on an irregular basis between 1993 and 2011. Monitoring of these bores was discontinued following a 2011 groundwater monitoring network review based on the observation that construction details (e.g. bore depth, screened interval) was unknown. During 2016, a number of historic bores were inspected via down-hole bore camera to establish the bore depth, screened interval and overall bore condition (Streamline Hydro 2016). Following the inspection, as well as a review of drilling records to establish the screened lithology, a number of historic bores were re-added to the monitoring schedule to allow comparison between current and historic groundwater quality at these locations. The bores that were re-added to the monitoring program include GW01, GW02, GW05, GW09, GW11, GW21, GW22, GW25 and GW30 (it is noted that GW25 and GW30 were drilled during a later program, though the construction dates are unknown).

Bore GW05, which is a historic bore, was included as part of the K2W monitoring network and has been regularly monitored for groundwater level and groundwater quality data from August 1993 to present.

- K2W bores - bores that were drilled in September/October 2008 as part of a network to monitor for seepage from the K2W ash disposal facility (AGE 2008). These bores include the series between GW50 and GW62 (Table 3-1). A number of bores in this series, including GW52A, GW54B and GW59B, have been destroyed by the progression of mining and were re-drilled at nearby locations.
- Hydrocarbon monitoring bores - bores that were drilled in April 2011 in areas that were down-gradient of historic hydrocarbon storage and treatment areas as well as sites within Meandu Creek that are down-gradient of mining. These bores include the series between GW33 and GW40.

Bores GW41 and GW42 were drilled in June 2013 to monitor groundwater conditions down-gradient of the tailings dam (in the case of GW42) and in an area of spoil adjacent to the Meandu Creek diversion (in the case of GW41). The sections of Meandu Creek that have been diverted from the original stream bed area shown on Figure 17.

- SRE (surface rights extension) area bores - bores that were drilled in February 2014 to monitor groundwater conditions in the area east of the current surface rights area. These bores include the series GW43 to GW46. Additional bores were added to this area of the network in July 2015, including bores that were drilled to monitor groundwater conditions in the Maronghi Creek beds to the east of the mining operation; these bores include the series GW62 to GW65.
- EEE bores - bores that were drilled in August 2016 to provide additional data in areas that are down-gradient of prior voids and spoil dumps and to provide further information to support the EEE Project. These bores include the series GW66 to GW78.

The bores listed above are all constructed as standpipe piezometer bores and are utilised for both water level and water quality sampling.

Summary data (bore ID, location, construction details, lithology screened) for groundwater bores that are currently used for monitoring of groundwater levels and potential groundwater quality impacts at

Meandu Mine are shown in Table 3-1. The layout of the current monitoring bore network is shown on Figure 10. Table 3-1 includes colour-coding of the screened lithology to make the identification of the monitored unit easier; this colour-coding is consistent with the symbol colours shown on Figure 10.

It should be noted that a number of bores that are identified in Table 3-1 have been decommissioned since the study commenced; these bores are identified with an asterisk (*) in Table 3-1.



Table 3-1: Summary Details for Current Groundwater Monitoring Bores

Bore ID	Easting (AGD84)	Northing (AGD84)	Collar RL (mAHD)	Depth (m)	Slotted Interval		Gravel Pack		Lithology Screened	
					From	To	From	To		
GW01	388907	7035284	430	32.7	21.12	31.97	19.12	31.97		Coal Measures below Queen Seam - coal interbedded with sandstone
GW02	389371	7035545	427	30	18.53	29.38	16.53	29.98		Regolith – Sandstone, conglomerate, interbedded coal
GW05	391057	7035095	462.05	28.97	not known		not known			Queen Seam
GW09	390653	7034309	480	44.85	33.31	44.29	31.31	44.85		Sandstone below Queen Seam
GW11	388023	7034135	448	38.8	27.45	38.2	25.45	38.81		Coal Measures below Queen Seam - siltstone interbedded with coal
GW21	388411	7031772	471	>74.2	57.62	74	55.62	74.52		Coal Measures below Queen Seam - sandstone interbedded with coal
GW22	387834	7032484	533	54.6	37.3	54.17	35.3	54.64		Coal Measures below Queen Seam - sandstone interbedded with coal
GW25	388981	7035227	431.22	13.9	5.3	13.9	not known			Regolith
GW30	388747	7035094	433	9.86	5.5	9.45	not known			Regolith
GW33	389405	7035241	447.41	26	15	21	14	21		Spoil
GW34	389484	7035323	442.07	42	36	42	35	42		Regolith - Coal/interburden
GW35	389319	7035033	450.23	36	30	36	29	36		Spoil
GW36	388741	7034927	440.52	30	18	30	17	30		Regolith - Coal/interburden
GW37	390581	7035905	431.48	36	30	36	29	36		Regolith - Sandstone
GW38	389371	7035574	425.83	24	18	24	17	24		Regolith - Sandstone
GW39	389931	7036198	420.33	12	6	12	5	12		Meandu Creek alluvium - sand/sandy clay
GW40	389797	7036058	421.06	12	6	12	5	12		Meandu Creek alluvium - sand/sandy clay
GW41	390598	7035085	447.56	13	10	13	7	13		Interface between spoil/ natural ground (siltstone)
GW42	389156	7033104	468.01	37	34	37	29	37		Interface between spoil/ natural ground (coal)
GW43_d	391373.4	7030178.7	554.41	145.5	139.5	145.5	135	145.5		Queen Seam
GW43_s	391368	7030177.6	554.66	66	54	66	51	66		Basalt
GW44_d	393995.9	7031155.3	514.19	146	140	146	137	146		Queen Seam
GW44_s	393998.5	7031154.9	514.1	97.5	94.5	97.5	92	97.5		Queen Seam
GW45_d	393709.5	7031396.3	499.28	150	144	150	140	150		Queen Seam
GW45_s	393707.1	7031396.5	498.8	78.5	75.5	78.5	72	78.5		King Seam
GW46_d	394328.5	7033545.5	483.81	124.5	118.5	124.5	114	124.5		Queen Seam
GW46_s	394330.4	7033547.7	483.62	67	64	67	58	67		King Seam
GW50_d*	390851	7034372	468.69	60.46	54.46	60.46	47.75	60.46		Queen Seam
GW50_s*	390851	7034377	468.75	24.76	18.76	24.76	16.1	24.76		Regolith
GW51_d*	391356	7034536	478.29	72.48	66.48	72.48	50	72.48		Queen Seam
GW51_s*	391357	7034541	478.35	18.5	15.5	18.5	10.8	18.5		Regolith
GW52A	391103	7034274	491.1	36	33	36	27	36		Regolith

Bore ID	Easting (AGD84)	Northing (AGD84)	Collar RL (mAHD)	Depth (m)	Slotted Interval		Gravel Pack			Lithology Screened
					From	To	From	To		
GW53	391365	7034041	491.49	20.08	16.56	19.56	12	19.56		Regolith
GW54B	390852	7033867	520.36	82.1	76.1	82.1	71.8	82.1		Spoil/ Regolith
GW55_d	391055	7033169	522	78.48	69.48	78.48	61.18	78.48		Queen Seam
GW55_s	391081	7033152	517.28	21.44	18.44	21.44	13.0	21.44		Regolith
GW56_d	391084	7033145	517.39	148	136	148	90	148		Ace Seam
GW56_s	391957	7032145	587.59	40.46	34.46	40.46	24	40.46		Basalt
GW58_d	392049	7032032	594.36	170	149	161	113	161		King Seam
GW58_s	392596	7032687	569.31	61	49	61	40.9	61		Basalt
GW59B	391863	7033510	583.97	144	129	141	125	144		King Seam
GW60	393208	7034410	539.97	109	97	109	75	109		Queen Seam
GW61_d	392708	7035418	467	53.5	41.5	53.5	24	53.5		Regolith
GW61_s	392708	7035408	467	18.2	12.2	18.2	7	18.2		Regolith
GW62_d	391092.1	7029146.6	597.81	96.5	75.5	87.5	73.5	87.5		Ace Seam
GW62_s	391090.8	7029147.7	597.83	48.5	36.5	48.5	34	48.5		Basalt
GW63_d	393974.7	7032351.3	482.05	108	60	72	57	72		Queen Seam
GW63_s	393973.3	7032350.4	481.93	18	12	18	10	18		Regolith
GW64_d	394859.5	7033646.9	465.66	50	38	50	35	50		Maronghi Creek beds
GW64_s	394860.5	7033645.9	465.43	25	13	25	10	25		Maronghi Creek beds
GW65	394670.1	7034730.9	494.9	72	60	72	57	72		Maronghi Creek beds
GW66*	390815	7034128	491.13	42	36	42	33	42		Spoil
GW67*	390860	7034678	458.82	12	9	12	9	12		Regolith - sandstone/ minor coal
GW68	390901	7034904	451.64	17.5	14	17.5	13	17.5		Regolith - sandstone/ minor coal
GW69	390513	7035358	440.1	24.5	18.5	24.5	17	24.5		Regolith - sandstone beneath coal
GW70	392450	7035248	493.3	26	20	26	19	26		Interface between spoil and underlying clay
GW71	392560	7034978	508.32	35	29	35	28	35		Interface between spoil and underlying clay
GW72	391927	7035105	517.22	41	35	41	34.5	41		Interface between K2 Tailings and underlying sandstone
GW73	392860	7035713	459.54	20	17	20	16.5	20		Regolith – clay and weathered gravel
GW74	392772	7036160	455.95	20	17	20	16	20		Regolith - Sandstone
GW75	389146	7035091	455.97	36	30	36	30	36		Spoil
GW76	389122	7035242	438.79	9	6	9	6	9		Spoil
GW78	388621	7035268	431.46	12	7.5	12	6.5	12		Regolith - weathered clay, conglomerate

Notes * Bores have been decommissioned since commencement of assessment

4.0 ENVIRONMENTAL VALUES

4.1 Introduction

The environmental values (EV's) and water quality objectives for Meandu Creek and Black Creek are outlined in the surface water quality, sediments and aquatic ecology investigations report that has been prepared for the EEE Project by Ecological Services Professionals Pty Ltd (ESP 2018). This section relies in part on the description of EV's and water quality objectives taken from the ESP report, with additions as required to incorporate groundwater considerations.

Groundwater within the Meandu Mine mining area flows towards and is captured by Meandu Creek (upstream of Meandu Creek Dam) and Black Creek. For areas of AMD impacted groundwater, Meandu Creek is the receptor of concern and is therefore the focus for this report.

The conceptual model for the groundwater system at Meandu Mine (Section 8) considers that groundwater that flows towards Meandu Creek (including groundwater seepage from the NW void where AMD has been identified) flows towards and is captured by either the Meandu Creek alluvium or by seepage to the ground surface to be collected via site drains and/or retention dams. In terms of groundwater management it is generally considered that groundwater that occurs within alluvium is managed as surface water; therefore the groundwater EV's for Meandu Creek, as well as for Black Creek, are taken to be the same as the surface water EV's that have been defined in the ESP (2018) report.

4.2 Meandu Creek Upstream of Meandu Creek Dam

It is noted in the ESP (2018) report that:

Meandu Creek Dam and Meandu Creek upstream of the dam has been significantly modified through the creation of the dam and diversions to facilitate mining operations. Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam form part of the overall site water management systems for Meandu Mine and the Tarong power stations. Water is managed to protect the integrity of water quality and aquatic ecosystems in the receiving environment (i.e. Meandu Creek downstream of Meandu Creek Dam). Public access to Meandu Creek Dam and Meandu Creek within the Meandu Mine lease is prohibited.

Based on the above, 'industrial use' is the EV currently applicable to Meandu Creek upstream of Meandu Creek Dam, and the waters of Meandu Creek Dam.

As discussed in Section 4.1, the groundwater EV's for Meandu Creek upstream of Meandu Creek Dam are assessed to be the same as the surface water EV's, i.e. industrial use.

With respect to assessing the impacts of AMD seepage on Meandu Creek, groundwater quality is assessed at Meandu Creek alluvium bore GW39 with respect to the trigger levels that are defined within the Meandu Mine Environmental Authority (EA) EPML00709113.

4.3 Black Creek and Black Creek Dam

It is noted in the ESP (2018) report that:

Black Creek has been substantially modified from its natural state through the creation of Black Creek Dam (which receives runoff from Meandu Mine and the Tarong power stations), construction of the Ash Dam and construction of the diversion channel. As Black Creek has been substantially modified from its natural state and is used for industrial purposes, it was de-gazetted as a watercourse under the Water Act 2000 by the former Department of Natural Resources and Mines (DNRM), now Department of Natural Resources, Mines and Energy (DNRME). Similar to

Meandu Creek Dam, Black Creek Dam forms part of the overall site water management systems for Meandu Mine and Tarong power stations. Water is managed for industrial use and to protect the integrity of water quality and aquatic ecosystems in Meandu Creek downstream of Meandu Creek Dam. Public access to Black Creek and Black Creek Dam is prohibited.

As such, 'industrial use' is the EV currently applicable to Black Creek and Black Creek Dam.

Black Creek is an ephemeral creek system with a relatively small catchment with alluvium being shallow to absent. Shallow groundwater flow within the Black Creek catchment is conceptualised to occur within the shallow Tertiary Regolith, where discharge to surface may occur towards Black Creek dam. The EV for groundwater in the Black Creek catchment is assessed to be industrial use.

5.0 DATA REVIEW AND DISCUSSION

5.1 Available Data

Available data for the review includes:

- Rainfall data from the Tarong Bureau of Meteorology (BoM) rainfall station No. 040199 (discussed in Section 5.2);
- Information from previous reports on groundwater bore location and construction (e.g. AGE (2008));
- Groundwater level data (discussed in Section 5.3), surface water quality data and groundwater quality data from site groundwater monitoring bores (discussed in Section 5.4);
- Time domain electromagnetics (TEM) geophysics data (discussed in Section 5.5) from two separate surveys, including:
 - A land-based survey that was undertaken in July 2015, for the purpose of identifying potential seepage pathways from spoil-filled prior voids as well as the overall geophysics response of the area within and adjacent to Meandu Creek;
 - An airborne (helicopter-based) survey that was undertaken in March 2017.
- 3-dimensional models of the various mine surfaces (e.g. current topographic surface, current deepest mined surface, final landform, final deepest mined surface) from the mine planning and life of mine (future) study undertaken for the EEE Project by Xenith Consulting (Xenith 2017).
- Geological data available from:
 - Site groundwater monitoring bores and geological exploration bores;
 - The site geological model;
 - 1:100,000-scale geological mapping;
 - Previous publications that discuss the geology of the Meandu Mine and the Tarong Basin, including Pegrem (1986) and Flood and Garces (1986).

5.2 Rainfall Data

Monthly rainfall data from the Tarong BoM rain gauge No. 040199 for the period from January 1998 to end of June 2017 is presented on Figure 11. The data has been analysed to provide a rainfall residual mass (RRM) curve, which is plotted on Figure 11 as well as the groundwater level graphs presented as Figures 12 to 16. Data from the Tarong rainfall gauge, which is located approximately 7.5 km north-west of the Meandu Mine lease boundary, is used for assessment of the RRM due to the length of record at this site (1920 to present).

The RRM is calculated by subtracting the long-term average monthly rainfall from the actual monthly rainfall, to provide a monthly “departure” from average conditions. If the monthly rainfall is above average the resulting rainfall departure number is positive, whereas if rainfall is below average, the number is negative. The monthly rainfall departures are summed cumulatively to provide the RRM. A number of below-average rainfall months will result in a falling RRM curve, while a number of above average rainfall months will result in a rising RRM curve. The RRM curve is used extensively in groundwater investigations due to the strong correlation at many locations between the RRM and groundwater level trends, especially for areas where groundwater recharge is occurring due to rainfall.

Annual rainfall totals for each water year between 2009 and 2017 are shown below in Table 5-1 (the use of water year totals is appropriate for this report as this also allows a comparison of wet-season rainfall when the majority of groundwater recharge occurs). From Table 5-1 the high annual rainfall totals for the 2010-2011 and 2012-2013 years are evident, as well as the high wet season totals for these years (- the period between November and March) when the wet season total was greater than the average annual total. From review of Table 54-1 it is also evident that rainfall for the most recent water years (2013-2014, 2014-2015, 2015-2016 and 2016-2017) was below average as both yearly and wet season totals. This is evident from the RRM curve (Figures 12 – 16) where the RRM curve is displaying a steady downward trend which indicates a potential for falling shallow groundwater levels over this period.

Table 5-1: Tarong Rainfall for 2009-2017 Water Years Compared to Long-Term Average

Year	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
2009-2010	0	0	17	30	91	147	57	84	201	29	42	6	704
					Total Nov to Mar - 580 mm								
2010-2011	32	100	136	48.4	13	333	315	57	144.8	49	103	4	1335.2
					Total Nov to Mar - 862.8 mm								
2011-2012	19	43	12	78	9	132	99	107	66	17	20	105	707
					Total Nov to Mar - 413 mm								
2012-2013	52	2	13	18	165	65	312	161	144	33.2	34.8	35	1035
					Total Nov to Mar - 847 mm								
2013-2014	20	8	29	46	120	26	31	14	91	56	28	18	487
					Total Nov to Mar - 282 mm								
2014-2015	0	58	17	23	38	118	96	95	21	55	81	11	613
					Total Nov to Mar – 368 mm								
2015-2016	0	65	10	70	66	116.6	81	43	49	23	0	81	604.6
					Total Nov to Mar – 355.6 mm								
2016-2017	35	24	82	42	74	38	82	24	180	0	28	17	626
					Total Nov to Mar – 398 mm								
Long Term Average	36.5	26.2	31.6	63.1	78.2	110.3	100.2	95.4	63.5	42.0	39.9	39.4	730.2
					Long-Term Average – 447.6 mm								

5.3 Groundwater Level Data

5.3.1 Available Data

Groundwater level data is available as follows:

- Historic bores - a number of historic groundwater sites were added to the Meandu Mine groundwater monitoring network in August 2016, following downhole camera inspection of the bores, bore re-development and assessment of the geology/construction details. For these bores, water level data is available between approximately August 1993 and January 2007 as well as at quarterly intervals since November 2016 (except for bore GW25, which is located within natural

sediments to the west of the NW spoil dump, where water level monitoring recommenced in February 2015).

- K2W bores - for bores that were drilled for monitoring of water levels adjacent to the K2W/K2N ash disposal voids, groundwater data is available at approximately quarterly intervals since October 2008. Additional bores have been added to the program as required to replace bores that have been decommissioned (e.g. due to being dumped over), or for other programs as required (for example, bore GW54B was drilled to replace bore GW54A when it was dumped over during raising of the Queen West (QW) spoil dump.
- Hydrocarbon bores - for bores that were drilled for monitoring of water levels down-gradient of historic hydrocarbon disposal sites or to monitor groundwater conditions adjacent to Meandu Creek, groundwater data is available from May 2011.
- SRE bores – for bores that were drilled to the east of the Meandu Mine area to provide groundwater data in support of the surface rights extension (SRE), data is available at quarterly intervals from February 2014 (from bores GW43-46) and September 2015 (for bores GW62-65).
- EEE bores - for bores that were drilled in 2016 to provide in-fill to the existing groundwater monitoring network (and to provide additional data for the EEE Project), data is available at quarterly intervals since November 2016.

5.3.2 Data Presentation and Analysis

Bore hydrographs are shown on Figures 12 to 16, with the hydrographs grouped to show water level trends in distinct hydrogeological units or in specific areas of the mine; these figures include the following information:

- Figure 12 includes hydrographs for bores screened within the shallow groundwater units at Meandu Mine. This includes bores that monitor:
 - Tertiary basalt (the two bores monitored for this review, GW56_s and GW58_s, have been dry since construction in 2008);
 - Regolith/Overburden: This includes bores that have been constructed within weathered Triassic sediments (regolith) or fresh Triassic sediments above the coal seams (overburden);
 - Meandu Creek alluvium (bores GW38 and GW39).

Figure 12 contains two water level plots. The upper plot shows water level data for bores located in the western area of Meandu Mine (generally west of the tailings storage dam) and adjacent to Meandu Creek. The lower plot shows water level data for bores that monitor groundwater levels in the eastern area of Meandu Mine, including bores drilled to monitor groundwater conditions around the K2W/K2N ash disposal voids.

- Figure 13 includes hydrographs for bores screened within spoil or at the interface between base of spoil and the underlying natural material. Figure 13 contains two water level graphs, as follows:
 - The upper graph shows water level data for bores located in the western area of Meandu Mine (down-gradient of the tailings storage facility, within the NW spoil dump or adjacent to the western rehabilitation/ Central pit area).
 - The lower graph shows water level data for bores located within or adjacent to the Queen West (QW) spoil dump.
- Figure 14 shows hydrographs for bores monitoring the Ace Seam (upper plot) and King Seam (lower plot).
- Figure 15 shows hydrographs for bores monitoring the Queen Seam. Figure 15 contains two water level graphs, as follows:

- The upper graph shows water level data for bores located in the central and western area of Meandu Mine (down-gradient of the tailings storage facility, within the NW spoil dump or adjacent to the western rehabilitation/ Central pit area). The graph also contains water level data for two bores (GW21, GW22) that monitor the coal measures below the Queen Seam west of Meandu Creek (refer Figure 10 for bore locations). The hydrographs for these bores are plotted on this graph (rather than Figure 16 – refer below) because the groundwater elevation at these sites is such that they plot better on the Queen Seam graph.
- The lower graph shows water level data for Queen Seam bores located within the eastern area of the mine and adjacent to the King 2 West (K2W) ash disposal void.
- Figure 16 contains two graphs that contain data as follows:
 - The upper graph shows hydrographs for bores monitoring coal measures below the Queen Seam. These bores are located at the western edge of the mining operation adjacent to Meandu Creek, where the dip of the coal seams brings these units close to surface (the Ace and King Seams are absent beneath Meandu Creek and the Queen Seam exists only in the southern area of Meandu Creek (south of west-east hydrogeological cross section 3 – refer Figure 8 for cross section and Figure 2 for cross section location).
 - The lower graph shows hydrographs for bores monitoring the Maronghi Creek beds to the east of the mining operation.

Groundwater level trends for individual bores are discussed in Table 5-6.

5.4 Groundwater Chemistry

5.4.1 Available Data

The availability of groundwater chemistry data is summarised below in Table 5-2. The bores are differentiated as per the general categories outlined in Section 3.0, i.e.:

- Historic monitoring bores;
- K2W monitoring bores;
- Hydrocarbon monitoring bores;
- SRE bores; and,
- EEE bores.

Table 5-2: Summary of Groundwater Chemistry Availability for Site Monitoring Bores

Groundwater bores	Bores	Commencement of monitoring	Frequency	Parameters
K2W monitoring bores	GW05, GW50 – GW62	2008 to Dec 2015	quarterly	- pH - Electrical conductivity (EC) - Total dissolved solids (TDS) - Major ions - Fluoride - As, B, Mo, Se, V (total/dissolved)
		Mar 2016 to present	quarterly	- pH - Electrical conductivity (EC) - Total dissolved solids (TDS) - Major ions - Fluoride - Al, As, B, Cd, Co, Cu, Fe, Mn, Mo, Ni, Se, V, Zn (total/dissolved)
Historic Monitoring Bores	GW01 GW02 GW09 GW11 GW21 GW22 GW25	1993 to 2010	Generally six-monthly or annual	- pH - Electrical conductivity (EC) - Total dissolved solids (TDS) - Major ions - As, Cd, Co, Cu, Fe, Mn, Ni, Se, Zn (total)
		2010 to Aug 2017	No data	
		Aug 2017 to present	quarterly	- pH - Electrical conductivity (EC) - Total dissolved solids (TDS) - Major ions - Fluoride - Al, As, B, Cd, Co, Cu, Fe, Mn, Mo, Ni, Se, V, Zn (total/dissolved)
Hydrocarbon monitoring bores	GW34- GW42	Aug 2011 to Nov 2014	Quarterly	- pH - Electrical conductivity (EC) - Total dissolved solids (TDS) - Major ions - Fluoride - TPH, BTEX
		May 2015 to present	Quarterly	- pH - Electrical conductivity (EC) - Total dissolved solids (TDS) - Major ions - Fluoride - Al, As, B, Cd, Co, Cu, Fe, Mn, Mo, Ni, Se, V, Zn (total/dissolved)
			Annual	TPH
SRE Bores	GW43- GW46	Feb 2014 to present	Quarterly	- pH - Electrical conductivity (EC) - Total dissolved solids (TDS) - Major ions - Fluoride - Al, As, B, Cd, Co, Cu, Fe, Mn, Mo, Ni, Se, V, Zn (total/dissolved)
	GW63- GW65	Aug 2016 to present	Quarterly	
EEE bores	GW66- GW78	Nov 2016 to present	Quarterly	- pH - Electrical conductivity (EC) - Total dissolved solids (TDS) - Major ions - Fluoride - Al, As, B, Cd, Co, Cu, Fe, Mn, Mo, Ni, Se, V, Zn (total/dissolved)

Water quality results from field sampling and laboratory analysis for the full period of record are presented in Appendix A and include:

- Appendix A-1 – pH data (field and laboratory), EC data (field and laboratory), TDS, major ions and fluoride;
- Appendix A-2 – dissolved concentration of dissolved and total metals/metalloids.
- Appendix A-3 – summary statistics for pH, EC, TDS, major ions, fluoride for the individual groundwater units at Meandu Mine; and,

- Appendix A-4 - summary statistics for metals/metalloids for the individual groundwater units at Meandu Mine

Prior to discussion of potential or actual impacts of AMD on groundwater quality, an understanding is required of the background water quality at the Meandu Mine site as well as the chemistry of mine-impacted groundwater that is related to factors other than AMD (e.g. ash seepage). The following sections present a discussion of background as well as mine-impacted (including AMD) water chemistry.

5.4.2 Factors that Impact Groundwater Chemistry at Meandu Mine

Groundwater chemistry at Meandu Mine is affected by a number of natural processes that impact on groundwater occurrence and movement, including:

- Proximity to groundwater recharge areas.
- The residence time of groundwater in the system, with EC/TDS tending to increase with increasing residence time.
- The impact of faults on groundwater flow and residence time. For example, the coal seams tend to be the main conduits for groundwater flow within the Triassic coal measures (rather than the interburden, which tends to be dry and hydraulically “tight”). Therefore, the occurrence of faults that have a large enough throw to completely displace the coal seams, resulting in the abrupt termination of a permeable coal seam on one side of the fault against relatively impermeable interburden on the other side of the fault, may result in increased groundwater residence time due to the disruption in groundwater flow (refer also discussion in Sections 2.2 and 2.3). An example of this phenomenon is interpreted at bores GW44 (s&d), which are screened within the Queen Seam on the south-east side of a regional fault (refer Figure 10 for locations) and GW45 (s&d), which are located on the north-west side of the fault with GW45_d screened within the Queen Seam and GW45_s screened within the overlying King Seam. The groundwater quality within the Queen Seam is significantly different on either side of the fault, with GW44 (s&d) generally recording an EC in excess of 10,000 $\mu\text{S}/\text{cm}$ and GW45_d generally recording an EC of $\sim 1,200$ $\mu\text{S}/\text{cm}$. The difference in water quality is interpreted to be related to an increased residence for groundwater on the south-east side of the fault, with groundwater flow towards the north-west (i.e. towards the pits) disrupted by the fault.
- Flow of groundwater between different groundwater units (e.g. recharge water entering the basalt and seeping down to the underlying coal measures could be expected to have a different groundwater chemistry to groundwater that is recharged directly to the coal measures).

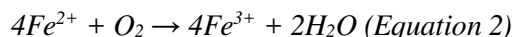
5.4.3 AMD Chemistry

Acid and metalliferous drainage (AMD) is generated from the oxidation of pyrite that is present in the coal and/or interburden material. The process generates a number of iron species and results in the precipitation of ferrous hydroxide minerals (as described below) and in the process a number of additional metals/metalloids are leached from the sediment into the seepage water (as discussed below in Section 5.4.5). The oxidation of pyrite to produce hydrogen ions (which lowers water pH) and ferrous hydroxides progresses as follows:

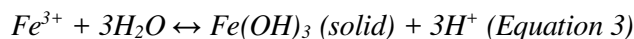
- Pyrite in the presence of water and oxygen is oxidised to form sulfate (SO_4^{2-}), ferrous iron (Fe^{2+}) and hydrogen ions (H^+), where the presence of free H^+ ions acts to lower the groundwater pH. This reaction is shown below as Equation 1.



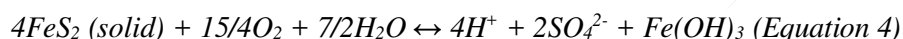
- Soluble Fe^{2+} is free to react further (in the presence of oxygen) to produce the ferric ion (Fe^{3+}) as shown in Equation 2.



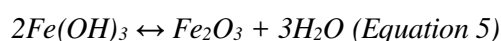
- The reaction shown in Equation 2 may then proceed to the reaction shown below as Equation 3, where Fe^{3+} and H_2O are converted to ferrous hydroxide ($\text{Fe}(\text{OH})_3$) and H^+ ions, which further lowers pH.



- The complete reaction described above is shown below in Equation 4.

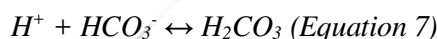


Ferrous hydroxide ($\text{Fe}(\text{OH})_3$) is often observable in AMD areas as a yellow or red stain on rocks or within streams that is known as “yellow boy”. Through the loss of water, the ferrous hydroxide can be converted to Fe_2O_3 (the rust-red mineral haematite) as shown below in Equation 5.

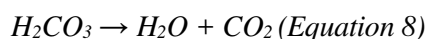


It is this reaction process (i.e. rapid conversion of Fe^{2+} to Fe^{3+} then $\text{Fe}(\text{OH})_3$ as groundwater discharges to the ground surface) that is interpreted to be occurring in areas where AMD is evident.

AMD depletes the buffering capacity of water through the addition of H^+ ions, which converts carbonate to bicarbonate (Equation 6) and then to carbonic acid (Equation 7), with the buffering capacity completely depleted at a pH of ~4.2 as all carbonate and bicarbonate within groundwater/ surface water is converted to carbonic acid:



The carbonic acid then readily breaks down into water and carbon dioxide, as shown below in Equation 8.



Based on the chemistry summarised above it could be expected that AMD-impacted groundwater would have low pH and relatively high iron. This is the case, however iron concentration is interpreted to be a poor indicator of AMD impacts due to the relatively high concentration of iron in groundwater (especially in areas where basalt occurs, which is the case at Meandu Mine) and observation that the relatively high iron concentrations tend to occur at the initial site of seepage where groundwater seepage is oxidised as shown in the reactions above. Better indicators of AMD-impacted groundwater are interpreted to include sulfate, cobalt, manganese, nickel and zinc, as discussed further below.

5.4.4 Mine-Impacted Groundwater Quality

An assessment of mine-impacted groundwater quality has been undertaken for this report, by first assessing the bores that could be regarded as being hydraulically isolated background bores (and therefore containing background water quality), with the remaining bores assessed to be mine-affected to some degree. Locating hydraulically isolated background bores for each groundwater unit is challenging at Meandu Mine for the following reasons:

- The coal seam bores (Ace Seam, generally dry, as well as King Seam and Queen Seam) are difficult to locate in background areas as the units do not exist to the east and west of the mining area (due to basin-scale faulting, as well as the dip of the coal seam bringing the deeper seams close to surface beneath Meandu Creek, i.e. the unit pinches out). The limit of the coal seams in the eastern area of the mining lease can be seen on Figure 2 as the boundary between the Tarong

beds and the Maronghi Creek beds; this is a faulted contact that defines the eastern boundary of the Tarong Basin. For this assessment it is interpreted that mine-affected bores are located either adjacent to the pits or between/down-gradient of the pits, while background bores tend to be more distant from the mining area and up-gradient with respect to regional groundwater flow (i.e. to the east of the mining operation). Another assumption for background bores is that a cone of depression exists towards the pits, so groundwater in the background bores is sourced from areas that are distant from mining.

- The Tertiary basalt occurs as ridge-cap deposits in the mining area and tends to be unsaturated. There is only one basalt bore within the mining area that contains water (GW43_s - others are dry), and GW43_s was specifically constructed at a location where water was encountered in basalt during geological drilling (it has been observed from geological drilling that the basalt is generally dry). In areas that could be regarded as being hydraulically isolated from mining (i.e. up-gradient, topographically elevated areas to the east of the pits) the basalt tends to be unsaturated. The regolith groundwater unit is often saturated within the mining area or areas that are down-gradient, i.e. towards Meandu Creek. This means that the regolith tends to contain water in mine-affected or potentially mine-affected areas and to be dry in upgradient (background) areas. As such, locating bores that could be considered as background or reference bores within this unit is difficult and there are no bores within the current monitoring network that are assessed to be background bores.
- The Meandu Creek alluvium, which is the main groundwater unit that could be impacted by AMD and down-gradient seepage of ash or other mine impacted water, was ephemeral prior to mining. The main indicator bore for mining impacts on the alluvium prior to off-site groundwater flow (towards Meandu Creek Dam) is GW39 (refer attached Figure 10 for bore location). The water quality in this bore is likely to be reflective to some degree of Meandu Dam water quality as water from the dam backs up into the upstream alluvium.

Bores that are assessed to be background bores (i.e. unimpacted by mining) include the following (refer Figure 10 for bore locations):

- Alluvial bore GW39;
- King Seam bores – GW45_s, GW46_s, GW58_d; and
- Queen Seam bores GW43_d, GW44_d, GW44_s, GW45_d, GW46_d, GW63_d.

Table 5-3 shows summary water quality data for a number of sites within the Meandu Mine site. The data shown in Table 5-3 are median values for a range of parameters that are potential indicators of mine-impacted water. The data includes selected surface water sites within or adjacent to Meandu Creek, to allow comparison with groundwater data. The sites that are included in Table 5-3 include:

- Surface water sites within and adjacent to Meandu Creek (refer Figure 17 for site locations), including:
 - Sites where AMD-impacted seepage is monitored (Bullgang Drain and Ramp 7-1).
 - Retention Dams RD7, which receives drainage water from the Bullgang Drain and Ramp 7-1 areas (AMD impacted water), as well as water that is pumped from RD9 as required for site water management).
 - RD8, which collects water overflows from RD7. Water from RD8 is either re-used for site processes or reports to Meandu Creek upstream of compliance release point CP3.
 - RD2 contains raw water from K2E Pit, via RD17A/RD17B to RD01. RD2 water is used at the CHPP (Coal Handling and Preparation Plant). RD2 overflows into Meandu Creek downstream of RD8 and upstream of CP3.

- Meandu Creek 5, which is a pool within Meandu Creek that is downstream of RD7.
- Sites that are up-gradient of the Bullgang Drain/Ramp 7-1/ RD7/RD8 system, include Meandu Creek 1 to 4, RD9 and RD14B.
- Supernatant water from the K2W/K2N ash disposal voids;
- Groundwater bores (Figure 10), including data for the following bore classes and sub-classes – the summary statistics for each:
 - all groundwater bores;
 - bores screened within the Meandu Creek alluvium;
 - bores screened within Tertiary Regolith;
 - bores screened within Tertiary Basalt;
 - bores screened within Spoil;
 - bores screened within Coal Measures (all data);
 - bores screened within the Ace Seam;
 - bores screened within the King Seam – all data;
 - bores screened within the King Seam – those assessed to be mine-affected;
 - bores screened within the King Seam - those assessed to be background bores;
 - bores screened within the Queen Seam – all data;
 - bores screened within the Queen Seam - those assessed to be mine-affected; and
 - bores screened within the Queen Seam - those assessed to be background bores.

Summary statistics for the groundwater units identified above are included as Appendix B-1 (pH, EC, major ions, fluoride) and Appendix B-2 (dissolved metals/metalloids).

Table 5-3: Median Values of EC and Mine-Impacted Water Indicator Parameters

Site	pH	EC	Sulfate	Fluoride	Aluminium	Arsenic	Boron	Cobalt	Iron	Manganese	Molybdenum	Nickel	Selenium	Vanadium	Zinc
		(µS/cm)	(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)
Surface water sites - within/adjacent to Meandu Creek															
RD14B	7.6	1369	114	0.20	0.02	0.003	0.09	0.007	N/A	0.01	0.002	0.003	N/A	N/A	0.03
Meandu Creek-4	7.2	523	96	0.15	0.02	N/A	0.05	N/A	0.1	0.06	N/A	0.002	N/A	N/A	0.01
RD10	6.7	1174	205	0.20	0.02	N/A	0.08	0.004	N/A	0.13	0.002	0.006	N/A	N/A	0.02
Meandu Creek-3	7.8	3041	141	0.25	0.05	N/A	0.12	0.002	0.1	0.14	N/A	0.002	N/A	N/A	0.01
Meandu Creek-1	6.7	5028	172	0.2	N/A	N/A	0.13	0.003	0.1	1.12	N/A	0.002	N/A	N/A	0.01
RD9	7.1	1186	198	0.20	0.01	N/A	0.08	0.008	N/A	0.02	0.002	0.007	N/A	N/A	0.02
Meandu Creek-2	6.7	3047	171	0.20	N/A	N/A	0.12	0.003	0.1	2.04	N/A	0.002	N/A	N/A	0.01
RD7	6.1	1684	446	0.20	0.03	N/A	0.08	0.245	11.9	10.60	0.003	0.175	N/A	N/A	1.16
RD8	6.7	1545	235	0.15	0.45	0.003	0.08	0.167	7.5	8.29	0.003	0.145	N/A	N/A	0.61
Meandu Creek-5	6.7	3090	332	0.20	N/A	N/A	0.09	0.003	0.1	1.43	N/A	0.002	N/A	N/A	0.01
Bullgang Drain	6.1	3019	1224	0.10	0.01	N/A	0.07	0.689	122.0	28.80	0.001	0.523	N/A	N/A	4.85
Ramp 7-1	5.3	3034	1000	0.20	0.41	0.004	0.10	0.730	85.5	31.40	0.007	0.537	N/A	N/A	4.84
K2W/K2N Ash Voids															
K2W/K2N Ash Void	7.6	2510	657	7.50	0.17	0.063	2.86	0.04	N/A	0.694	1.5	0.070	0.07	1.34	0.15
Tailings Void															
Tailings Void	7.54	1685	344	0.2	0.01	N/A	0.12	0.004	0.08	0.09	0.0085	0.006	N/A	N/A	0.020
Groundwater Data															
All groundwater bores	6.0	2750	134	0.20	0.04	0.002	0.15	0.031	3.8	0.31	0.002	0.011	N/A	0.02	0.06
Alluvium	6.0	2866	179	0.20	0.01	N/A	0.07	0.010	0.2	0.40	0.002	0.010	N/A	N/A	0.04
Regolith	5.7	3245	263	0.20	0.08	0.001	0.25	0.040	1.8	5.53	0.001	0.019	N/A	0.02	0.13
Basalt	6.8	2290	66	0.20	0.01	N/A	0.14	N/A	1.5	0.05	N/A	0.005	N/A	N/A	0.01
Spoil	5.6	2780	505	0.20	0.03	0.003	0.11	0.061	19.8	4.38	0.003	0.031	N/A	0.07	0.08
Coal Measures	6.3	2145	66	0.10	0.02	0.002	0.13	0.012	4.2	0.11	0.002	0.005	N/A	N/A	0.03
Ace Seam	5.9	955	44	0.20	N/A	N/A	0.23	0.001	1.6	0.08	N/A	0.056	N/A	N/A	0.02
King Seam - All	6.1	1780	53	0.10	0.01	0.001	0.16	N/A	2.7	0.14	0.036	0.002	N/A	N/A	0.01
King Seam - Mine Affected	6.2	2745	698	0.20	N/A	0.003	0.24	N/A	0.9	0.06	0.062	0.002	N/A	N/A	0.03
King Seam - Background	6.0	1720	52	0.10	0.01	0.001	0.14	N/A	6.8	0.15	0.002	0.002	N/A	N/A	0.01
Queen Seam - All	6.9	2140	58	0.10	0.02	0.002	0.11	0.026	3.3	0.09	0.002	0.004	N/A	N/A	0.01
Queen Seam - Mine Affected	6.9	2220	57	0.10	0.02	0.002	0.17	0.026	1.2	0.10	0.002	0.006	N/A	N/A	0.03
Queen Seam - Background	7.2	2070	74	0.10	0.015	0.004	0.08	N/A	3.7	0.09	0.002	0.003	N/A	N/A	0.01

Concentration assessed to be elevated relative to background

N/A

Majority or all of samples below the LOR

5.4.5 Data Presentation and Analysis

5.4.5.1 Parameters that are Indicative of Impacts from Mining

From assessment of available data (summarised in Table 5-3 above), the parameters that are indicative of potential impacts from mining on groundwater are shown below in Table 5-4.

Table 5-4: Parameters Assessed to be Indicative of Mining Impacts on Groundwater

Parameter	AMD Indicator	Ash Seepage Indicator	General Mining Indicator
Physical Parameters/ Ions			
pH	X		X
EC			X
Sulfate	X	X	X
Fluoride		X	
Metals/ Metalloids			
Aluminium			X
Arsenic		X	
Boron		X	
Cobalt	X		
Iron	X		X
Manganese	X		X
Molybdenum		X	
Nickel	X		
Selenium		X	
Vanadium		X	
Zinc	X		

Available groundwater data is included as Appendix A-1 (pH, EC, major ion and fluoride data) and Appendix A-2 (dissolved and total metal/metalloid data).

5.4.5.2 Data Presentation

Available water quality data is presented in a number of formats to allow assessment of water quality trends at individual bores as well as a spatial representation of water quality data for selected indicators of AMD and general mining impacts. Water quality trends at each monitoring bore site are discussed in Table 5-6. Figures include:

- Figure 18, which shows graphs of pH concentration trends for regolith/alluvium bores;
- Figure 19, which shows graphs of pH concentration trends for spoil and coal seam bores;
- Figure 20, which shows graphs of EC concentration trends for regolith/alluvium bores;
- Figure 21, which shows graphs of EC concentration trends for spoil and coal seam bores;
- Figure 22, which shows graphs of sulfate concentration trends for regolith/alluvium bores;
- Figure 23, which shows graphs of sulfate concentration trends for spoil and coal seam bores;
- Graphs of metals/metalloids that are indicative of AMD are included as follows:
 - Figure 24 shows graphs of dissolved cobalt concentration trends for regolith/alluvium bores;
 - Figure 25 shows graphs of dissolved cobalt concentration trends for bores screened within spoil and coal seams, as well as ash and tailings water samples;
 - Figure 26 shows graphs of dissolved iron concentration trends for regolith/alluvium bores;

- Figure 27 shows graphs of dissolved iron concentration trends for bores screened within spoil and coal seams, as well as ash and tailings water samples;
- Figure 28 shows graphs of dissolved manganese concentration trends for regolith/alluvium bores;
- Figure 29 shows graphs of dissolved manganese concentration trends for bores screened within spoil and coal seams, as well as ash and tailings water samples;
- Figure 30 shows graphs of dissolved nickel concentration trends for regolith/alluvium bores;
- Figure 31 shows graphs of dissolved nickel concentration trends for bores screened within spoil and coal seams, as well as ash and tailings water samples;
- Figure 32 shows graphs of dissolved zinc concentration trends for regolith/alluvium bores;
- Figure 33 shows graphs of dissolved zinc concentration trends for bores screened within spoil and coal seams, as well as ash and tailings water samples.

A number of figures have been prepared that show the spatial distribution of selected water quality parameters, as discussed in the following sections.

5.4.5.3 Electrical Conductivity

Figure 34 shows EC data for site groundwater bores, the K2W and K2N ash disposal voids, the tailings void, Bullgang Drain and Ramp 7-1. The data has been colour-classed according to EC data range, to provide a visual indication of zones of low and high salinity. From review of Figure 34 the following observations are made:

- A high salinity plume ($> 10,000 \mu\text{S/cm}$) is evident that extends from the area around GW52A to GW69, with this plume also evident from the aerial geophysics data (Figure 43, Section 5.5.4. The bores that are recording high EC within the plume are screened within regolith or the interval between spoil and regolith. The plume occurs in the location of a natural surface water drainage channel, which extends through the mine infrastructure area and ultimately discharges towards RD1/ RD2.
- Areas of confirmed AMD seepage (e.g. Bullgang Drain and Ramp 7-1) are relatively low in EC (median value of $\sim 3,000 \mu\text{S/cm}$ – refer Table 4-3), as are the tailings void, K2W/K2N ash voids (median EC of $\sim 2,500 \mu\text{S/cm}$, and spoil monitoring bores (median EC $\sim 2,800 \mu\text{S/cm}$ – refer Appendix A-3)).
- High EC groundwater ($> 13,000 \mu\text{S/cm}$) is observed in bore GW78, which is located on the western side of Meandu Creek and screened within the regolith to a depth of 12 m. The EC recorded at bore GW78 is significantly higher than the EC of mine-impacted water from any site sources. Review of geophysics data (Section 5.5) does not indicate a source of high EC groundwater to the west of Meandu Creek, therefore the high EC at this site may be a result of the residence time for groundwater at this location. The installation of additional groundwater monitoring bores to the west of Meandu Creek is recommended as a means of monitoring water quality and validating data from geophysics investigations.
- High EC ($> 12,000 \mu\text{S/cm}$) groundwater is also observed at bore GW73, which is located within the Black Creek catchment in the north-east area of the mining lease. As discussed in Section 7.3, The Black Creek catchment ultimately discharges to Meandu Creek downstream of the Meandu Creek Dam.

5.4.5.4 Sulfate

Figure 35 shows data for sulfate concentration for the sites discussed above for Figure 34. Observations include.

- high sulfate concentrations are recorded at:
 - sites that are known to be impacted by AMD (Bullgang Drain, Ramp 7-1);
 - the K2W/K2N ash disposal voids and sites that are impacted by ash seepage (e.g. GW53 and GW59B);
 - bores that are screened within spoil (e.g. GW75, GW48)
 - groundwater bores that record high EC, therefore the sulfate concentration is elevated as a percentage of the total ions; examples include GW73 (Black Creek catchment) as well as GW50_s, GW67 and other bores within the saline plume between GW52A and GW69.
- sulfate is interpreted to be the most reliable indicator parameters of mining impacts to groundwater.

5.4.5.5 Piper Trilinear Diagram and Water Type

Figure 36 shows a Piper trilinear plot for median data for each of the groundwater units discussed above. Mean water quality data for each groundwater unit, as well as a number of surface water sites, are shown below in Table 5-5. The data has been converted from mg/L to milliequivalents/litre (meq/L) for plotting on the Piper diagram (Figure 36) and to allow discussion of the water type for each unit. Observations include:

- The alluvium and regolith groundwater units have a similar major ion chemistry and are both strongly sodium-chloride type water (>70% meq/L sodium and > 80% meq/L chloride).
- The basalt aquifer has unique groundwater chemistry relative to other groundwater units and plots in a different location on the cation and anion plots (and hence combined plot) compared to other units (note that of the three basalt bores on site, only one contains water – the other two are dry). The basalt aquifer is of a mixed water type (magnesium-sodium-carbonate) rather than the sodium-chloride water type observed for other groundwater units. The basalt aquifer is higher in carbonate/bicarbonate (50% meq compared to 2 to 12 % meq for other units), higher in magnesium (45% meq compared to 20 – 26% meq for other units) and lower in sodium (43%, meq compared to 75 to 86% meq for other units).
- The spoil groundwater unit, which is an anthropogenic groundwater unit, is entirely mine-affected and has a higher proportion of sulfate relative to other groundwater units (>20% meq, compared to 11-13 % meq for alluvium/regolith units). The water in the spoil aquifer is of sodium-chloride (Na-Cl) water type.
- The coal measures have a distinct chemistry relative to other groundwater units (although the groundwater is still sodium-chloride type) and are summarised as follows:
 - For coal measures bores that are assessed to be background, the unit is relatively low in sodium (55% meq compared to 72 to 75% for alluvium/regolith), relatively high in carbonate/bicarbonate (12% meq compared to 2-5% meq for alluvium/regolith), relatively high in calcium (19% meq compared to ~5% meq for alluvium/regolith) and relatively low in sulfate (8% meq compared to 11-13% meq for alluvium/regolith).
 - For groundwater samples from mine-affected coal measures bores, the sulfate is elevated compared to background bores (14% meq compared to 8% meq), the calcium is slightly lower and the sodium is slightly higher. This causes the mean data from the background/

mine impacted samples to plot on slightly different locations on the anion/ cation plots. The most significant change is assessed to be the sulfate data, with mine-affected samples plotting closer to the sulfate content of spoil samples than samples from any other groundwater unit.

- Samples from the K2W/K2N ash disposal void and NWB tailings void are of Na-Cl water type (>50 meq% sodium and chloride); however, the sulfate meq% is significantly higher than for the natural groundwater units (>40% - refer Table 5-5), therefore the water type is assessed to be Na-Cl-SO₄.
- Samples from areas where AMD-impacted seepage is evident (Bullgang Drain, Ramp 7-1) have a distinctly different water chemistry and are of Na-Mg-SO₄ type (the samples have a lower chloride content and higher magnesium content than other sites and the sulfate meq% is >50%.
- From Figure 36, it is evident that the samples from Bullgang Drain and Ramp 7-1 plot in a distinct area of the anion plot, where the SO₄ meq% is ~60%. The natural groundwater units, which are of Na-Cl water type, plot close to the bottom right-hand corner of the cation and anion plots. As the water becomes more mine-affected (which can be determined by an increase in the meq% of sulfate and magnesium and relative decrease in sodium and chloride), the samples plot closer to the samples for Bullgang Drain and Ramp-7-1, particularly in terms of moving further along the sulfate line in the anion plot.

Table 5-5: Milliequivalent Data and Water Type for Site Groundwater/Surface Water Samples

Groundwater Unit/ Site	Percentage milliequivalent/L (meq/L) of Total Cation/Anion						Water Type
	Ca	Mg	Na + K	Cl	CO ₃ + HCO ₃	SO ₄	
Alluvium	5.6	20.0	74.4	81.6	5.4	13.1	Na-Cl
Regolith	4.6	23.6	71.8	86.4	2.4	11.2	Na-Cl
Basalt	12.9	44.6	42.6	44.4	50.4	5.2	Mg-Na-CO ₃
Spoil	7.1	25.9	67.0	72.4	7.0	20.6	Na-Cl
Coal Measures - Background	18.9	26.1	55.0	79.9	11.8	8.3	Na-Cl
Coal Measures - Mine-Affected	11.4	25.9	62.7	74.9	11.0	14.2	Na-Cl
Bullgang Drain	10.3	42.4	47.4	31.7	0.2	68.1	Na-Mg-SO ₄
K2N Ash Void	22.8	27.2	49.9	53.1	0.0	46.9	Na-Cl-SO ₄
K2W Ash Void	31.2	18.6	50.2	51.0	0.2	48.8	Na-Cl-SO ₄
Tailings Void	16.6	28.5	54.9	52.7	5.1	42.3	Na-Cl-SO ₄
Ramp 7-1	10.7	41.4	47.9	38.1	2.1	59.8	Na-Mg-SO ₄

5.4.5.6 Dissolved metals/metalloids

Figures 37 to 41 show concentration data for groundwater and selected surface water sites, for a number of dissolved metals/metalloids that are assessed to be indicators of AMD impacts. Figures include:

- Figure 37 shows data for cobalt concentration. Relatively high cobalt concentrations are recorded at sites that are known to be AMD impacted (Bullgang Drain, Ramp 7-1) as well as a number of spoil bores or bores that monitor the interface between spoil and the underlying regolith (GW75, GW66 and GW52A).
- Figure 38 shows data for iron concentration. Relatively high iron concentrations are recorded at sites in areas where AMD seepage has been identified (Bullgang Drain, Ramp 7-1) as well as a number of spoil monitoring bores (GW54B, GW70, GW71, GW72).
- Figure 39 shows data for manganese concentration. Relatively high manganese concentrations are recorded at sites where AMD seepage has been assessed to be occurring (sites between

the NW void and Meandu Creek as well as bore GW78 (west of Meandu Creek where an EC $>13,000 \mu\text{S/cm}$ is recorded), sites close to the inferred origin of the saline groundwater plume that extends to the NW of the QW void area (GW50_s, GW67) and sites within buried tailings (GW72) spoil (GW70) in the Black Creek catchment.

- Figure 40 shows data for nickel concentration. Relatively high nickel concentrations are recorded at sites that are known to be AMD impacted (Bullgang Drain, Ramp 7-1) as well as a number of spoil bores or bores that monitor the interface between spoil and the underlying regolith (GW75, GW66, GW67, GW52A).
- Figure 41 shows data for zinc concentration. Relatively high nickel concentrations are recorded at sites that are known to be AMD impacted (Bullgang Drain, Ramp 7-1) as well as a number of spoil bores or bores that monitor the interface between spoil and the underlying regolith (GW75, GW35, GW66, GW67, GW52A).

Table 5-6: Summary of Water Level and Water Quality Observations and Trends

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
GW01	Western mining area, adjacent to Meandu Creek	Historic bore re-added to program in 2016	Coal Measures below Queen Seam	Water Level - Water level data for this site is shown on Figure 16 from 2000 to 2007 and from recommencement of monitoring from November 2016 to present. The water level at this site is relatively stable, with the water level almost unchanged from the last reading in December 2007 to the next reading in November 2016. Water Quality - Electrical conductivity (EC) data between January 2000 to December 2007 and from November 2016 to May 2017 has been relatively consistent, ranging from ~5,000 to 6,000 $\mu\text{S}/\text{cm}$ (refer Figure 21).
GW02	Western mining area, adjacent to Meandu Creek	Historic bore re-added to program in 2016	Regolith	Water Level - Water level data for this site is shown on Figure 12 from 2000 to 2007 and from recommencement of monitoring from November 2016 to present. The water level at this site is relatively stable, with the water level almost unchanged from the last reading in December 2007 to the next reading in November 2016. Water Quality - Electrical conductivity (EC) data from January 2000 to December 2007 and from November 2016 to May 2017 has been relatively consistent, ranging from ~2,300 to 3,300 $\mu\text{S}/\text{cm}$ (refer Figure 20).
GW05	1240 m north-west of K2W void 450 m north-east of Tailings void	Background monitoring	Queen Seam	Water Level - The water level in this bore (Figure 15) conforms to the trend of the RRM curve (i.e. the Queen Seam at this site responds to rainfall recharge). Water Quality - Groundwater at this site is assessed to be un-impacted by site activities.
GW09	Unmined area between QW dump and Tailings void	Historic bore re-added to program in 2016	Sandstone below Queen Seam	The EC at GW09 increased significantly between July 2003 and January 2005, from ~1,700 $\mu\text{S}/\text{cm}$ to ~4,300 $\mu\text{S}/\text{cm}$ (Figure 21). The rise in EC corresponded to a period when the water level decreased from ~456 mAHd to ~449 mAHd between January 2003 and January 2005 (7 m water level decrease over a period of approximately 2 years). From review of historic aerial photos, it is evident that the period between July 2003 and January 2005 corresponded with the development of both the Queen West (QW) pit and the North West B (NWB) pit. Therefore, it is likely that the reduction in water level is related to mining of either or both of the QW and NWB pits. GW09 is screened from 31.3 to 44.3 m below ground level in sandstone interburden below the Queen Seam and it is possible that the increase in EC is related to downward seepage of higher EC groundwater from overlying units as the water level in the coal seams and interburden units decreased due to mining.
GW11	West of Meandu Creek	Historic bore added to	Coal Measures – below Queen Seam	Water Level

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
		program in 2016		- Water level data is shown on Figure 16. Data at this site exists between August 1993 and January 2007 (data is shown on Figure 16 from January 2000, though the water level trend between 1993 and 2000 was relatively flat), followed by a gap in monitoring data with monitoring re-commencing in November 2016. The water level at this site has not changed significantly (~1 m) between 2007 and 2016. Water Quality - EC data from January 2000 to December 2007 and from November 2016 to May 2017 has been relatively consistent, ranging between ~1,800 to 2,100 $\mu\text{S}/\text{cm}$ (refer Figure 20).
GW21	South-west of mining area in natural ground	Historic bore added to program in 2016	Coal Measures below Queen Seam	Water Level - Water level data is shown on Figure 15. Data at this site exists between August 1993 and January 2007 (data is shown on Figure 15 from January 2000). The water level decreased by approximately 7 m between 1993 and 2000 (approximately 1 m/year water level reduction), with the water level relatively stable from 2000 to 2007. There is a gap in monitoring data between 2007 and the re-commencement of monitoring in November 2016. The water level at this site has increased by approximately 2.7 m between 2007 and 2016. Water Quality - EC data from January 2000 to December 2007 and from November 2016 to May 2017 has been relatively consistent, ranging from ~1,200 to 1,400 $\mu\text{S}/\text{cm}$ (refer Figure 21).
GW22	South-west of mining area in natural ground	Historic bore added to program in 2016	Coal Measures below Queen Seam	Water Level - Water level data is shown on Figure 15. Data at this site exists between August 1993 and January 2007 (data is shown on Figure 15 from January 2000). The water level decreased by approximately 3.5 m between 1993 and 2000, with the trend consistent with the reduction observed from the RRM curve (i.e. the water level reduction is interpreted to be related to climate). The water level relatively stable from 2000 to 2007. There is a gap in monitoring data between 2007 and the re-commencement of monitoring in November 2016. The water level at this site has increased by approximately 5 m between 2007 and 2016. The water level trend at this site is interpreted to be consistent with the trend of the RRM curve. Water Quality - EC data between January 2000 and October 2011 was relatively consistent, ranging from ~1,100 to 2,000 $\mu\text{S}/\text{cm}$ (refer Figure 21). The last three readings (December 2016, March 2017, September 2017) have been erratic, ranging from 1,920 $\mu\text{S}/\text{cm}$ to 7,250 $\mu\text{S}/\text{cm}$. Ongoing data collection will be required to establish with an increasing EC trend is evident at this site.
GW25	Western side of NW spoil dump, east of Meandu Creek	Historic bore re-added to program in 2015. Used to monitor for AMD impacts from NW spoil dump	Regolith	Water Level The water level has risen at this site from 5.27 m below top of casing (mTOC) in October 2009 to 1.7 mTOC in May 2017 (Figure 12), suggesting the occurrence of seepage at this site. Water Quality This site is interpreted to be impacted by seepage from the NW spoil dump, based on the following:

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
				• EC has risen from <1,000 $\mu\text{S}/\text{cm}$ in 1999 to > 2,000 $\mu\text{S}/\text{cm}$ in August 2016 (Figure 20); • Sulfate has risen from <100 mg/L in 1999 to > 450 mg/L in August 2016 (Figure 22); • Manganese is elevated at this site relative to other bores in the area (~6 to 16 mg/L – Figure 28); • This site contains concentrations of dissolved aluminium Appendix (A-2), nickel (Figures 30 and 40) and zinc (Figures 32 and 41) that are higher than other bores in the area; • In addition, the concentration of dissolved iron is increasing, from below the LOR over 5 sample events (March 2015 to February 2016) to over 3 mg/L in September 2017 (Figure 26).
GW30	• West of NW void, adjacent to Ramp 7	Monitoring between NW void and Meandu Creek	Regolith	Water Level Water level data at this site (Figure 12) is relatively sparse, with 3 data points up to January 2007 and a further 3 data points shown on Figure 12 since the re-commencement of monitoring in November 2016 (though quarterly monitoring at this sites is currently occurring) The water level at this site increased by approximately 2.5 m between the 2007 and 2016 readings, though it is not possible to make any observations with respect to seepage because there is a data gap over a significant rainfall period (2008 to 2013). Water Quality Water quality data is available at this bore from June 2005 to November 2011 as well as from re-commencement of quarterly monitoring in November 2016. The EC at this site is relatively high (~7,500 to 9,000 $\mu\text{S}/\text{cm}$) though sulfate concentration is relatively low (generally <200 mg/L and AMD indicator metals/metalloids are not present at elevated concentrations. The recorded EC at this site increased from < 2,000 $\mu\text{S}/\text{cm}$ in 2005/2006 (two readings) to >8,000 $\mu\text{S}/\text{cm}$ 1 year later in January 2007. The EC has been relatively consistent since that time, so no inferences are made with respect to the potential for this site to be impacted by AMD seepage from the NW void and ongoing monitoring/assessment is recommended.
GW33	• NW Spoil dump	Water level monitoring in spoil	Spoil	Water Level The water level at this site (Figure 13) indicates that the site responds to rainfall recharge. Since early 2014 the water level has been rising during a period when the RRM curve was falling. However, a water level reduction of ~3 m was recorded between February and August 2016 and the lower water level has persisted through four sampling events (to May 2017). Water Quality No water quality sampling is undertaken from this bore due to bore construction issues (due to spoil collapse during construction the grout became diluted with water and would not cure, so the pH at this site remained elevated). The bore is used for water level monitoring only.
GW34	• Western haul road, upgradient of Bullgang Drain	Hydrocarbon monitoring, AMD monitoring	Queen Seam beneath spoil	Water Level The water level in this bore (Figure 12) shows a response to recharge events such as the 2010/2011 wet season. The water level at this site has been showing a rising water level trend between 2013 and 2017 over a period with the RRM curve has been in decline, suggesting that the water level at this site is impacted by seepage from the overlying spoil (refer also to

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
				comments below for GW35). The water level and water level response is almost identical to bore GW36. Water Quality Potentially impacted by seepage from NW spoil dump based on water quality data, though data is inconclusive. It is noted that: • Sulfate concentration has been reducing over time at this site, from > 700 mg/L in 2011 to < 400 mg/L in 2016 (Figure 22); • The dissolved iron concentration is sporadic at this site, though the concentration is generally >10 mg/L (Figure 26).
GW35	• Western haul road, NW spoil dump	Hydrocarbon monitoring, AMD monitoring	Spoil (NW spoil dump)	Data from this bore is indicative of groundwater conditions in the NW spoil dump. The bore has been removed due to re-contouring of the NW spoil dump, with the final reading in February 2016. It is noted that: Water Level • The hydrograph response is almost identical to the response seen in bores GW34 and GW36 (regolith below spoil), except that the water level in GW35 (monitoring spoil) is 1 m higher (Figure 7), indicating a downward flow potential from the spoil to the underlying sediments (i.e. the regolith in this area is being recharged by the spoil). Water Quality • The Sulfate concentration at this site has been relatively consistent between August 2011 and February 2016, generally in the range of 550 to 650 mg/L (Figure 23) • The concentrations of dissolved iron, manganese, nickel and zinc are elevated relative to other spoil monitoring bores (Figures 26, 28, 30 and 32 respectively).
GW36	• West of NW spoil dump, • Down-gradient of Ramp 4 hydrocarbon dump • East of RD10	Hydrocarbon monitoring, AMD monitoring	Regolith beneath spoil	Water Level The water level in this bore (Figure 12) conforms to the trend of the RRM curve (i.e. the regolith beneath spoil at this site responds to rainfall recharge, which is interpreted to be related to downward flow from the overlying spoil aquifer – refer comment above for GW35). Water Quality Potentially impacted by seepage from NW spoil dump based on water quality indicators. It is noted that: • The Sulfate concentration has increased from < 50 mg/L in 2011 to > 450 mg/L in May 2017 (Figure 23). • The dissolved iron concentration is generally in the range of 80 – 90 mg/L (Figure 27). • The dissolved manganese concentration is within the range of 2.4 to 2.8 mg/L (Figure 29). For reference, the manganese trigger value for ANZECC 2000 90% species protection is 2.5 mg/L.
GW37	North-west area of mine, down-	Hydrocarbon monitoring	Regolith (Sandstone)	Water Level

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
	gradient of workshop area			- The water level trend at this site is consistent and relatively flat (Figure 12), with the site showing a poor correlation with the RRM curve (e.g. compared to bores GW34 and GW36, which are interpreted to be recharged via the overlying spoil). Water Quality - The dissolved iron concentration is relatively high at this site (>50 mg/L – Figure 26) and manganese (> 5 mg/L – Figure 28), though the reason for this is unclear as the site is remote from areas of known AMD seepage.
GW38	Adjacent to Meandu Creek, upstream of RD7	Hydrocarbon monitoring AMD Monitoring	Regolith (Sandstone)	Water Level - The water level trend is similar to the trend for GW37, i.e. the site shows only a subdued response to rainfall recharge events (Figure 12). Water Quality Potentially Impacted by AMD seepage, based on: - The EC level has increased from ~3,000 $\mu\text{S}/\text{cm}$ in 2011 to > 5,000 $\mu\text{S}/\text{cm}$ in 2016 (Figure 20). - The concentration of dissolved nickel has increased from <0.004 mg/L in 2011 to ~0.02 mg/L in 2016 (Figure 30). - The concentration of dissolved zinc has increased from ~0.02 mg/L in 2011 to >0.1 mg/L in 2016 (Figure 32).
GW39	Meandu Creek alluvium, downstream of RD2	Monitoring of Meandu Creek alluvium down-gradient of mining	Meandu Creek alluvium	Water Level - The water level in GW39 shows a consistently flat water level trend, with the water level approximately 2.4 m below ground level (Figure 12). The site is located in the Meandu Creek alluvium upgradient of the Meandu Creek Dam. The water level in the bore, which is at approximately 418 mAHD, is similar to the water level in Meandu Creek Dam. It is interpreted that the water in Meandu Creek Dam will back up into the Meandu Creek alluvium for some distance upstream, thereby exerting a control on water levels at the location of GW39. Water Quality - The EC at this site has been relatively consistent between August 2012 and August 2017 (~2,500-2,800 $\mu\text{S}/\text{cm}$) and the sulphate is relatively low (generally < 200 mg/L). In addition, there is no evidence of elevated concentration of AMD indicator metals (cobalt, iron, manganese, nickel, zinc). - It is assessed that there is no evidence to date of water quality impacts from AMD seepage in the Meandu Creek alluvium at this location, based on review of water quality data (refer Appendix A for water quality summary data).
GW40	Meandu Creek alluvium, upstream of RD2	Monitoring of Meandu Creek alluvium down-gradient of mining	Meandu Creek alluvium	- Water level and water quality as per comments for GW39 above, with the exception that the EC is generally slightly higher at GW40 (~3,000 to 3,500 $\mu\text{S}/\text{cm}$) compared to GW39 (~2,500-2,800 $\mu\text{S}/\text{cm}$). - It is therefore assessed that there is no evidence to date of water quality impacts from AMD seepage in the Meandu Creek alluvium at this location, based on review of water quality data (refer Appendix A for water quality summary data).

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
GW41	Down-gradient of Tailings Storage area		Interface between spoil/ natural ground (siltstone)	Assessed to be impacted by seepage from the NWB tailings dam from the QW void area. It is noted that: Water Level - The water level has risen significantly at this location (6.7 m) since monitoring commenced in November 2013 (Figure 13). Water Quality This site is assessed to be within the high EC plume that is downgradient of the QW void. - The EC is elevated at this site ($> 12,000 \mu\text{S/cm}$ – Figure 21). - Sulfate concentration is generally $> 700 \text{ mg/L}$ (Figure 23). - Dissolved iron concentration is generally $> 10 \text{ mg/L}$ (iron levels have reduced from 21 mg/L in November 2014 to $\sim 2.8 \text{ mg/L}$ in August 2017).
GW42	South-west area of mine, adjacent to Meandu Creek diversion	Monitoring of spoil adjacent to Meandu Creek	Interface between spoil/ natural ground (coal)	Water Level - The water level has fallen significantly at this location (7 m) since monitoring commenced in August 2013 (Figure 13). It has been interpreted from previous hydrocarbon assessment reports that this site receives seepage water from the area of spoil to the south of the site. This area of spoil has been rehabilitated and it is interpreted that the spoil water level may be falling due to a reduction in the rate of groundwater recharge due to rehabilitation of the spoil. - It is noted that the water level at this site is below the base of the adjacent Meandu Creek; the water level in August 2016 was 434.36 mAHD in GW42, compared to a ground elevation in Meandu Creek adjacent to the bore location of approximately 460 mAHD. Water Quality Groundwater at this site is assessed to be impacted by seepage generated from the spoil aquifer to the south of the bore, based on the following water quality parameters: - The dissolved iron concentration is elevated, generally $\sim 20 \text{ mg/L}$ (Figure 27). - The dissolved manganese concentration is relatively consistent at $\sim 4.5 \text{ mg/L}$ (Figure 29).
GW43_s	East of Meandu Mine	Monitoring east of SRE area	Basalt	Water Level - The water level graph for this bore is shown on Figure 15 - Mining-related drawdown first commenced at this site in the underlying Queen Seam (due to the approach of mining in the K4S pit), with the commencement of drawdown evident in the basalt aquifer after approximately September 2015. The rate of drawdown in the basalt aquifer between May 2015 (prior to the onset of drawdown) and March 2018 averages 0.73 m/year, compared to an average drawdown rate of 1.72 m/year for the underlying Queen Seam over the same period Water Quality - The EC at this site has been consistent since commencement of monitoring, ranging from $2,210$ to $2,360 \mu\text{S/cm}$ (Figure 20)

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
GW43_d	East of Meandu Mine	Monitoring east of SRE area	Queen Seam	Water Level - This bore has recorded a decreasing downward water level trend since monitoring commenced in February 2014, with the drawdown interpreted to be related to mining; GW43_d is located close to the current mining area in K4S. Water Quality - The EC at this site has been consistent since commencement of monitoring, consistently < 800 $\mu\text{S/cm}$ (Figure 21) and lower than the EC of the overlying basalt (range from 2,210 to 2,360 $\mu\text{S/cm}$ recorded in GW43_s)
GW44_s	East of Meandu Mine	Monitoring east of SRE area	Queen Seam	The bores at sites GW44 and GW45 are reviewed together, as the sites were designed to be located on either side of a fault that is upthrown on the east and downthrown on the west, resulting in the Queen Seam being closer to surface on the eastern side of the fault. This has resulted in truncation of the coal seams on the eastern side of the fault against lower-permeability interburden on the western side of the fault and disrupted the flow of groundwater from east to west. The effect of this is evident in both water level and water quality data, as discussed below. Water Level - The water levels in the Queen Seam bores at this location are shown on Figure 15, with the water level for the King Seam bore (GW45_s) shown on Figure 14. The water level in Queen Seam bores GW44_s and GW44_d is ~5 m higher than for the Queen Seam on the western side of the fault (GW45_d). This is interpreted to indicate that water is being "held up" on the eastern side of the fault as groundwater flow from east to west is disrupted by the fault. - The water level in the King Seam on the western side of the fault (GW45_s) is similar to the deeper Queen Seam bore at this location (GW45_d), with the water level on the western side of the fault at ~RL480 mAHD and the water level on the eastern side of the fault at ~RL485 mAHD. - The downward water level trend that is observed in all bores at this location is interpreted to be related to climate, with the trend consistent to the trend observed in the RRM curve. Water Quality - The water quality is significantly different on either side of the fault. For Queen Seam bores to the east (GW44_s&d), where the groundwater flow from east to west is interpreted to be impeded by the fault, the EC is >10,000 $\mu\text{S/cm}$ (Figure 21, Appendix A-1). On the western side of the fault the EC of the Queen Seam bore (GW45-d) is significantly lower (~1,300 $\mu\text{S/cm}$) while the EC of the King Seam bore (GW45_s) is ~6,000–6,400 $\mu\text{S/cm}$. - The variability of EC on either side of the fault is interpreted as further evidence that groundwater flow from east to west is being impeded by the fault, with a greater residence time for water on the eastern side of the fault resulting in a higher groundwater EC.
GW44_d			Queen Seam	
GW45_s			King Seam	
GW45_d			Queen Seam	

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
GW46_s	East of Meandu Mine	Monitoring east of SRE area	King Seam	Water Level The water level graph for this bore is shown on Figure 14. The downward water level trend that is observed in all bores at this location is interpreted to be related to climate, with the trend consistent to the trend observed in the RRM curve. Water Quality The EC at this site has been consistent since commencement of monitoring, ranging from 1,720 to 1,820 $\mu\text{S}/\text{cm}$ (Figure 21, Appendix A-1).
GW46_d	East of Meandu Mine	Monitoring east of SRE area	Queen Seam	Water Level - The water level graph for this bore is shown on Figure 14. The downward water level trend that is observed in all bores at this location is interpreted to be related to climate, with the trend consistent to the trend observed in the RRM curve. The water level in the Queen Seam at this location is slightly lower than the water level in the overlying King Seam (GW46_s), indicating a downward potential for groundwater flow at this location. - The reason for the increase in water level that is observed in both bores at this site following 3 rounds of monitoring (Figure 14) is uncertain and ongoing review of the data will be required to establish water level trends for this site. Water Quality The EC at this site has been consistent since commencement of monitoring, ranging from 1,720 to 1,820 $\mu\text{S}/\text{cm}$ (Figure 21, Appendix A-1).
GW50_s*	Approximately 740 m north-west of the current area of ash emplacement in the K2W void (Figure 1) This bore has been decommissioned since commencement of this assessment.	Down-gradient monitoring of K2W/K2N ash disposal voids	Regolith	Water Level - The water level has been increasing in this bore since approximately August 2010 (Figure 12); the trend differs from that observed in bores where water levels are dominated by rainfall recharge/discharge patterns (as discussed above) in that the water level has continued to rise at a time when the water level in other bores was falling (i.e. the period between January 2013 and January 2015 when the rainfall residual mass curve displayed a falling trend). The water level trend had started to flatten off and then fall prior to rising slightly again following 2015 wet season rainfall. - The distance from the K2W void, and the response of bores that are closer to the K2W void, suggests that the water level at this site is impacted by phenomena other than K2W ash disposal (e.g. other mining activities in other areas, interaction with spoil with distinct characteristics, distribution of rainfall recharge, etc.). Water Quality The following observations are made with respect to groundwater quality at this site: - The EC at this site is higher than is recorded at any other bore within the Meandu Mine groundwater monitoring network, with an EC in the range of 19,000 to 20,000 $\mu\text{S}/\text{cm}$ (Figure 20). It is noted that the water quality in bores that monitor the QW spoil dump up-gradient of the site record a significantly lower EC (for example, spoil monitoring bore GW54B, which is located upgradient of GW50_s, records an EC of approximately 3,500 $\mu\text{S}/\text{cm}$). By contrast, bore GW52A, which monitors regolith below spoil, records an EC of over 12,000 $\mu\text{S}/\text{cm}$;

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
				- The sulfate concentration is within the range of approximately 750 to 900 mg/L (Figure 22), which is in the upper range of sulfate concentration recorded at site. The concentration of other major ion parameters is also elevated (Appendix A-1), which is consistent with the high TDS concentration that is recorded at this site. - Dissolved iron is present at relatively elevated concentration, in the range of 45 to 60 mg/L (Figure 26, Appendix A-2). - Dissolved manganese is present at relatively elevated concentration, in the range of 20 to 60.3 mg/L (Figure 28, Appendix A-2). - Dissolved nickel is present at relatively elevated concentration, in the range of 0.13 to 0.14 mg/L (Figure 30, Appendix A-2). - Dissolved zinc is present at relatively elevated concentration, in the range of 0.37 to 0.52 mg/L (Figure 32, Appendix A-2).
GW50_d*	Approximately 740 m north-west of the closest point of ash deposition in the K2W void and 350 m north-west of the Queen West (QW) spoil dump This bore has been decommissioned since commencement of this assessment.	Down-gradient monitoring	Queen Seam	Water Level - GW50_d is located approximately 740 m north-west of the closest point of ash deposition in the K2W void and 350 m north-west of the Queen West (QW) spoil dump. The water level in this bore displays a consistent rising water level trend during a period when Queen Seam bore GW51_d, which is closer to the K2W void, is displaying a flat or falling water level trend (Figure 15). The water level trend in GW50_d almost exactly parallels the water level trend in the shallow monitoring bore at the same site (GW50_s – refer Figure 15), though the water level in GW50_s is approximately 2 m higher than the water level in GW50_d. Water Quality - The Queen Seam at this site is assessed to be un-impacted by seepage from the K2W ash disposal void. It is noted that, despite the potential for downward seepage at this site (due to the higher water level in the shallow bore at the same site (GW50_s) the EC is consistently ~1,400 µS/cm compared to ~20,000 µS/cm in the overlying regolith (as recorded at GW50_s). - It should be noted that this bore has been decommissioned since commencement of this assessment.
GW51_s*	Approximately 620 m to the north/north-west of the K2W void This bore has been decommissioned since commencement of this assessment.	Down-gradient monitoring of K2W/K2N ash disposal voids	Regolith	Water Level - The water level in GW51_s increased in response to the 2010-2011 wet season rainfall; however, since that time the water level has remained relatively constant (Figure 12). It is concluded that shallow groundwater in the area of GW51_s is responding to changing climatic conditions, but is not showing water level impact to date from ash disposal in the K2W void. Water Quality - GW51_s is screened within regolith beneath approximately 4 m of spoil. The EC at this site is relatively low (~2,500-3,500 µS/cm (Figure 20) compared to monitoring bores GW52A and GW50_s, which monitor the regolith to the west and regularly record an EC in excess of 12,000 µS/cm (refer separate discussion for GW50_s and GW52A in this table). - Based on review of other water quality parameters (sulfate, metals/metalloids) it is concluded that there is no evidence of seepage impacts at this site.

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
GW51_d*	Approximately 620 m north/north-west of the K2W ash disposal void. This bore has been decommissioned since commencement of this assessment.	Down-gradient monitoring of K2W/K2N ash disposal voids	Queen Seam	Water Level - The groundwater level at this site (Figure 15) is interpreted to be responding to the background rainfall recharge/discharge cycle rather than seepage from the K2W void. Water Quality - The Queen Seam at this site is assessed to be un-impacted by seepage from the K2W ash disposal void. It should be noted that this bore has been decommissioned since commencement of this assessment.
GW52A	Approximately 500 m north-west of K2W ash disposal void Down-gradient of QW spoil dump, monitoring regolith below spoil. This bore has been decommissioned since commencement of this assessment.	Down-gradient monitoring	Regolith	Water Level - The hydrograph trend for GW52A is shown on Figure 12. GW52A is a replacement bore for GW52, which was located approximately 60 m north of GW52A and screened within the same formation (regolith below spoil). The hydrograph for GW52A can therefore be reviewed as a continuation of the hydrograph for GW52 (also shown on Figure 12). Bore GW52 responded to significant recharge events such as the 2010/2011 wet season and the water level at this site has risen by approximately 7.2 m between October 2008 (at GW52) and August 2016 (at GW52A). The water level in GW52A has been relatively steady since mid-2013, over a period when the RRM curve has been in decline, suggesting that water levels at this site are influenced by seepage from the adjacent QW spoil dump. Water Quality - The EC at this site is regularly in excess of 12,000 $\mu\text{S}/\text{cm}$ (Figure 20). Figure 20 also shows the EC for bore GW52, which had a similar EC except during and following the 2010/2011 wet season rainfall when the EC dropped from $\sim 13,000 \mu\text{S}/\text{cm}$ to less than $1,000 \mu\text{S}/\text{cm}$. The low EC was evident over three successive sampling events and is interpreted to be the result of recharge at this site. Due to the extremely rapid reduction in EC and the extremely rapid increase in EC by June 2012 (Figure 20) the recharge must have been extremely localized and may have been enhanced by seepage through the bore annulus. - The Sulfate level is relatively elevated in GW52A ($> 500 \text{ mg/L}$ - Figure 22), reflecting the relatively high EC/TDS at this site. - The bore is also relatively high in concentrations of dissolved metals, including aluminium (Appendix A-2), manganese (Figure 28), nickel (Figure 30) and zinc (Figure 32).
GW53	138 m west of the limit of ash deposition in K2W void	Monitoring of K2W seepage	Regolith	Water Level Bore GW53 is screened within in-situ material (regolith/coal) at a location between the K2W void and the Queen west pit (Figure 10). The bore is located on the old access ramp to the K2W void; therefore, as the level of ash increases the ash gets closer to GW53 as ash and water moves up the old access ramp;

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
				- Water in this bore is interpreted to be sourced entirely from seepage from the K2W void as the bore was dry but began to contain water once the water level in the adjacent K2W void rose above the base of the screens. The water level in the K2W void reached a level coinciding with the base of screens in GW53 in approximately August-September 2012. Approximately 12 months later (August 2013) water began to be detected (initially as mud) in the base of the bore. The water level has risen by 7.68 m between November 2013 and August 2016 (Figure 12). It is noted that the water level decreased between the November 2015 and February 2016 readings; the deposition of ash within the K2W void ceased in December 2015 and it is interpreted that the reduction in water level is related to a reduction of pore pressure within the K2W void due to the cessation of ash deposition. A decrease in water level is also noted over the same period at a number of other sites including GW55_d and GW60. At GW53 the water level reduction was of a relatively short duration as the water level rose over the next two monitoring events (Figure 12); Water Quality - The EC at this site has reduced from >8,000 $\mu\text{S}/\text{cm}$ in November 2014 to ~4,000 $\mu\text{S}/\text{cm}$ in August 2016 (Figure 12). The high initial EC may have been related to the soil salinity as the sediments became initially saturated, with the more recent EC values reflecting the EC of the seepage water; - The sulfate concentration has increased from ~500 mg/L in November 2014 to ~900 mg/L in 2017 (Figure 22); - The dissolved aluminium concentration is in the range of 0.31 to 0.4 mg/L (Appendix A-2), which is similar to the concentration observed in water samples from the K2N ash disposal void; and, - GW53 records concentrations vanadium (ash indicator parameter) at concentrations above the LOR; GW53 is the only ash monitoring bore to record concentrations of vanadium above the LOR. - GW53 also records concentrations of selenium (ash indicator parameter) that are, for some sampling events, just above the LOR (no other monitoring bores on site record selenium at concentrations above the LOR).
GW54B	Western site of the QW soil dump	Down-gradient monitoring	Interface between spoil and the underlying regolith	Water Level Bore GW54B screens the interface between spoil and the underlying regolith and was sited to monitor seepage from the Queen West void at a location to the west of GW54A (Figure 10) once GW54A was dumped over with spoil. The hydrograph for both bores is shown on Figure 7. The water level in GW54A rose in response to wet season rainfall. The water level within the Queen West spoil dump (as measured in bore GW54A) was higher than the water level in GW54B, as is evident from the bottom hydrograph in Figure 7, where, for the period where there is overlap in the available data from GW54A and GW54B, the water level in GW54A was approximately 2 m higher than the water level in GW54B. It is therefore concluded that the water level response in GW54B is partly related to rainfall and partly related to seepage from the adjacent Queen West spoil dump. Water Quality

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
				- The EC in both GW54A and GW54B is relatively low (~2,800 – 3,500 $\mu\text{S}/\text{cm}$ – Figure 21) at a location that is upgradient of GW52A (where the EC is > 12,000 $\mu\text{S}/\text{cm}$). Therefore, it does not appear that the spoil is the source of the high EC water at GW52A and bores down-gradient. - GW54A is also relatively low (compared to GW52A) in other water quality parameters such as sulfate and dissolved metals/metalloids.
GW55_d	~170 m west of the K2W void	Monitoring adjacent to K2W	Queen Seam	Water Level - Bore GW55_d is located approximately 170m west of the K2W void. The Queen Seam at this location responds to rainfall recharge, as is evident from the water level rise recorded in response to the 2010-2011 wet season recharge event, which occurred at a time when the water level in the K2W void was lower than the water level in the bore (Figure 15). The water level has displayed a rising water level trend over the period when the RRM curve was falling (2013 to 2016) suggesting that water levels at this site are impacted by the water level in the adjacent K2W void. A sharp decrease in water level is evident between the May and August 2016 sampling events. This may be related to the cessation of ash deposition in December 2015, though further monitoring will be required as this water level reduction was evident over only one monitoring event. Water Quality Water quality in GW55_d is interpreted to be impacted by seepage from the adjacent K2W void based on the following: - The sulfate concentration rose from <200 mg/L in 2009 to >800 mg/L in 2015. However, since 2015 the sulfate concentration has been steadily reducing to a concentration August 2017 of <500 mg/L (Figure 21) - GW55_d is high in concentrations of dissolved metals relative to other Queen Seam bores, including aluminium (Appendix A-2), iron (Figure 27), manganese (Figure 29), nickel (Figure 31) and arsenic (Appendix A-2). - However, GW55_d is not elevated in metal/metalloid parameters that are specific to ash dam monitoring, including molybdenum, selenium or vanadium (Appendix A-2).
GW55_s	~170 m west of the K2W void	Monitoring adjacent to K2W	Regolith	GW55_s has been dry for all monitoring events since construction in 2008 – the base of screen is above K2W void water level.
GW56_d	~900 m east of K4E pit and 900 m south-west of the K2E pit.	Monitoring in the eastern mining area	Ace Seam	Water Level - The water level in GW56_d has been steadily decreasing since mid-2009 (Figure 14). It is interpreted that the water level at this location is impacted by drainage towards the adjacent K4E or K2E pits. Water Quality - The EC at GW56_d has been stable since monitoring commenced in 2009 and has been consistently within the range of 860 to 1040 $\mu\text{S}/\text{cm}$.

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
GW56_s	~900 m east of K4E pit and 900 m south-west of the K2E pit.	Monitoring in the eastern mining area	Basalt	GW56_s has been dry for all monitoring events since construction in 2008
GW58_d	Eastern area of mining at the southern end of the K2E pit.	Monitoring adjacent to K2E pit	King Seam	Water Level - The overall water level trend in this bore is downward (Figure 14), with some response evident to recharge events such as the 2010-2011 and 2012-2013 wet seasons. The reducing water level trend is interpreted to be related to seepage towards the adjacent King 2 East (K2E) pit (Refer Figure 10 for bore location). Water Quality - GW58_d records relatively low EC, i.e. <1,200 $\mu\text{S}/\text{cm}$ between February 2014 and August 2016 (Figure 21, Appendix A-1); - The concentration of other measured parameters (e.g. sulfate, dissolved metals/metalloids) is also relatively low. - It is interpreted that the King Seam at this location is not impacted by mine seepage, which is interpreted to be because the groundwater flow direction at this location is towards the pits.
GW58_s	Eastern area of mining at the southern end of the K2E pit.	Monitoring adjacent to K2E pit	Basalt	GW58_s has been dry for all monitoring events since construction in 2008
GW59B	160 m east of K2W void, west of K2E pit	Monitoring adjacent to K2W	King Seam	Water Level - GW59B is located approximately 60 m from the original King Seam monitoring bore GW59A (Figure 10). Only one water level was recorded for GW59A (due to access issues), however it is noted that the water level in the King Seam at this location has increased by over 10 m since 2010 (based on the relative difference between the water level in bores GW59A and GW59B – refer Figure 14). - The water level in GW59B since 2013 is difficult to interpret (refer Figure 14); the water level reduced significantly between November 2013 and November 2014 (3.2 m) before increasing by nearly 6 m between November 2014 and December 2015. Between December 2015 and August 2016, the water level reduced again by almost 6 m (so that the water level is almost the same in August 2016 as in November 2014). The cause of this change in water level is not clear, however it is noted the bore is located between the K2W ash disposal void (to the west) and the K2E Pit (to the east) and the water level may therefore be influenced by both features. Water Quality It is interpreted that the water quality at GW59B is impacted by seepage from the adjacent K2W void, based on the following: - The EC has increased from ~2,000 $\mu\text{S}/\text{cm}$ in May 2014 to 3,240 $\mu\text{S}/\text{cm}$ in May 2017 (Figure 21);

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
				- The sulfate concentration is elevated (~800 mg/L) relative to other King Seam bores such as GW58_d (<100 mg/L) and is similar to the sulfate concentration in ash void water samples (refer Figure 23); - The concentration of dissolved boron (ash seepage indicator parameter) has increased from <0.2 mg/L in 2014 to ~0.3 mg/L in 2017 and is higher than for any other coal seam bore (Appendix A-2); - The concentration of dissolved molybdenum (ash seepage indicator parameter) has increased significantly between 2014 and 2016 (from <LOR to ~0.03 mg/L) and is higher than observed in any other monitoring bore on site (Appendix A-2).
GW60	Eastern crest of K2E pit	Monitoring adjacent to K2E pit and spoil storage area	Queen Seam	Water Level - Located adjacent to the eastern crest of a former area of mining in the K2E pit (which is now filled with spoil). The water level responded significantly to rainfall recharge during the 2010/2011 wet season but the response was relatively subdued to the 2012/2013 wet season recharge event (Figure 15). To overall water level trend has been falling since 2011, indicating that seepage towards the K2E Pit is occurring at this site. Water Quality - The concentration of measured parameters (e.g. EC (Figure 21), sulfate (Figure 23), dissolved metals/metalloids) is relatively low and the trend is relatively consistent. - It is interpreted that the Queen Seam at this location is not impacted by mine seepage, which is interpreted to be because the groundwater flow direction at this location is towards the pit.
GW61_s	North of K2E pit, adjacent to RD17 in Black Creek catchment, near area of prior tailings disposal	Down-gradient monitoring in Black Creek Catchment	Regolith	Water Level - GW61_s and GW61_d are located to the north of the K2E Pit and adjacent to dam RD17, in a location that was a former area of tailings disposal. The water level trend for these bores generally conforms to the trend of the RRM curve (Figure 12), i.e. water levels are influenced by rainfall recharge, with a reduction in water level occurring during periods of the year when rainfall is below the monthly average. The water level in GW61_s rose above the level of the deeper bore at the same site (GW61_d) following 2010/2011 wet season rainfall and the water level in GW61_s has remained approximately 1.0 to 1.5 m above the water level of GW61_d since that time, indicating a potential for downward water movement (recharge) at this site. Water Quality - The pH is generally >7.0 in the deep bore at this site (GW61_d) and generally <6.0 in the shallow bore (GW61_s) (refer Figure 18); - The EC is higher in the deeper bore at this site (~4,000–5,000 µS/cm in GW61_d compared to ~1,000 µS/cm in GW61_s), though it is noted that the EC trend in the shallow bore is far more erratic than in the deep bore (refer Figure 20); - The sulfate concentration is correspondingly higher in the deep bore at this site (due to the higher TDS), though the sulfate concentration is relatively low in both bores (~100-150 mg/L in GW61_d and <100 mg/L in GW61_s – refer Figure 22);
GW61_d			Regolith	

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
				- Both bores record relatively low concentrations of dissolved metals/metalloids, however it is observed that: - The dissolved Iron concentration is relatively high in GW61_d (~2.5-3.0 mg/L) compared to GW61_s (~0.5-0.09 mg/L) – refer Figure 26 and Appendix A-2; however; - The dissolved aluminium concentration is higher in the shallow bore at this site (GW61_s, where the concentration tends to be ~0.08 mg/L, compared to GW61_d where all samples are <LOR) – refer Appendix A-2.
GW62_d	East of Meandu Mine	Monitoring in surface rights extension (SRE) area	Ace Seam	• Bore Dry
GW62_s			Basalt	• Bore Dry
GW63_d			Queen Seam	Water Level - The water level trend is slightly downwards, but is interpreted to be conforming to the current downward trend of the RRM curve (i.e. the observed water level reduction is interpreted to be related to current low-rainfall conditions and not mining impacts). Water Quality - The EC at this location is relatively low, consistently ~1,030 µS/cm
GW63_s			Regolith	• Bore Dry
GW64_d			Maronghi Creek beds	- The water level is consistent in this bore (refer Figure 16) and is above the water level recorded in the shallow bore at this site (GW64_s). - The EC is relatively consistent, generally ~2,500 µS/cm
GW64_s			Maronghi Creek beds	- The water level is consistent in this bore, approximately 1 m above the base of screens - Due to the low water level, the bore has only been sampled for water quality on one occasion, recording an EC of 5,246 µS/cm, which is higher than the EC of the deep bore at this site (GW63_d generally ~2,500 µS/cm)
GW65			Maronghi Creek beds	- The water level is consistent in this bore (refer Figure 16) and is higher than the other Maronghi Creek beds bores (GW64_s and GW64_D) due to the higher surface elevation of the site (approximately 30 m higher elevation than GW64) - The EC at this site ranges from ~3,000 to 3,500 µS/cm
GW66*	Down-gradient of QW void	Monitoring of spoil down-gradient of QW void	Spoil	- Water level data is only available at this site since November 2016 and trends are not yet established. - The EC at this bore is in the range 3,600-3,800 µS/cm, which is consistent with EC data for other bores that monitor the QW spoil.
GW67*	Down-gradient of QW void	Monitoring of regolith down-gradient of QW void	Regolith	- Water level data is only available at this site since November 2016 and trends are not yet established. - The EC at this bore is in the range 8,440 to 9,930 µS/cm (Figure 20), with a sulfate concentration >600 mg/L (Figure 22). This bore is located within the high EC plume that is

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
				interpreted to be emanating from the area of the QW spoil dump/ K2W void (refer also Figure 34).
GW68	Down-gradient of QW void	Monitoring of regolith down-gradient of QW void	Regolith	- Water level data is only available at this site since November 2016 and trends are not yet established. - This bore is located further down-gradient than bore GW67 (discussed above). The EC at this bore is consistently >12,000 $\mu\text{S}/\text{cm}$ (Figure 20), with a sulfate concentration >600 mg/L (Figure 22). This bore is located within the high EC plume that is interpreted to be emanating from the area of the QW spoil dump/ K2W void (refer also Figure 34).
GW69	Down-gradient of QW void	Monitoring of regolith down-gradient of QW void and NWB tailings storage	Regolith	- Water level data is only available at this site since November 2016 and trends are not yet established. - This bore is located further down-gradient than bore GW68 and GW41 (discussed above). The EC at this bore is consistently >12,000 $\mu\text{S}/\text{cm}$ (Figure 20), with a sulfate concentration ~600 mg/L (Figure 22). This bore is located within the high EC plume that is interpreted to be emanating from the area of the QW spoil dump/ K2W void (refer also Figure 34).
GW70	Within K2E rehabilitated spoil	Monitoring within K2E rehabilitated spoil	Interface between spoil and regolith	- Water level data is only available at this site since November 2016 and trends are not yet established. - The EC in this bore is relatively high (>8,000 $\mu\text{S}/\text{cm}$ – Figure 21 and Appendix A-1), though the sulfate concentration is relatively low (~130 mg/L). Groundwater from this site also shows high concentrations of iron (>200 mg/L – Figure 27) as well as nickel (Figure 31) and zinc (Figure 33), which are potential AMD indicator parameters.
GW71	Within K2E rehabilitated spoil	Monitoring within K2E rehabilitated spoil	Interface between spoil and regolith	- Water level data is only available at this site since November 2016 and trends are not yet established. - GW71 is located up-gradient of GW70 (discussed above). The EC at this site is relatively low (~3,500 $\mu\text{S}/\text{cm}$ – Figure 21) and the sulfate is also low (<200 mg/L – Figure 23). A notable feature at this site is that the pH is low (generally <5.0 – Figure 19) and the dissolved aluminium concentration is relatively high (>4 mg/L – Appendix A-2), which is interpreted to be related to dissolution of aluminium from the spoil due to the low pH.
GW72	Within K2 tailings dump, overlain by K2E rehabilitated spoil	Monitoring within K2 tailings	Interface between K2 tailings and regolith	- Water level data is only available at this site since November 2016 and trends are not yet established. - GW72 is screened within the K2 tailings storage area, which is overlain by K2E rehabilitated spoil. The site records relatively low EC (<3,000 $\mu\text{S}/\text{cm}$ – Figure 21) but high sulfate (>500 mg/L – Figure 23) and high iron (>100 mg/L – Figure 27).
GW73	Black Creek catchment, down-gradient of GW61_s & GW61_d	Monitoring of regolith within Black Creek catchment	Regolith	- Water level data is only available at this site since November 2016 and trends are not yet established. - The EC at this site is relatively high (>10,000 $\mu\text{S}/\text{cm}$ – Figure 20) as is the sulfate concentration (>800 mg/L – Figure 22). However, the site does record relatively low concentrations of AMD indicator metals/metalloids, e.g. cobalt, iron, manganese, nickel and zinc (Figures 24, 25, 27, 30, 32 respectively, Appendix A-2).

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
GW74	Black Creek catchment, down-gradient of GW73	Monitoring of regolith within Black Creek catchment	Regolith	- Water level data is only available at this site since November 2016 and trends are not yet established - GW74 is located within the Black Creek catchment and down-gradient of GW73 (discussed above). The EC at this site is relatively low ($\sim 3,000 \mu\text{S}/\text{cm}$ – Figure 21)) but the sulfate is relatively high ($\sim 500 \text{ mg}/\text{L}$ – Figure 23). A notable feature at this site is that the pH is low (generally ~ 4.0 – Figure 19) and the dissolved aluminium concentration is relatively high ($\sim 8 \text{ mg}/\text{L}$ – Appendix A-2), which is interpreted to be related to dissolution of aluminium from the regolith due to the low pH.
GW75	Western area of NW void, within rehabilitated spoil	Monitoring of spoil within NW void area	Spoil	- Water level data is only available at this site since November 2016 and trends are not yet established - The EC at this site is relatively low ($\sim 3,500 \mu\text{S}/\text{cm}$ – refer Figure 21 and Appendix A-1). However, the sulfate concentration is relatively high ($\sim 1,000 \text{ mg}/\text{L}$ – refer Figure 23 and Appendix A-1) as is the concentration of AMD indicator parameters including cobalt (Figure 25), iron (Figure 27), manganese (Figure 29), nickel (Figure 31) and zinc (Figure 33, refer also Appendix A-2). - It is interpreted that groundwater at this site is impacted by AMD seepage.
GW76	Western area of NW void, within rehabilitated spoil	Monitoring of spoil to west of NW void area	Spoil	- Water level data is only available at this site since November 2016 and trends are not yet established - The EC at this site is relatively low ($\sim 2,500 \mu\text{S}/\text{cm}$ – refer Figure 21 and Appendix A-1) and the sulfate concentration is also low ($< 50 \text{ mg}/\text{L}$ – refer Figure 23 and Appendix A-1). The concentration of some AMD indicator parameters is relatively high (e.g. iron (Figure 27), and manganese (Figure 29)). Based on low sulfate and relatively low concentrations of AMD indicator parameters such as cobalt, nickel and zinc, it is interpreted that the groundwater at this site is not impacted by AMD seepage at this stage.
GW78	Western side of Meandu Creek	Monitoring of regolith to the west of Meandu Creek	Regolith	Water Level - Water level data is only available at this site since November 2016 and trends are not yet established. However, it is observed that: - The water level in the bore is approximately 426.7 mAHD (May 2017) - Bores on the eastern side of Meandu Creek (e.g. GW25, GW30) record water levels of ~ 429.5 mAHD, indicating a flow potential from east to west (the ground level in the adjacent area of Meandu Creek is approximately 427 mAHD at this location). - Based on relative water level data, it is concluded that the bore is too close to Meandu Creek to establish whether groundwater in this bore is derived from the eastern or western sides of Meandu Creek. Water Quality - The EC at this site is high ($> 13,000 \mu\text{S}/\text{cm}$ – refer Figure 20 and Appendix A-1) and it is noted that there are no groundwater bores or surface water monitoring sites close to GW78 that record an EC as high as the concentration at this location. The sulfate concentration is relatively low ($\sim 400 \text{ mg}/\text{L}$) given the high EC at this location. Groundwater at this site is

Bore ID	Location	Bore Purpose	Unit Monitored	Comment
				relatively high in cobalt (Figure 24) and manganese (Figure 28), but relatively low in other AMD indicator parameters such as iron (Figure 26), nickel (Figure 30) and zinc (Figure 32). ○ There is insufficient data to establish the source of this water, e.g. whether the water originates from high EC groundwater to the west of Meandu Creek. Therefore, it is recommended that additional groundwater monitoring bores are installed to the west of GW78 to establish both the groundwater gradient and the groundwater quality to the west of Meandu Creek

Notes * Bores have been decommissioned since commencement of assessment

	Site assessed to be impacted or potentially impacted by seepage from K2W Void
	Site assessed to be impacted or potentially impacted by AMD seepage
	Site assessed to be impacted or potentially impacted by seepage from sources that may be other than ash voids or AMD

5.5 Geophysics Data

5.5.1 Transient Electromagnetics (TEM) Surveys

Land-based and airborne geophysical surveys have been undertaken at Meandu Mine using the transient electromagnetic (TEM) method, as discussed here and in Section 5.5.2 and 5.5.3. A simplified explanation of the TEM method is as follows:

- A direct current is passed through a transmitter loop that is located above the ground; this induces a primary electromagnetic (EM) field in the underlying ground.
- The current is abruptly terminated. As the primary EM field collapses, currents are induced in the subsurface (eddy currents) that expand from the source in an outward and downward direction and dissipate over time.
- The induced current produces a secondary magnetic field in the underground layers. The manner in which the induced current and secondary magnetic field are propagated is dependent on the resistivity of the ground through which the current travels.
- Readings of the intensity of the secondary magnetic field are picked up by a receiver coil, with the data subsequently processed to provide the relative resistivity of the ground at particular locations and depths.
- The data can then be colour-contoured to provide images of the resistivity of the surveyed ground.

For groundwater investigations it is common to present the data as electrical conductivity (EC), which is the inverse of electrical resistivity (i.e. low resistivity ground has high EC and high resistivity ground has low EC). The remainder of this report discusses the geophysics data in terms of EC, as this is the format in which the data has been presented for both geophysical surveys that are discussed below.

It should also be noted that the EC data that are presented from the TEM surveys are not directly comparable to the EC data that are recorded from groundwater samples, as the EC that is recorded by the TEM method is impacted by a number of factors in addition to the EC of groundwater. Factors that influence the EC of TEM data include:

- The relative proportion of clay minerals in the geological materials. Clays tend to have relatively higher EC, therefore clay-rich sediments will provide a different EC signature than, for example, clean quartz sand.
- The presence of conductive minerals. For example, AMD results in the precipitation of ferrous hydroxide and haematite, which may have a high EC relative to surrounding sediments.
- The rock type, for example basalt tends to have a high EC relative to the sandstone/siltstone units that are encountered at Meandu Mine (e.g. Tarong beds, Maronghi Creek beds).
- Saturated rock/sediment will tend to have a higher EC than the same unit in an unsaturated state.
- Saline groundwater will have a higher EC than fresh water.
- Weathered bedrock will tend to have a higher EC than the same bedrock unit in an unweathered state.
- The data is also influenced by infrastructure that affects the EM signature, such as steel buildings and transmission lines. The impact of this type of infrastructure was apparent in the airborne TEM survey (Section 5.5.3).

Therefore, in summary:

- dry ground, sand (i.e. quartz) aquifers, fresh water and unweathered basement rocks tend to record relatively low EC; and
- clays, saline seepage and weathered bedrock tend to record relatively high EC.

Determining what the EC data (as recorded by the TEM method) are indicating at different depths in the subsurface therefore becomes a matter of interpretation, with this interpretation aided by use of geological data (e.g. drilling logs, geological mapping), water quality data and field observations.

5.5.2 Land-Based Transient Electromagnetics (TEM) Survey

A land-based TEM survey undertaken in June 2015. The survey was undertaken using a trailer-mounted array that was towed behind a 4WD vehicle and is summarised as follows:

- Data acquisition was limited to areas where the trailer-based array could be towed by a vehicle. This meant that access was effectively limited to site access roads, as well as a rehabilitated area to the west of the NW void that was specially cleared to provide access for the survey. The location of geophysical survey lines is shown on Figure 42.
- The TEM method provided continuous data to a depth of investigation of approximately 50 m. Output data was provided as cross sections along the line of survey as well as colour contours in plan view that were obtained by contouring the available data at designated depth or RL intervals.
- The survey provided useful data on areas of seepage from the NW void and towards Meandu Creek and assisted in the development of a conceptual model for the mode of seepage at Meandu Mine.
- The survey also proved that the TEM technique provided useful data at Meandu Mine. However, gaps existed in the coverage due to the limitation of obtaining data in areas that had vehicle access.

In order to obtain data across the entire Meandu Mine site and regionally, an airborne TEM survey was undertaken as described in the next section.

5.5.3 Airborne Transient Electromagnetics (TEM) Survey

An airborne (helicopter) geophysics survey was undertaken over the Meandu Mine lease area and surrounding land in March 2017, and is summarised as follows:

- The original survey design included the acquisition of 1,107.5 line-kilometres of data, flown at 100 m spacing. The extent of the survey area, including the location of the actual flight lines, is shown on Figure 42.
- The intent of the survey was to build on the data set that was obtained from the June 2015 ground-based TEM survey to include the entire Meandu Mine lease area, extending west-east and north-south (e.g. along Meandu Creek) to obtain data in areas away from the mine to an extent that was practically achievable.
- Specific infrastructure (including the Tarong and Tarong North power station area, the mine infrastructure area, the dragline and private houses) could not be flown over. The flight lines for the survey are shown on Figure 42. Two obvious holes in the data (power station area, mine infrastructure area) are marked on the figure. Other smaller holes in the data (where the flight lines were deviated rather than stopping abruptly, as occurred for the above two examples) occurred at the location of features such as the dragline (within the Meandu Mine lease area) and private houses (outside the lease area).
- The nominal flight height for the geophysics array was 35 m above the ground; however, this height was not fixed and a greater height was necessary in areas where transmission lines existed, as well as in mining areas when flying over pits.
- Output from the survey included:
 - a factual report, describing the technical elements of the survey, the data interpretation methodology and the types of data acquired by the survey;

- a digital elevation model (DEM) over the survey area (based on elevation data collected during the survey);
 - raw data for all flight lines;
 - interpreted, colour-contoured EC data at a range of depths (from surface to 300 m depth) and RL (mAHD) intervals.
- The airborne TEM data was affected by a number of features that had to be considered when interpreting the data. These included:
 - High-voltage transmission power lines, which significantly affected the data to the full depth of acquisition. This data was not filtered out by the geophysics contractor (as they would have just cut holes in the data set), therefore the location of transmission lines was considered when interpreting the data.
 - The location of basalt, which records a high EC signature. The location of basalt, both at surface and at depth (i.e. areas where basalt exists below surficial cover) therefore had to be considered during interpretation of the data.
 - Other factors that must be considered when interpreting EM data, as outlined above in Section 5.5.1.

5.5.4 Discussion of Results from Geophysics Surveys

Output from the airborne geophysics survey is included in the following figures:

- Figure 43 shows contoured EC data for an interval between 2 and 4.2 m depth from surface. The following features are evident, as marked on Figure 43:
 - A high EC zone is evident along Meandu Creek to the west of the mining area. This is interpreted to be related to a combination of factors, including:
 - the presence of basaltic clays (from the southern area of the lease) within the Meandu Creek alluvium;
 - saline seepage from the mining area; and
 - saline seepage from high salinity areas to the west of Meandu Creek (e.g. the drainage channel adjacent to GW78, with the EC at GW78 >13,000 $\mu\text{S}/\text{cm}$).
 - The high EC zone within Meandu Creek appears to be mostly confined to the areas of alluvium and there are no channels evident from the geophysics data that suggest that drainage extends to the west of Meandu Creek; in fact, Meandu Creek appears to be the focus of drainage from the west and the east, with high EC areas to the west of Meandu Creek correlating strongly with current surface water drainage lines that flow from west to east towards Meandu Creek.
 - From review of geophysics data from surface to the full depth of investigation (~300 m depth) it is concluded that there is no evidence of flow paths to the west of Meandu Creek, with Meandu Creek acting as a capture zone for groundwater flow from the east (mining area) and west (with groundwater flow direction honouring topography in this area).
 - A saline plume is evident to the north-west of the former QW void. This coincides with the high EC groundwater plume identified from bores GW52A, GW50_s, GW67, GW68, GW41 and GW69 (refer Figure 34).
 - Relatively high EC conditions are also identified within storages such as the K2W and K2N ash voids and the NWB tailings dam. The groundwater EC of these storages is relatively low (Figure 34); therefore, the high EC signature from the geophysics is interpreted to be related

- to the mineralogy of the ash and tailings (for example pyrite, which has an elevated electromagnetic signature);
- A further zone of relatively high EC is evident in the spoil areas to the north of K2E pit and bores within the Black Creek drainage channel (e.g. around bores GW61_s, GW61_d, GW73 and GW74). The interpretation in this area is complicated by the presence of high voltage transmission lines (refer Figures 43 and 44 for locations). However, the results from the geophysics survey correlate with bore EC data (refer Figure 34) and appear to correlate with the presence of prior and current drainage channels that could act as conduits for seepage.
 - A high EC zone to the north of the mining lease (near RD18 and RD6 – refer Figure 43 and 44) correlates with the location of high voltage transmission lines, therefore the presence of saline seepage is not inferred at this location.
 - Figure 44 shows contoured EC data for an interval between 19 and 22.9 m depth from surface. The following features are evident, as marked on Figure 44:
 - The high EC zones that are evident in the shallow data for Meandu Creek (Figure 43) are largely absent from the image shown on Figure 44, which is interpreted to indicate that seepage is confined to a relatively shallow interval adjacent to Meandu Creek.
 - Relatively high EC zones are associated with the K2W ash void and QW void at the 19 to 22.9 m depth interval; however, the high EC plume that extends to the north-west of the QW void area is absent from Figure 44, indicating that the saline seepage is confined to the upper intervals in this area.

6.0 SEEPAGE FROM THE NW VOID

6.1 Introduction

Seepage of AMD-impacted water via the surface and groundwater systems is the main focus of the EEE Project and this report. The following sections present and discuss the identified mechanisms of seepage from the NW void and the potential for impacts on the environmental values of Meandu Creek.

6.2 Identified areas of Seepage from the NW Void

Seepage of AMD-impacted water from the NW void has been observed as seepage to Bullgang Corner, as well as relatively diffuse seepage that occurs towards the Ramp 7 haul road. Figure 45 contains four plots that can be used to understand the location and mechanisms for seepage, with observations as follows:

- The upper left plot shows an aerial photo, taken in May 2018. The plot shows the location of the NW void area, which has been filled and rehabilitated. Also shown on the plot are the locations of the current NWB tailings dam, Bullgang Corner, pre-mining drainage lines and the location of a conceptual section through the NW void and Meandu Creek (which is shown as Figure 46 and discussed below).
- The upper right plot shows contours of the deepest mined surface for the mine area, focussing on the NW void. The surface for the deepest mined void was prepared by contouring data points for the deepest ever surface at a given location. For areas that have not been mined, the deepest mined surface is the same as the original topographic surface. The plot shows the mined extent of the NW void and NWB tailings void and when compared to the aerial photo (upper left plot) the extent of the rehabilitated area to the west of the NW void (and adjacent to Meandu Creek) is evident. It is also noted that there is a direct connection (via tailings/spoil) between the NWB tailings void and the NW void.

- The lower left plot shows the extent and thickness of spoil in the area of the NW void. The spoil thickness was generated as the difference between the current topographic surface and the deepest mined void at any location. For areas that have never been mined, or for areas that are currently being mined, the spoil thickness is zero. The spoil reaches a maximum thickness of approximately 150 m beneath the area known locally as “Hitachi Hill”. It is also noted that the spoil thickness reduces to zero near Bullgang Corner; this is discussed further in the next dot point.
- The lower right plot shows the deepest mined void with the region at or below RL 435 mAHD shown in blue shading. This elevation was selected because it is the elevation at which seepage begins to occur from the NW void towards Bullgang Corner, with seepage occurring preferentially along a pre-development drainage line. The following observations are made with respect to this plot:
 - At RL432 mAHD, seepage via prior drainage channels begins to occur in the western area of the NW void. Therefore, at a groundwater elevation of RL435 (when seepage begins to occur along a prior drainage line towards Bullgang Corner) there will be a ~3 m thickness of saturated spoil above the western wall of the NW void along a wide area (as shown in the bottom right plot of Figure 45). In addition, the western wall of the NW void is relatively thin at this location (refer conceptual section in Figure 46) and it is conceptualised that this will allow diffuse seepage to occur through the western wall at an elevation slightly below RL432 when direct seepage via prior drainage lines can occur. This seepage mechanism allows a relatively large area of spoil west of the NW void to become saturated, with this seepage expressing at an area where the spoil approaches a zero thickness and the seepage therefore expresses at surface (i.e. along the eastern side of the Ramp 7 haul road – refer bottom left plot of Figure 45).
 - At RL435 seepage commences from the NW void along a pre-development drainage line and towards Bullgang Corner. This seepage initially occurs through spoil (refer also bottom left plot of Figure 45), with visible seepage occurring at the location where the spoil attains a zero thickness and the seepage therefore expresses at surface (i.e. at the location of Bullgang Corner).
 - The most recent water level for spoil monitoring bores within the NW void shows that a slight groundwater mound occurs within the void, with the water level at 438 mAHD in bore NWT (drilled at the top of Hitachi Hill), reducing to 435.36 mAHD in bore GW49 to the west. Significantly, the water level in all monitoring bores is above RL 435 mAHD, which is the elevation at which seepage from the NW void towards Bullgang Corner occurs along the pre-development drainage line and seepage over the western wall of the NW void (at RL432) is already occurring through approximately 3 m of saturated spoil.

Figure 46 is a conceptual cross section that has been generated at the location shown on Figure 45. Observations from Figure 46 and more generally for the NW void include:

- The deepest mined surface that is shown on Figure 46 was generated from the geological model that was prepared for the EEE Project.
- The current topographic surface was generated from a Lidar file for December 2016.
- The difference between the deepest mined surface and the current topographic surface is the region within the NW void that has been filled by mined spoil (a generic term that includes tailings, waste rock, coal rejects etc.).
- At the western limit of the NW void, a relatively thin wall of remnant coal measures remains. It is conceptualised that this thin wall of remnant material allows relatively diffuse seepage to occur

across a relatively wide area (as highlighted on the lower right plot of Figure 45). Seepage occurs initially to the rehabilitated spoil on the western side of the wall of remnant coal measures before reporting as seepage to the Ramp 7 haul road at a location where the spoil approaches a zero thickness.

- The predicted water level within the spoil is shown as a blue dashed line, with water level data available from bores NWT and GW49 and an assumption has been made that the water level within the NWB tailings void is at or close to surface. Available water level data indicates that the groundwater flow direction is from east to west (i.e. towards Meandu Creek) and that water within the NWB tailings void seeps to the NW void due to a direct connection between the two features (shown in the upper right plot of Figure 45).
- In summary, it is concluded that groundwater flow direction within the NW void is towards the west and north-west and exits the NW void by either:
 - seepage along a prior drainage channel at RL435 towards Bullgang Corner, where seepage is expressed at surface at a location where the spoil thickness approaches zero (i.e. Bullgang Corner); or
 - Seepage through and over the western wall of the NW void, commencing along prior drainage lines at RL432 and through saturated spoil at higher elevations. Seepage via the western wall also occurs as diffuse seepage through remnant natural material at locations where this material forms a relatively thin barrier to seepage.

The floor of the NW void is low permeability interburden material and it is conceptualised that this will restrict downward seepage due to the low vertical permeability of the interburden. However, groundwater movement to the west of the NW void (towards Meandu Creek) is interpreted to be possible, via the mechanisms discussed above.

Groundwater flow to the west of Meandu Creek is assessed to be unlikely for the following reasons:

- In the area adjacent to the NW void, the deepest seam mined (Queen Seam) does not occur beneath Meandu Creek due to the dip of the coal measures (i.e. the coal measures become more shallow beneath Meandu Creek).
- The lower coal seams (seams below the Queen Seam) also dip from west to east (i.e. the occurrence of the coal seams gets shallower to the west), with the coal measures discontinued to the west against the faulted margin of the Tarong Basin. Therefore, the dip of the strata and the shallow depth of coal measures beneath Meandu Creek combine to result in Meandu Creek acting as a capture zone for groundwater flow within the coal measures.
- It is conceptualised that there will be a natural flow of groundwater towards Meandu Creek on the western side of the creek (because generally, the water table is a subdued reflection of topography and the topography is elevated to the west of Meandu Creek. In other words, it is conceptualised that Meandu Creek is a capture zone for groundwater flow from the west and east.

The construction of additional groundwater monitoring bores to the west of Meandu Creek is recommended to test this hypothesis and to allow monitoring of groundwater levels and quality in this area.

Figure 47 is presented as a dedicated site plan to show the location and extent of AMD at Meandu Mine, including existing seepage flow paths. With reference to Figure 47 and Figure 45 it is observed that:

- Based on analysis of water quality data, AMD impacts are observed or inferred from groundwater monitoring bores GW25, GW34, GW35, GW36 and GW75, as well as surface water monitoring sites at Bullgang Drain and Ramp 7-1.

- A zone of seepage is identified along the western wall of the NW void, with seepage initially occurring at RL432 via prior drainage lines and extending over a wider area through saturated spoil at RL435.
- The zone of seepage-impacted spoil is assessed to extend from GW36 in the south (where seepage appears to be occurring via a prior drainage line towards Bullgang Corner in the north. In this area, AMD-impacted seepage occurs along the eastern side of Ramp 7 at an area where the spoil approaches a zero thickness (Figure 45)
- The area where seepage exits the void along a prior drainage line and towards Bullgang Corner/ Bullgang Drain is also shown on Figure 47.

7.0 OTHER GROUNDWATER AREAS INVESTIGATED

7.1 Introduction

As a result of investigations undertaken for the EEE Project, two additional areas for additional monitoring have been identified, based on review of water quality data. The two areas are:

- A saline plume that has been identified with an origin close to the QW void; groundwater within the plume moves through shallow regolith along a natural drainage line towards retention dams RD1 and RD2; and,
- An area within the Black Creek catchment in the northern area of the lease.

It is noted that neither of the areas are assessed at this stage to involve seepage that is related to AMD. The additional areas are discussed in this report for completeness, though it is noted that additional monitoring will be required and that any observations and conclusions that are presented in this report are preliminary and subject to modification.

7.2 High EC Groundwater Plume Down-Gradient of the QW Void

7.2.1 Description of the Plume

The existence of a high EC ($>10,000 \mu\text{S/cm}$) groundwater plume along an area that is down-gradient of the QW void has been interpreted, based mainly on analysis of groundwater EC and geophysics data. The saline plume extends from an area near the QW void (note that the QW void is not thought to be the source), with affected groundwater flowing through shallow regolith along a natural drainage line towards retention dams RD1 and RD2 (which are both to the east of Meandu Creek). Figure 48 contains four plots that can be used to review the location and mechanisms for seepage, with observations as follows:

- The upper left plot shows an aerial photo, taken in May 2018. The plot shows the location of the QW void area, which has been filled with spoil. Also shown on the plot are the locations of the adjacent K2N ash disposal void, the NWB Tailings Dam, NW Void, site retention dams (E.g. RD1, RD2) and pre-mining drainage pathways.
- The upper right plot shows contours of the deepest mined surface for the mine area, focussing on the QW void. The plot shows the mined extent of the QW void and the adjacent K2W and K2N voids, which are currently used for ash disposal. It is noted that a connection exists between the K2W ash disposal void and the QW void via a low point in the ridge between the two voids, which is at a RL of approximately 474 mAHD. The level of ash in the K2W void rose above 474 mAHD in early 2013, allowing for the possibility of seepage from the K2W void to the spoil within the QW void after this date.

- The lower left plot shows the extent and thickness of spoil in the Meandu Mine area, including the area of the QW void. The spoil attains a maximum thickness of approximately 150 m beneath the highest point of the QW spoil dump. It is also noted that the spoil thickness reduces to zero just north of the QW void (north of monitoring bore GW50_s) and that the area to the north of GW50_s comprises natural material within a pre-mining drainage line.
- The lower right plot contains features as follows:
 - The plot contains a background of airborne geophysics data, which shows a high EC feature that extends from north of the QW void, along the natural drainage line and towards retention dams RD1 and RD2. Note that there is a data gap (white area) north of GW69, where no data was collected as the helicopter could not fly over the mine infrastructure area. However, the land-based geophysics extended into this area and shows high-conductivity features in this area, therefore it is interpreted that the plume extends along the natural drainage line through this area and towards RD1 and RD2. It is noted that there is no visible evidence of seepage at the ground surface in the area where the plume is inferred, with seepage interpreted to be occurring via the groundwater system in the shallow regolith.
 - The plot includes groundwater EC data, where the bore location symbols have been colour-classed to show data within particular EC ranges. From this data it is noted that the EC of bores within the QW spoil (e.g. GW54A, GW54B, GW66) is relatively low (less than 4,000 $\mu\text{S}/\text{cm}$ – refer also Figure 34). By contrast, bores to the north of the QW void that are screened within regolith that is within or adjacent to the pre-mining drainage line record EC values above 10,000 $\mu\text{S}/\text{cm}$, with bore GW50_s (interpreted to be close to the source) recording an EC >20,000 $\mu\text{S}/\text{cm}$ (Figure 34, Appendix A-1). The high EC (>10,000 $\mu\text{S}/\text{cm}$) concentrations start at GW52A and are recorded in all regolith monitoring bores that are down-gradient of GW52A and within/adjacent to the pre-mining drainage line.

Based on interpretation of available data it is concluded that the spoil within the QW void is unlikely to be the source of the high EC groundwater, but that the source is close to monitoring bore GW50_s. It should be noted that it is interpreted, based on water quality data, that the high EC plume is not related to AMD and also that the plume is unrelated to groundwater quality impacts within the Black Creek catchment that are discussed below in Section 7.3.

7.2.2 Potential for Environmental Impacts

A preliminary assessment of the potential for high EC groundwater from within the plume to adversely impact the EV's of Meandu Creek is presented in this section. Figure 49 shows EC data for groundwater bores that are within the plume, as well as down-gradient sites RD1, RD2 and alluvial bores GW39 and GW40, which are within the Meandu Creek alluvium adjacent to RD2. Observations from this figure include:

- The legend in the figure shows the symbols used for each sampling point; the symbols have been arranged in order, starting from the top end of the plume (at bore GW52A) and finishing at alluvial bores GW39 and GW40.
- The bore that records the highest EC is GW50_s (which is assessed to be located close to the source). The EC has been increasing over the period for which monitoring is available, from ~15,000 $\mu\text{S}/\text{cm}$ to ~20,000 $\mu\text{S}/\text{cm}$;
- At sites downgradient of GW50_s the EC decreases to ~12,000-13,000 $\mu\text{S}/\text{cm}$.
- EC data for RD1 and RD2 is available from 1984 to present. From review of Figure 49 it is evident that the EC has varied in both RD1 and RD2 since the commencement of monitoring, but that the present day EC is similar to the EC that was recorded in 1984 (i.e. generally ranging between 800

and 1,200 $\mu\text{S}/\text{cm}$). The increase in EC that is observable between 1998 and 2007, when the EC increased from <1,000 to >2,000 $\mu\text{S}/\text{cm}$, is interpreted to be related to drought conditions that were prevalent at that time.

- Groundwater monitoring bores GW39 and GW40, which are screened within the Meandu Creek alluvium, generally record a higher EC than RD1/RD2, with the EC in GW40 being more variable than in GW39. GW40 is further upstream than GW39 and GW39 is assessed to be impacted to some degree by water backing up from Meandu Creek Dam. Therefore, the EC at GW40 may reflect more natural variation, while the EC range at GW39 is likely to be somewhat modulated by the water quality of Meandu Creek Dam.
- From review of the data discussed above, it is interpreted that, although the geophysics tends to indicate that the plume is migrating towards RD1 and RD2 (refer Figure 48), there is no discernible impact to date from the high EC groundwater within the plume. A potential reason for the apparent lack of water quality impact on RD1 and RD2 is the relatively low rate of seepage within the plume, as discussed further below.

With respect to the volume of impacted groundwater that is seeping towards RD1 and RD2 from the high EC plume, the following comments apply:

- The flow volume can be calculated using Darcy's Law, $Q = KiA$, where:
 - Q is the flow volume (m^3/day);
 - K is the hydraulic conductivity (m/day);
 - i is the hydraulic gradient (change in water level (m) over length (m), therefore the unit is m/m or dimensionless); and,
 - A is the cross-sectional area through which flow occurs (m^2).
- Hydraulic Conductivity (K) can be taken from recent slug tests¹ of groundwater monitoring bores GW68 and GW69 (which are both screened within regolith and both located within the plume)
 - GW69 – $K = 0.97 \text{ m}/\text{day}$.
 - GW68 – $K = 0.25 \text{ m}/\text{day}$.
- The hydraulic gradient (i) can be taken from the water level difference between bores GW68 and GW69, as follows:
 - The water RL in GW68 (May 2017) was 448.11 mAHD.
 - The water RL in GW69 (May 2017) was 435.02 mAHD.
 - The bores are 570 m apart along the same flow line (central part of surface water drainage system that contains the groundwater plume).
 - The gradient is therefore $13.09\text{m}/570\text{m} = 0.023$.
- The cross sectional area through which flow occurs (A) has been assessed as follows:
 - The width of the plume, based on interpretation of geophysics data, varies from a maximum width of ~350 m to a minimum of ~170 m close to RD1.
 - For the purpose of this calculation an average plume width of 250 m has been assumed.
 - The saturated thickness is assumed as the difference between the base of bore in GW69 (24.5 m below ground level (mbgl)) and a depth to water below ground surface of ~5m, giving a saturated thickness of 19.5 m

¹ A slug testing program has recently been undertaken on the majority of groundwater monitoring bores at Meandu Mine. The slug testing program was undertaken to provide site-specific aquifer properties for future monitoring programs.

- The cross-sectional area is therefore $250 \text{ m} \times 19.5 \text{ m} = 4,875 \text{ m}^2$
- For a K of 0.97 m/day (GW69), the discharge rate (Q) is calculated as $0.97 \text{ m/day} \times 0.023 \times 4875 \text{ m}^2 = \sim 108 \text{ m}^3/\text{day} = \sim 1.3 \text{ L/s}$
- For a K of 0.25 m/day (GW68), the discharge rate (Q) is calculated as $0.25 \text{ m/day} \times 0.023 \times 4875 \text{ m}^2 = \sim 28 \text{ m}^3/\text{day} = \sim 0.3 \text{ L/s}$

From the site dams register it is noted that RD1 has a capacity of 43.8 ML while RD2 has a capacity of 36.9 ML. Therefore, it is concluded that a groundwater inflow rate of between 0.3 and 1.3 L/s (0.025 to 0.1 ML/day) would be relatively insignificant when compared to surface water inflows to both dams over the course of a year.

From the preliminary assessment discussed above, it is concluded that, even if the saline plume has extended to RD1/RD2, the potential rate of inflow to the dams is calculated to be low and, based on available water quality data, it is evident that the plume has not made a discernible impact to date on the EC of dams RD1 and RD2. It may be further concluded that, due to the relatively low seepage rates and the presence of retention dams to intercept groundwater flow, the risk to the environmental values of Meandu Creek is also low.

Despite the results of the preliminary assessment discussed above, it is recommended that further monitoring be undertaken in an attempt to establish the source of the high EC plume, as well as the potential longevity of the plume. Recommendations are discussed further in Section 11.

7.3 Groundwater Quality in the Black Creek Catchment

Potential impacts on groundwater quality within the Black Creek catchment are interpreted based on water quality data. However, data from the majority of bores in this area is relatively recent (with data available from November 2016 for bores shown on Figure 50, with the exception of GW61_s and GW61_d, where data is available from 2009) and the water quality trends between bores within the catchment are not consistent (as discussed below); therefore, additional monitoring to establish trends will be required before conclusions can be made.

Figure 50 contains four plots that can be used to understand the location and potential mechanisms for water quality impacts, with observations as follows:

- The upper left plot shows contours of current topography (December 2016). The plot also shows the location of the K2E rehabilitation area (rehabilitation of in-pit and out of pit spoil dump areas), the current K2E pit, pre-mining drainage, the extent of the K2 tailings dump (now buried beneath spoil), the location of groundwater monitoring bores and the location of the surface water divide in this area.
- The upper right plot shows contours of the deepest mined surface for the mine area, focussing on the K2E void. The plot shows the mined extent of the K2E void, with the current (active) K2E pit to the south of the image. From review of the upper left (current topography) and upper right (deepest mined surface) it is observed that:
 - The approximate location of the surface water catchment divide for the K2E spoil is shown on the upper left plot. In general, surface runoff could be expected to be directed either to the north from this point (into the Black Creek catchment) or to the south towards the current K2E pit.
 - The groundwater catchment for the current K2E pit differs from the surface water catchment, with the approximate location of the groundwater catchment divide shown on the plot. From review of the upper right plot of Figure 50 it can be observed that the limit of mining in the K2E pit is further north than the surface water divide. Therefore, all recharge water that reaches the

base of spoil above the K2E void will be drained to the south towards the current K2E pit. The approximate groundwater catchment divide is shown wards the south, as all recharge that reports to the K2E void will drain to the south towards the current K2E pit.

- The lower left plot shows the extent and thickness of spoil in the area of the K2E void, with spoil being dumped over the K2W TSF and extending to the north as far as retention dam RD17A. The spoil attains a maximum thickness of approximately 75 m above the K2 TSF.
- The lower right plot contains features as follows:
 - The plot shows aerial geophysics (EM) data (refer Section 5.5 for discussion) for the interval 4.2 to 6.8 m below surface. The feature that is most evident are the zones of relatively high EC (red zones), which correlate with the location of pre-mining drainage. The high EC zones commence in the western area of the image, in an area that is unmined. Basalt exists at surface in the west of the mining area and, based on geophysics data, is interpreted to exist in the sub-surface for some distance to the east. The high EC zones are interpreted to be indicative of basaltic clays that are present throughout the surface drainage system in this area. The high EC zones do not correlate with groundwater salinity, as discussed below.
 - The plot shows EC data, where the bore location symbols have been colour-classed to show data within particular EC ranges, which are shown on the plot. The EC ($\mu\text{S}/\text{cm}$) from February/May 2017 is shown below each bore. From this data it is noted that the EC of bores within the Black Creek catchment is variable, ranging from $<1,000 \mu\text{S}/\text{cm}$ at GW61_s to $>12,000 \mu\text{S}/\text{cm}$ at GW73. The EC at GW73 is higher than at any site upgradient or down-gradient from the bore. The water quality data for GW73 also indicates high sulfate at this site (Figure 35); however, the concentration is consistent with the high EC (i.e., sulfate is not interpreted to be elevated as a percentage of other major ions). It is noted that GW73 is located at the confluence of a number of pre-mining drainage channels (which are also current drainage channels as the site is located in an unmined area). The reason for the high EC at this location is uncertain and will require further monitoring;
 - Bore GW74, which is down-gradient of GW73, records an EC of $\sim 3,400 \mu\text{S}/\text{cm}$ (February/May 2017). However, the most notable water quality feature of this bore is that the pH is generally ~ 4.0 (Appendix A-1), with the bore also recording relatively high concentrations of dissolved aluminium (Appendix A-2) and dissolved zinc (Figure 41);

The groundwater quality trends (high EC, low pH, high aluminium and zinc concentrations) are not consistent between bores in the Black Creek catchment and it is notable that bores GW73 and GW74 are constructed within natural material (regolith) that is down-gradient of spoil (a potential source of contaminants) but that the bores that are constructed within the upgradient mined spoil and tailings (e.g. GW70, GW72, GW61_s) do not tend to record elevated concentrations of the same parameters (or low pH). It is further noted that water quality data is available from bores GW70, GW72, GW73 and GW74 over a relatively short period (November 2016 to present, at quarterly intervals) and that additional data will assist the interpretation of water quality trends within the catchment.

It is therefore recommended that additional monitoring is undertaken into the source of the contaminants detected in GW73 and GW74, with the focus being on the potential source of the contaminants, which may potentially be derived from mine-impacted areas (i.e. spoil or tailings), from areas that are unimpacted by mining to the east (i.e. from the natural drainage lines that drain the ridgetop basalt) or from the area of the Tarong Power Station.

It should be noted that it is interpreted, based on water quality data, that the potential impacts on groundwater quality are not interpreted at this stage to be related to AMD and are not related to the high EC plume that is discussed above in Section 7.2.

8.0 CONCEPTUAL GROUNDWATER MODEL

8.1 Introduction

Elements of the conceptual groundwater model are discussed in the sections above and are summarised below. Figures that assist in understanding the conceptual model include:

- Figure 2 (surface geology);
- Figures 5 (long section) and Figures 6 to 9 (cross sections) through the Meandu Mine area; and
- Figure 46 (conceptual section through the NW void).

8.2 Groundwater Units

The groundwater units at Meandu Mine include:

- Quaternary alluvium, associated with Meandu Creek in the west of Meandu Mine and the Rocky Creek alluvium in the east of the mining area. Black Creek also drains the mining area to the north (ultimately draining to Black Creek Dam and Meandu Creek when/if the dam overflows). However, Black Creek is at the top of the drainage system in the Meandu Mine area and does not contain significant alluvial deposits. All of the creeks in the Meandu Mine area are ephemeral and the occurrence of water within Meandu Creek is limited to discontinuous ponds (which, in some cases, may be maintained by seepage from the mining area) and the lower reaches of the alluvium just upstream of Meandu Creek Dam, where it is concluded that water occurs within the alluvium due to water backing up into the alluvium from Meandu Creek Dam.
- Tertiary basalt, which is present as ridge-top deposits through the central-eastern area of Meandu Mine. The basalt is generally dry within the mining area.
- Tertiary regolith, which comprises the upper weathered interval of the underlying Tarong beds. It is conceptualised that the Tertiary regolith was generally dry prior to mining (except in the area of surface water features such as Meandu Creek, where the unit would be recharged by downward seepage from the alluvium following periods of rainfall). The Tertiary regolith is significant at Meandu Mine because topography is assessed to be the major factor that influences the occurrence and movement of seepage from the mining area, with shallow seepage being preferentially transported within the shallow regolith.
- Triassic Tarong beds, which are the host unit for the coal seams that are mined at Meandu Mine. Groundwater in the Tarong beds tends to occur within the coal seams, with the interburden generally dry. The coal seams are heavily faulted by north-west/ south-east trending faults, which have completely disrupted the continuity of the coal seams in many cases, resulting in the more permeable coal seams ending abruptly against less permeable interburden material. Groundwater occurrence and movement within the coal seams is therefore complex. The major coal seams that are mined at Meandu include the Ace Seam (the upper coal seam, which is generally dry), the King Seam (which may contain water, dependant on the RL at which the coal seam occurs) and the Queen Seam, which is the only mined seam that generally contains groundwater. The occurrence of coal seams continues below the Queen Seam, however these seams are not mined and only become significant in the western area of Meandu Mine, where the dip of the coal measures brings the lower coal seams close to surface beneath Meandu Creek.

- The Permian-Triassic Boondooma Igneous Complex is a granitoid unit that exists to the west of Meandu Mine, where the unit forms the western faulted margin of the Tarong Basin. The occurrence and quality of groundwater within the Boondooma Igneous Complex is unknown; however, groundwater within granite tends to be limited to fractures and the upper weathered portion of the unit.
- The Devonian-Carboniferous Maronghi Creek beds occur to the east of the mining area and define the faulted eastern margin of the Tarong Basin. The Maronghi Creek beds, which generally comprise low permeability mudstone and shale, contain groundwater within fractures that tend to contain groundwater in some areas but are dry in others. Where groundwater-filled fractures occur, the Maronghi Creek beds contain useable volumes of water for stock/domestic supply, though the water quality tends to be variable.

8.3 Groundwater Recharge

Recharge to the groundwater system is conceptualised to occur as follows:

- Recharge to coal seams occurs where the units subcrop beneath shallow Tertiary sediments and Quaternary alluvium. The main area where recharge of the coal seams is conceptualised is to the south of the Meandu Mine lease, where the coal seams subcrop beneath Yarraman Creek (refer to the north-south section that is shown on Figure 5).
- The Tertiary basalt is recharged via direct rainfall, with recharge preferentially occurring in fractured zones (i.e. groundwater occurs only in fractures and is not pervasive). As noted above, the basalt tends to be dry in the Meandu Mine area, so the units that underlay the basalt (generally the Tarong beds) will receive a component of recharge via downward leakage from the basalt (which may therefore have an impact on the groundwater chemistry of the underlying units).
- Recharge to the Tertiary regolith will be via direct rainfall recharge, or via seepage from adjacent areas of spoil (as discussed elsewhere in this report).
- The spoil is recharged via direct rainfall recharge. The spoil is porous and of relatively high permeability (based on observations of seepage following rainfall). Within previously mined voids, groundwater within the spoil tends to occur in the lower portion of the spoil pile and there is no evidence to date (from water level monitoring within the NW void and QW void) of either significant groundwater mounds or perched water tables within the spoil.

8.4 Groundwater Inflow to Mine Voids

The pits at Meandu Mine generally receive only minor volumes of groundwater inflow; however, mine geological personnel (N Ferdinands pers. comm.) have provided the following observations of groundwater occurrence within the current operational areas of Meandu Mine:

- in the K2E pit, groundwater inflow occurs from the Queen Seam coal and from Tertiary basalt on the eastern/southern side of the pit;
- in the Central pit, groundwater inflow occurs through:
 - faults and joint surfaces;
 - the Queen Seam, especially the plies above the D&E plies;
 - from spoil on the Meandu Creek diversion side of the pit (inferring that, in the area where the Meandu Creek diversion occurs over mined spoil, downward seepage from the creek channel to the spoil occurs);
- in the K4E pit, minor groundwater inflow is observed from the Queen Seam;

- in the K4S pit, minor groundwater inflow is observed from the low wall ramp area and from faults;
- in the area of the K2W ash void, groundwater seepage is observed from the base of Tertiary basalt along the eastern/southern wall of the pit void.

While it is observed that groundwater inflow occurs from faults in the mining area, it is not conceptualised that faults act as major conduits for groundwater flow in a regional sense (i.e. in areas beyond Meandu Mine). This is because:

- faults tend to be closed and “tight”, however in mining areas the faults can open up as material is removed by mining, allowing the faults to act as groundwater conduits;
- the groundwater that is capable of being stored within individual faults is generally low and dissipates quickly once the fault is exposed by mining; therefore, ongoing seepage tends to be due to surface water that has recharged the faults (i.e. the faults are acting as conduits for surface water drainage).

8.5 Groundwater Flow Direction

The factors that influence groundwater flow direction at Meandu Mine are complex and for this reason there has been no attempt to construct maps of groundwater elevation contours; rather, general observations of groundwater flow are provided as follows:

- For the shallow groundwater units (e.g. Tertiary basalt, Tertiary regolith, Quaternary alluvium) the groundwater flow direction honours topography (i.e. flows from highest elevation to lowest elevation).
- It is conceptualised that the Tertiary regolith was dry prior to mining and likely contained groundwater only in areas adjacent to surface water features such as Meandu Creek. Within the central area of Meandu Mine, the Tertiary regolith tends to contain groundwater as a result of seepage from mining areas or recharge through spoil, but the flow of groundwater within the regolith in these areas will still honour topography as discussed above.
- Within the Triassic Tarong beds, the interburden tends to be dry and groundwater flow occurs in the more permeable coal seams. Due to the truncation of the coal seams by faulting, the conduit for groundwater flow (the coal seam) may be terminated abruptly and this will result in complex flow patterns. In general, however, the groundwater flow direction in the coal seams is conceptualised as follows:
 - Pre-mining - groundwater flow would be generally to the west/ north-west (i.e. towards Meandu Creek).
 - Post-mining/current – groundwater flow is towards the pits and groundwater inflow is removed via pumping and enters the surface water control system. Therefore, it is concluded that groundwater flow within the coal seams towards Meandu Creek only occurs in the western area of the mine (i.e. the area below and west of the NW void).

8.6 Groundwater Seepage Pathways

As discussed in Section 6, the following general mechanisms for seepage at Meandu Mine have been identified;

- The major preferential pathway for groundwater seepage from voids is either the natural ground surface or the deepest mined surface, dependant on what surface exists at a given location. In other words, groundwater seepage occurs predominantly via shallow seepage within the regolith unit or the underlying coal measures (where the regolith has been mined out) and the seepage

pathways can therefore be defined by the topography of the deepest mined surface (which includes the natural surface in areas that have not been mined).

- Seepage from spoil-filled voids tends to occur when the water level within the spoil rises to a level where seepage from the void is possible via topographic low-points such as pre-mining drainage channels or haul roads into the pit.
- In areas where out-of-pit dumping of spoil has occurred, the flow of groundwater within the spoil, as well as pathways for seepage from the spoil, will tend to honour the underlying topography.

The main focus for this report has been on seepage from the NW void, due to the observation of AMD-impacted seepage from this area. Groundwater seepage from this area, including presentation of the conceptual model for seepage, is discussed in Section 6.0 and summarised on Figure 46.

9.0 CONTROL MEASURES

9.1 Groundwater Monitoring

Monitoring of groundwater for water level and water quality, as well as ongoing assessment and interpretation of the data, is regarded as a long-term control measure as this monitoring will be required for the duration of mining as well as for some period beyond closure.

The current groundwater monitoring network at Meandu Mine comprises 63 bores at 50 sites (Figure 10), with the network having developed over time to address changes in mine development as well as findings and recommendations from previous studies. In addition, replacement bores have been drilled as necessary to replace bores that have become unserviceable or have been decommissioned in advance of mining operations.

Based on the review undertaken for this report, it is concluded that the current monitoring schedule for water level and water quality (i.e. quarterly sampling) is appropriate in terms of sampling frequency and the parameters that are monitored and that the current monitoring schedule should be maintained.

Further monitoring has been recommended in this report with respect to the saline plume that has developed to the NW of the QW void as well as the water quality of the Black Creek catchment. Drilling of additional groundwater bores and ongoing monitoring will likely be required, though the number and location of bores is yet to be established. However once established, any additional monitoring bores should be incorporated into the Meandu Mine monitoring network for long-term monitoring and assessment.

Specific recommendations with respect to additional groundwater monitoring bores are presented and discussed in Section 11.

9.2 Seepage from NW Void

Potential short-term and long-term control measures for the groundwater seepage from the NW void area are summarised as follows:

- Groundwater pumping (via dedicated pumping bores) to maintain the water level below the spill point of approximately RL432 in the western area of the NW void and approximately RL435 in the area where the NW void spills to Bullgang Corner (refer Figure 45 for locations). In practice, the water level adjacent to the seepage areas defined in Figure 45 should be maintained at a level that is as far as practically achievable below the spill points to encourage drainage away from the seepage areas and towards the pumping bores.

Groundwater pumping is a short to medium-term engineering solution that would ideally be reduced or phased out over time as passive control measures become increasingly effective.

Once the sites of groundwater pumping bores have been established, additional groundwater monitoring bores will be required to establish the efficacy of pumping measures. The number and locations of monitoring bores should be established as part of the design of the pumping bore network.

- A key long-term control measure will be to reduce the rate of recharge to the spoil, which could be achieved by means such as:
 - contouring the spoil to encourage runoff of rainfall and discourage pooling of water that could report to the spoil as recharge;
 - revegetating the spoil to further reduce the potential for recharge to the spoil;
 - progressively phasing out and rehabilitating the NWB tailings dam, which is currently interpreted to seep directly to the NW void.

10.0 SUMMARY AND CONCLUSIONS

10.1 Introduction

Following the issuing of the Notice to conduct or commission an environmental investigation into the presence of AMD at the Meandu Mine, an analysis of available data, including regional and local-scale geological data (e.g. from drilling, geological mapping, previous reporting, published papers), surface water and groundwater chemistry, groundwater level data, geophysics and site observations has been undertaken. The analysis has enabled conclusions to be reached with respect to the chemistry of AMD seepage at Meandu Mine, zones of existing seepage, mechanisms for seepage, potential impacts on the Meandu Creek environment and recommended control measures.

10.2 Environmental Evaluation Notice Requirements

A summary of investigations undertaken and conclusions from this study, with reference to the requirements of the Environmental Evaluation Notice, are presented below. The requirements of the Environmental Evaluation Notice are in italics, with the summary/conclusions from this investigation following.

1. *A summary of groundwater quality data relevant to the investigation.*

Groundwater quality data is presented in Section 5.4 and relevant findings are summarised as follows:

- Groundwater quality data is available for the Meandu Mine site from 1993 to present, from a network of monitoring bores that has evolved to currently comprise 63 bores at 50 sites, with the network expanded over the years to address specific monitoring requirements and monitoring recommendations. The availability of groundwater quality data is presented in Table 5-2.
- The parameters monitored at Meandu Mine have evolved over time, as shown in Table 5-2. In summary, the progression of parameters has included:
 - Historic bores from 1993 to 2010 – pH, EC, TDS, major ions, total metals/metalloids (As, Cd, Co, Cu, Fe, Mn, Ni, Se, Zn);
 - K2W bores from 2008 to December 2015 – pH, EC, TDS, major ions, fluoride, ash-specific metals/metalloids (total/dissolved As, B, Mo, Se, V)
 - Hydrocarbon monitoring bores from August 2011 to November 2014 – pH, EC, TDS, major ions, fluoride, TPH, BTEX. From May 2015 monitoring included total/dissolved metals (Al, As, B, Cd, Co, Cu, Fe, Mn, Mo, Ni, Se, V, Zn)

- All bores from 2016 to present – pH, EC, TDS, major ions, fluoride, total/dissolved metals/metalloids (Al, As, B, Cd, Co, Cu, Fe, Mn, Mo, Ni, Se, V, Zn)
2. *Identification and characterisation of the groundwater environmental values (EV's) for Meandu Creek that may be impacted by AMD from Meandu Mine.*
- The environmental values (EV's) for Meandu Creek objectives for Meandu Creek are outlined in the surface water quality, sediments and aquatic ecology investigations report that has been prepared for the EEE Project by Ecological Services Professionals Pty Ltd (ESP 2018). The EV currently applicable to Meandu Creek upstream of Meandu Creek Dam, as well as for Black Creek is assessed to be 'industrial use'.
 - It is generally considered that groundwater that occurs within alluvium is managed as surface water; therefore, the groundwater EV's for Meandu Creek, as well as for Black Creek, are taken to be the same as the surface water EV's that have been defined in the ESP (2018) report.
 - With respect to assessing the impacts of AMD seepage on Meandu Creek, groundwater quality is assessed at Meandu Creek alluvium bore GW39 with respect to the trigger levels that are defined within the Meandu Mine Environmental Authority (EA) EPML00709113.
3. *Studies to determine the presence and extent of AMD at Meandu Mine, which must include:*
- a. *contaminant hydrogeological investigations inclusive of drilling and installation of monitoring bores (if required);*
- The hydrogeological investigations undertaken for the EEE project include:
 - The installation of an additional 12 groundwater monitoring bores, to bring the current monitoring network to a total of 63 bores at 50 sites (it is noted that 6 bores at 4 sites have been decommissioned during the course of this assessment, but replacement bores are currently being planned);
 - An airborne geophysics investigation, comprising 1,107.5 line kilometres of transient electromagnetics (TEM) survey. The survey was undertaken to improve the understanding of geology and potential seepage zones at Meandu Mine, including seepage from site storages and backfilled voids as well as groundwater conditions within and to the west of Meandu Creek.
 - Information obtained from the geophysics investigation has been used, in conjunction with other data (geological data, water quality data, location of pre-mining drainage, delineation of the deepest mined surface) to establish the location and extent of seepage pathways as well as the mechanisms for seepage. The investigations that have been undertaken to determine the location of AMD-impacted seepage from the NW void as well as the mechanisms for seepage, are presented in Section 6.0 of this report.
- b. *investigations to identify physical and/or environmental influences relating to storage areas (coal rejects, overburden, waste rock and topsoil) that may determine the occurrence, rate of progression or volume of AMD generated at Meandu Mine, for example ...water infiltration and drainage characteristics;*
- The characterisation and classification of material types (rejects, overburden, waste rock etc.) is discussed in the RGS Environmental report that has been prepared for the EEE Project.

- Water infiltration and drainage characteristics of the NW void, which has been identified as the source of AMD-impacted seepage towards Meandu Creek, are presented and discussed in Section 6.0.
- From studies undertaken for this report, it has been identified that there is a subdued groundwater mound within the NW void (rather than a distinct groundwater mound and/or perched water tables within the spoil), with recharge occurring via direct rainfall to the spoil as well as via seepage from the adjacent NWB tailings dam due to the existence of a direct hydraulic connection between the NWB tailings dam and the NW void.
- A conceptual model for seepage from the NW void has been developed, as discussed in Section 6 and presented in Figure 46.
- c. *a dedicated site plan showing the location and extent of AMD at Meandu Mine, including existing seepage flow paths.*
- The seepage mechanisms and flow paths for AMD from the NW void towards Meandu Creek are presented in Section 6. Figure 47 is a dedicated site plan that shows AMD-impacted surface water and groundwater monitoring sites and seepage areas, with seepage flow paths also shown on Figure 45. The main seepage flow paths and mechanisms are identified as:
 - seepage along a prior drainage channel at RL435 towards Bullgang Corner, where seepage is expressed at surface at a location where the spoil thickness approaches zero (i.e. Bullgang Corner); or
 - Seepage through and over the western wall of the NW void, commencing along prior drainage lines at RL432 and through saturated spoil at higher elevations. Seepage via the western wall also occurs as diffuse seepage through remnant natural material at locations where this material forms a relatively thin barrier to seepage.
- 4. *Studies to determine whether AMD at Meandu Mine has impacted on or has the potential to impact on the environmental values of groundwaters including Meandu Creek. These studies must include:*
 - a. *water quality investigations to determine any impacts on environmental values of groundwater and surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine.*
 - b. *water quality investigations to determine future impacts on environmental values of groundwater and surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine.*
- Section 5.4 presents the water quality assessment that was undertaken with respect to AMD water quality and water quality observations from surface water and groundwater sites. From review of the chemistry data it is concluded that the primary indicators of AMD seepage include:
 - pH;
 - Sulfate, which is assessed to be the most reliable indicator of AMD-impacted groundwater as well as the most reliable general indicator of mining-impacted groundwater;
 - Metals/metalloids including Co, Fe, Mn, Ni and Zn.
- AMD-impacted groundwater is assessed to be present at a number of groundwater monitoring sites that are adjacent to the NW void and Meandu Creek; these sites are shown on Figure 47.

- It is concluded that, to date, AMD impacts are not evident in groundwater monitoring bores that monitor the Meandu Creek alluvium, which include GW40 and EA compliance monitoring bore GW39.
 - From review of geophysics data from surface to the full depth of investigation (~300 m depth) it is concluded that there is no evidence of flow paths to the west of Meandu Creek, with Meandu Creek acting as a capture zone for groundwater flow from the east (mining area) and west (with groundwater flow direction honouring topography in this area).
 - Ongoing review of groundwater monitoring bores will be required, with particularly reference to the AMD-indicator parameters identified above and assessment with respect to the EA water quality triggers for Meandu Creek alluvium monitoring bore GW39.
- c. *identify short-term and long-term measures including (if relevant) further lines of investigation, monitoring requirements and operational or mine planning measures that should be developed and/or implemented to prevent environmental harm occurring from AMD at Meandu Mine.*
- Short term and long term control measures for AMD-impacted seepage from the NW void are discussed in Section 9 and include:
 - A recommended short to medium-term engineering control measure is groundwater pumping (via dedicated pumping bores) to maintain the water level below the spill point of approximately RL432 in the western area of the NW void and approximately RL435 in the area where the NW void spills to Bullgang Corner (refer Figure 45 for locations). In practice, the water level adjacent to the seepage areas defined in Figure 45 should be maintained at a level that is as far as practically achievable below the spill points to encourage drainage away from the seepage areas and towards the pumping bores.
Groundwater pumping would ideally be reduced or phased out over time as passive control measures become increasingly effective.
Once the sites of groundwater pumping bores have been established, additional groundwater monitoring bores will be required to establish the efficacy of pumping measures. The number and locations of monitoring bores should be established as part of the design of the pumping bore network.
 - A key long-term control measure will be to reduce the rate of recharge to the spoil, which could be achieved by means such as:
 - contouring the spoil to encourage runoff of rainfall and discourage pooling of water that could report to the spoil as recharge;
 - revegetating the spoil to further reduce the potential for recharge to the spoil;
 - progressively phasing out and rehabilitating the NWB tailings void, which is currently interpreted to seep directly to the NW void.
5. *A predictive model for Meandu Mine in relation to potential AMD impacts ... which must include ...*
- a. *mine water modelling that takes into account ... groundwater and in-pit and in-mine spoil water;*
 - b. *potential contaminant pathways;*
 - c. *... model the dissolution and transport of metals to the receiving environment from Meandu Mine;*

- d. capacity to predictively model water quality impacts from AMD on groundwater and Meandu Creek.*
- The predictive model has been prepared for the EEE Project by Golder Associates (Golder 2018). JBT has provided groundwater-related liaison, input and review to the Goldsim model as required during the course of the Project.

10.3 Other groundwater areas investigated

As a result of investigations undertaken for the EEE Project, two additional groundwater areas have been identified, based on review of water quality data. The two areas are:

- A saline plume that has been identified with an origin close to the QW void; groundwater within the plume moves through shallow regolith along a natural drainage line towards retention dams RD1 and RD2 (discussed in Section 7.2 of this report); and,
- An area within the Black Creek catchment in the northern area of the lease (discussed in Section 7.3 of this report).

It is noted that neither of the areas are assessed at this stage to involve seepage that is related to AMD. The additional areas are discussed in this report for completeness, though it is noted that additional monitoring will be required and that any observations and conclusions that are presented in this report are preliminary and subject to modification. Recommendations for further monitoring are presented in Section 11.

11.0 RECOMMENDATIONS

Recommendations arising from this investigation include:

- It is recommended that groundwater extraction bores are installed within spoil of the NW void is recommended, in order to reduce the rate of groundwater seepage from the spoil. The bores should be located to allow a reduction in groundwater level in the following areas:
 - the area where seepage occurs over the western wall of the NW void (refer Figures 45 and 47 for location); and
 - the area where seepage occurs from the NW void towards Bullgang Corner (refer Figures 45 and 47 for location).

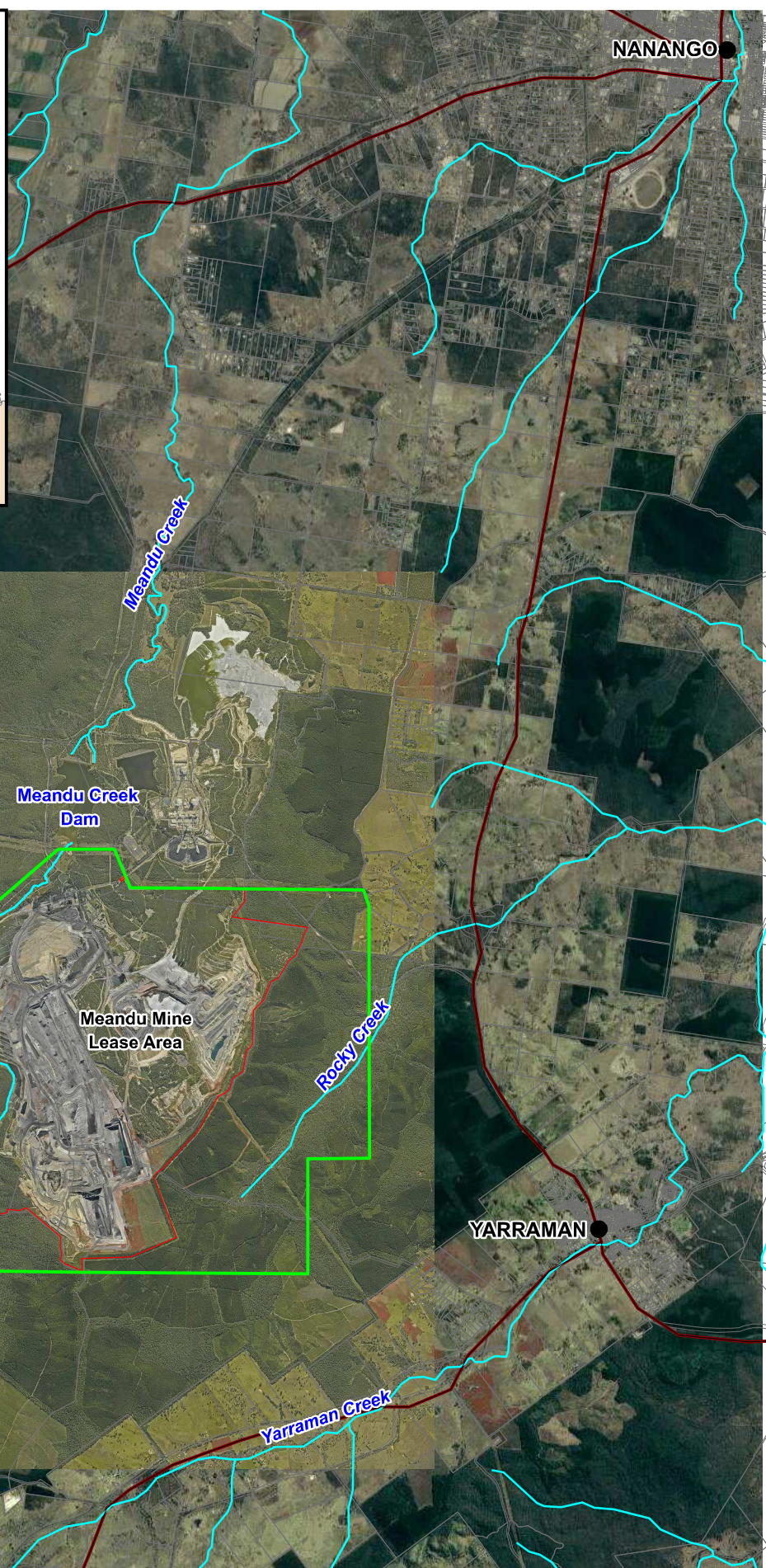
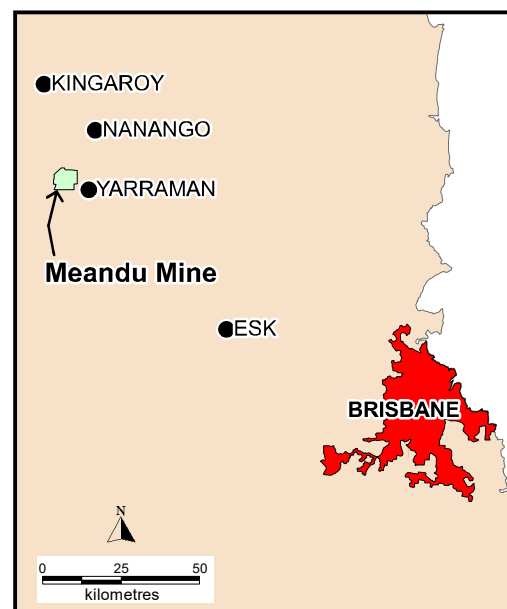
It is noted that a number of trial groundwater extraction bores already exist (GW48, GW49), though these have not been pumped regularly to date. It is recommended that pumping occur initially from these bores, with additional bores added if/as required.

The installation of additional monitoring bores will also be required to assess the efficacy of pumping (for example, bores within the spoil at the locations where seepage has been assessed to occur, as shown on Figures 45 and 47).

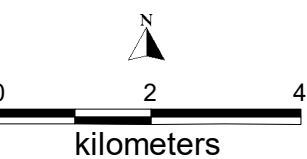
- The installation of additional groundwater monitoring bores to the west of Meandu Creek is recommended as a means of determining whether the high EC recorded at GW78 is indicative of water quality to the west of Meandu Creek and to validate data from geophysics investigations. A separate assessment will be required to establish bore sites, as the terrain in this area is steep, access via existing tracks is limited, and the ownership of land in the forested areas to the west of Meandu Creek (e.g. State forest or National Park) needs to be established.
- Although not related to the AMD investigations that have been undertaken for this report, additional areas for further groundwater monitoring have been identified for areas to the northwest of the QW void (Section 7.2) as well as for Black Creek catchment (Section 7.3). . Drilling of additional groundwater bores and further monitoring commitments will likely be a requirement for each area though the number and location of bores is yet to be established. However once established, any additional monitoring bores should be incorporated into the Meandu Mine monitoring network for long-term monitoring and assessment and in line with requirements for the groundwater monitoring program outlined in the EA (EPML00709113).

12.0 REFERENCES

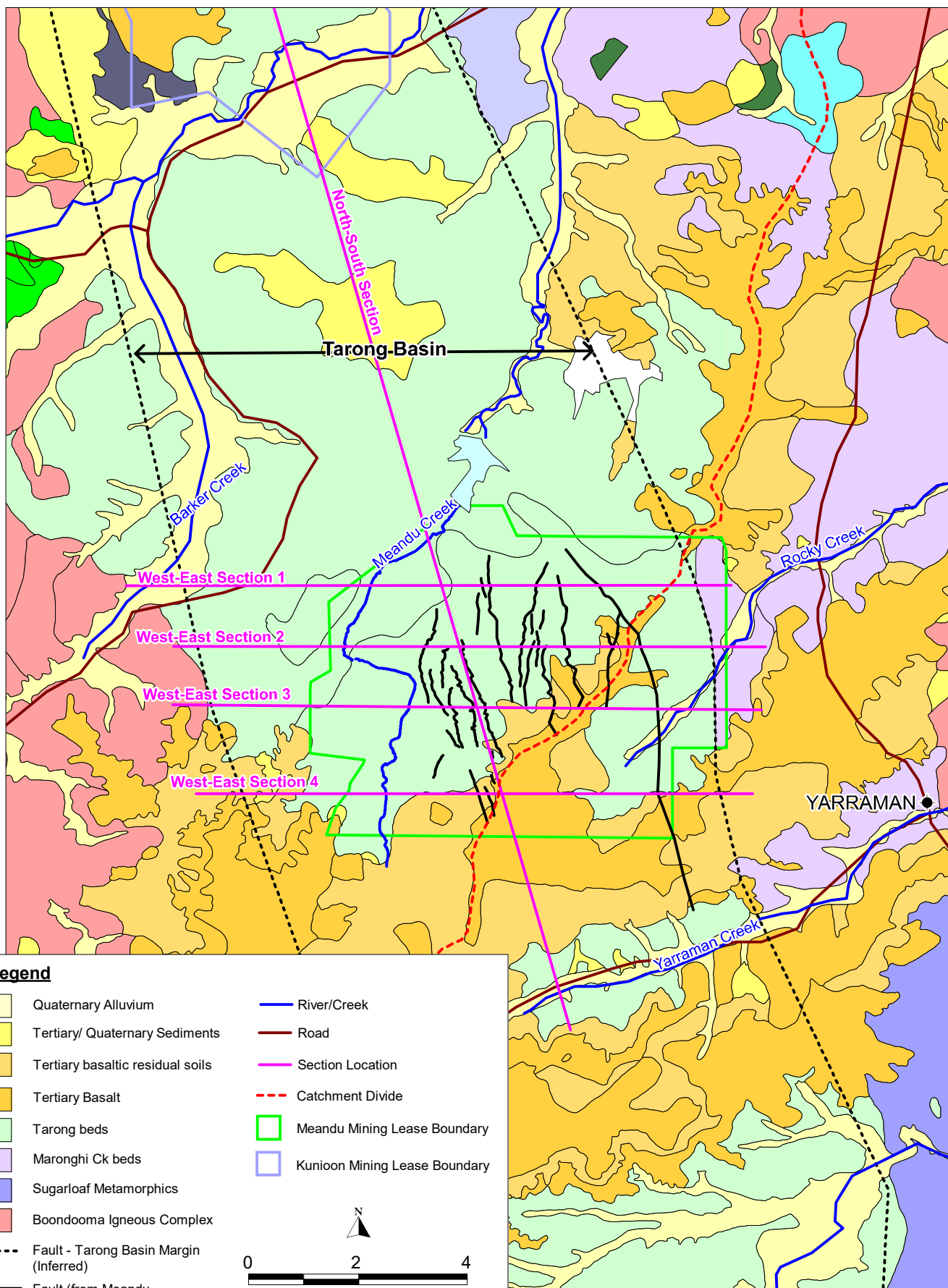
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- Meandu Mining Lease
- Surface Rights Area

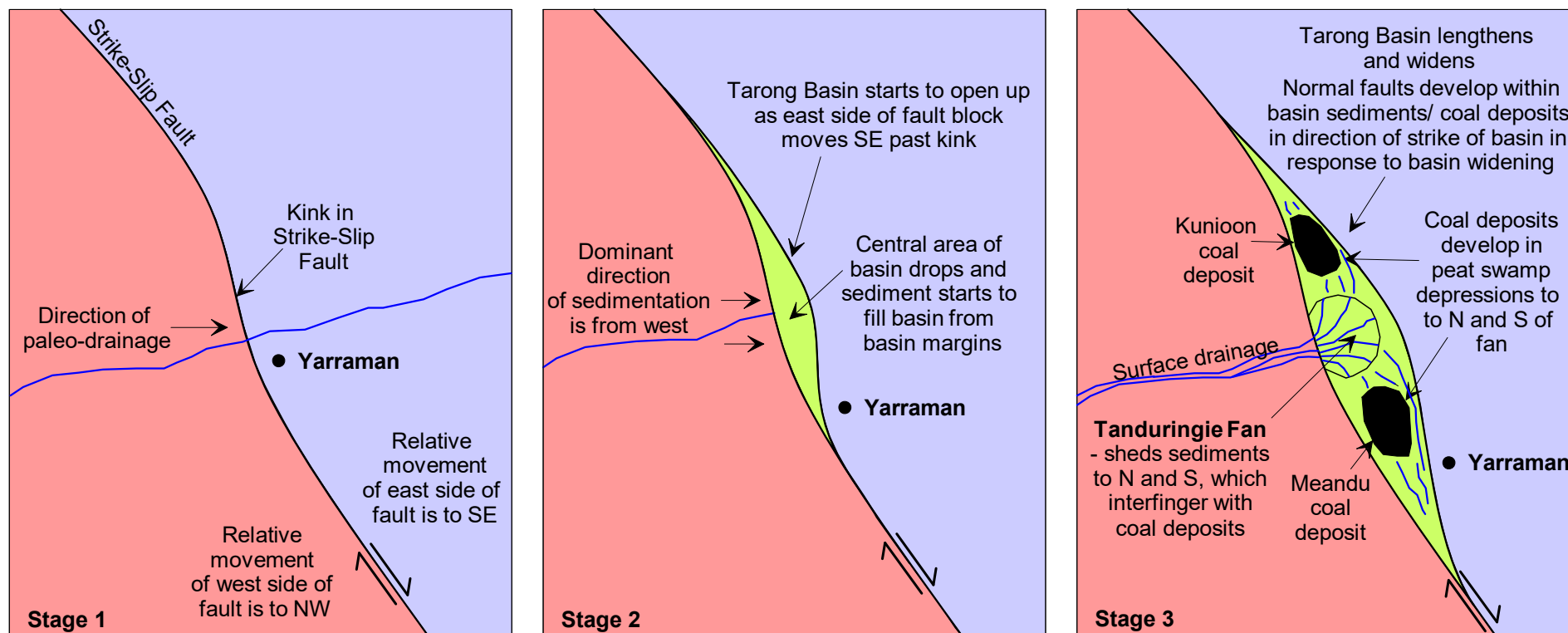


CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Location of Meandu Mine	
CHECKED	DATE		
SCALE 1:100,000	A4	PROJECT No JBT01-012-059	FIGURE No 1

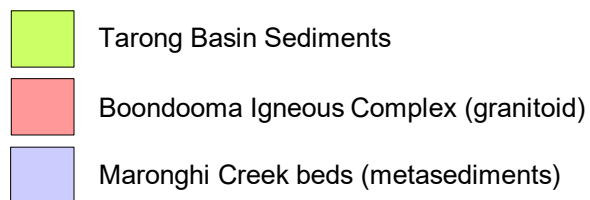


CLIENT Stanwell Corporation	
DRAWN JWB	DATE Aug 2018
CHECKED	DATE
SCALE 1:100,000	A4

PROJECT Meandu Mine - Environmental Evaluation
TITLE Surface Geology
PROJECT No JBT01-012-059
FIGURE No 2

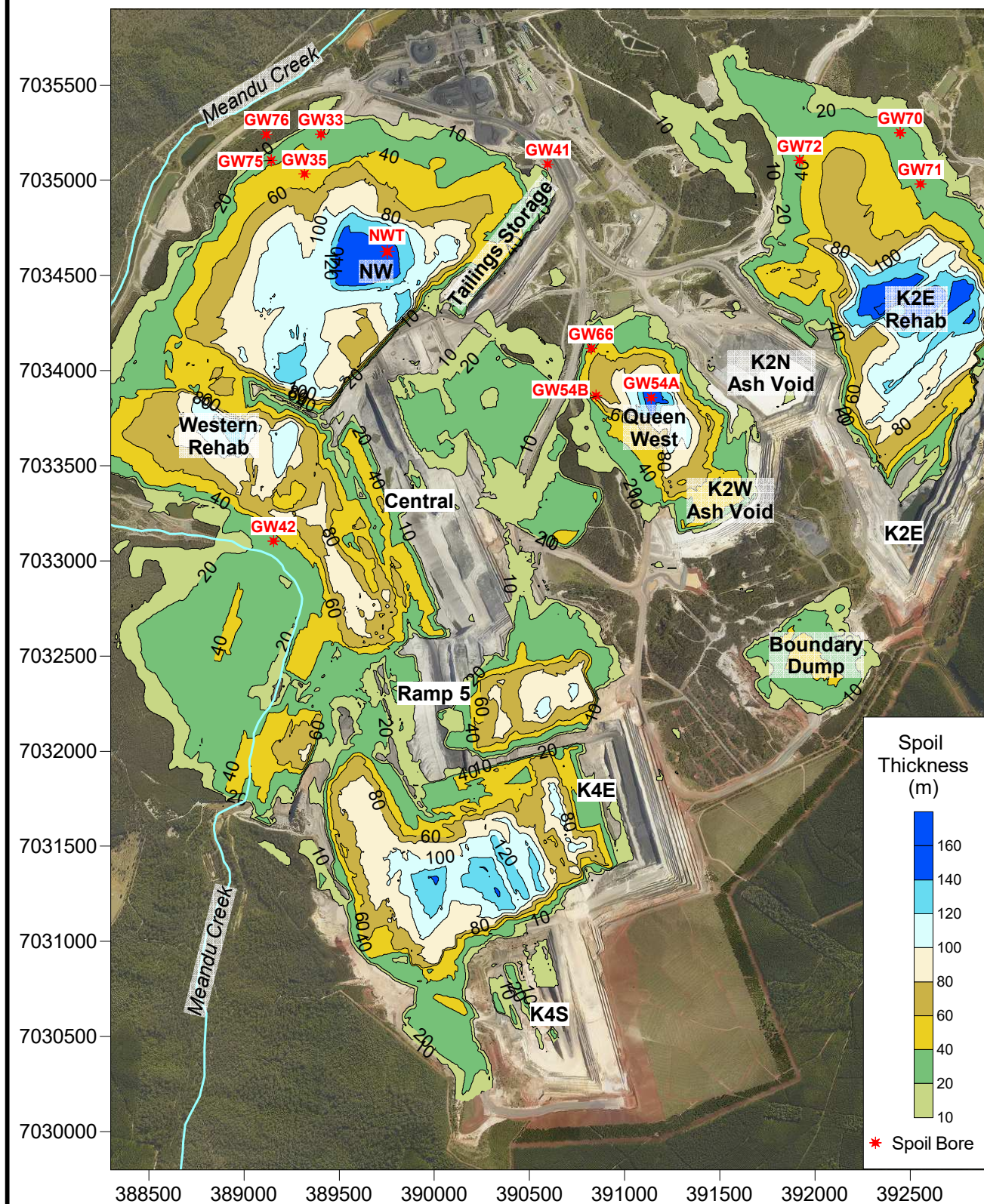


Simplified Geology



**Stages in the development of the Tarong Basin
(after Flood & Garces, 1986)**

	CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
	DRAWN JWB	DATE Aug 2018	TITLE Stages in the Development of the Tarong Basin	
	CHECKED	DATE		
	SCALE As Shown		PROJECT No. JBT01-012-059	FIGURE No. 3



CLIENT Stanwell Corporation

DRAWN JWB DATE Aug 2018

CHECKED DATE

SCALE As Shown

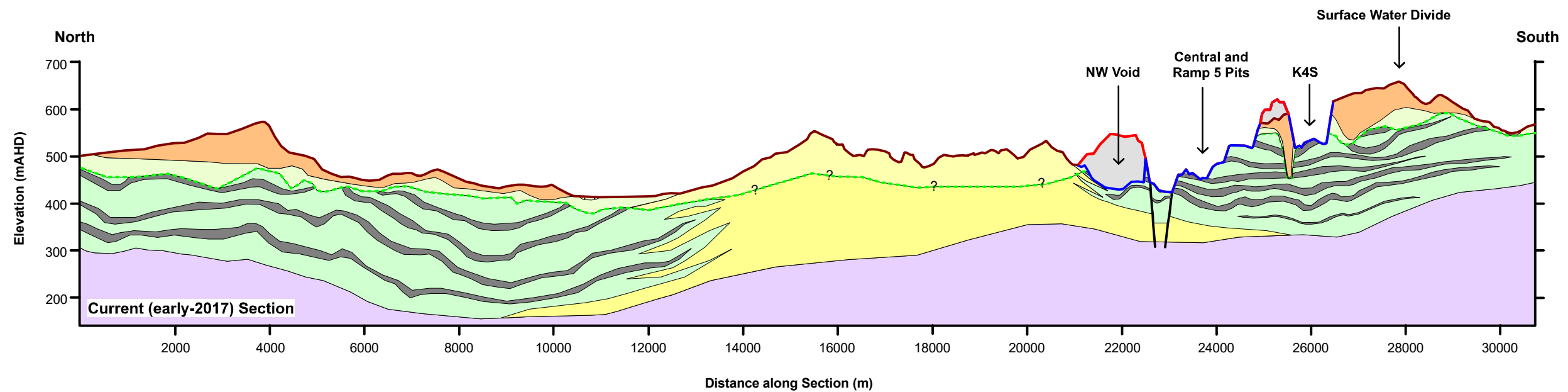
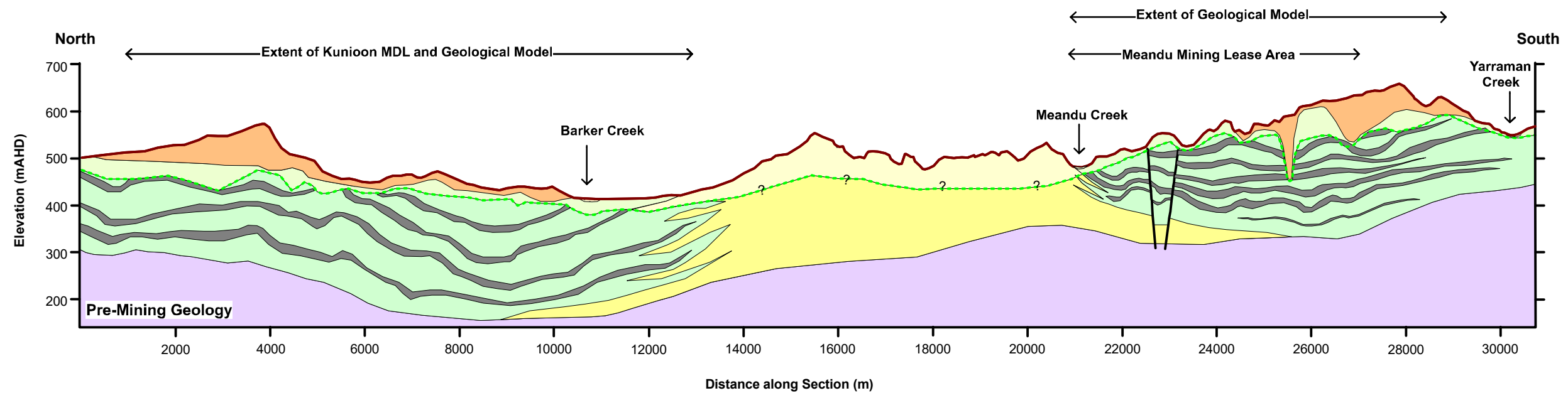
PROJECT Meandu Mine - Environmental Evaluation

TITLE Thickness of Mined Spoil (m)

PROJECT No. JBT01-012-059

FIGURE No.

4

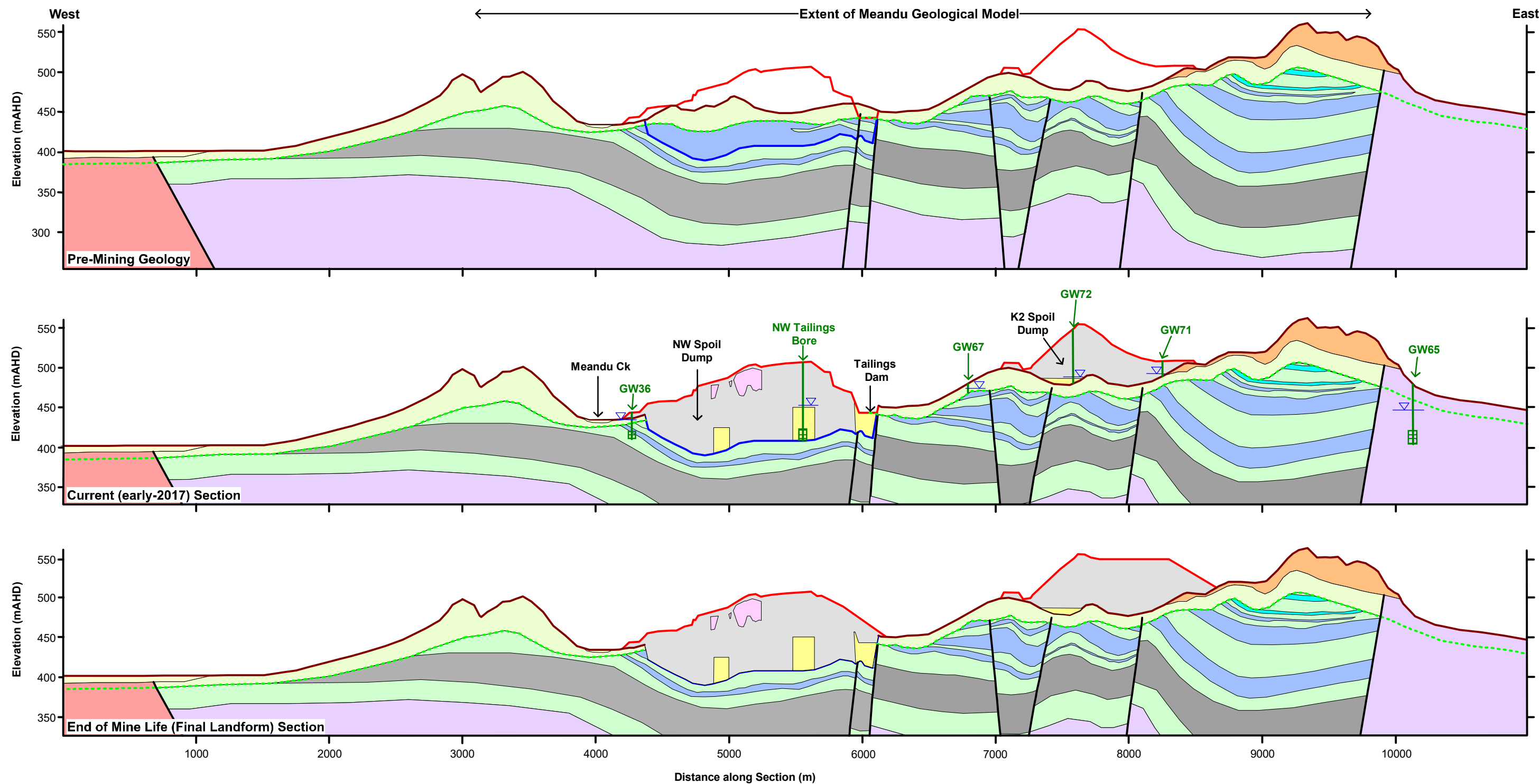


Legend

	Quaternary Alluvium		Coal Seams
	Tertiary Basalt and residual soils		Mined Spoil
	Triassic Tanduringie Fan (weathered)		Carboniferous Maronghi Creek beds
	Triassic Tanduringie Fan (fresh)		Base of Weathering
	Triassic Tarong beds (coal measures) - weathered		Original Topographic Surface
	Triassic Tarong beds (coal measures) - Fresh		Current Topographic Surface
			Deepest Mined Surface
			Fault

200 m
 Horizontal scale 1:100,000 at A3
 Vertical scale 1:10,000 at A3
 10 x vertical exaggeration
 2000 m

		CLIENT Stanwell Corporation	PROJECT Environmental Evaluation
DRAWN JWB	DATE Aug 2018	TITLE Hydrogeological Sections North-South Section	
CHECKED	DATE	PROJECT No JBT01-012-059	
SCALE As Shown	A3	FIGURE No 5	



Legend

- | | | |
|--|---|---------------------------|
| Quaternary Alluvium | Queen Seam - multiple coal seams separated by interburden | Final Topographic Surface |
| Tertiary Basalt and residual soils | Prince and Lower Seams - Base uncertain | Deepest Mined Surface |
| Triassic Tarong beds (coal measures) - weathered | Triassic Boondooma Igneous Complex | Fault |
| Triassic Tarong beds (coal measures) - Fresh | Carboniferous Maronghi Creek beds | Waste (General Spoil) |
| Ace Seam - multiple coal seams separated by interburden | Base of Weathering | Rejects |
| King Seam - multiple coal seams separated by interburden | Original Topographic Surface | Tailings |
| | Current Topographic Surface | Ash |

- GW65** Existing Site Monitoring Bore
- Measured water level
- Screened interval

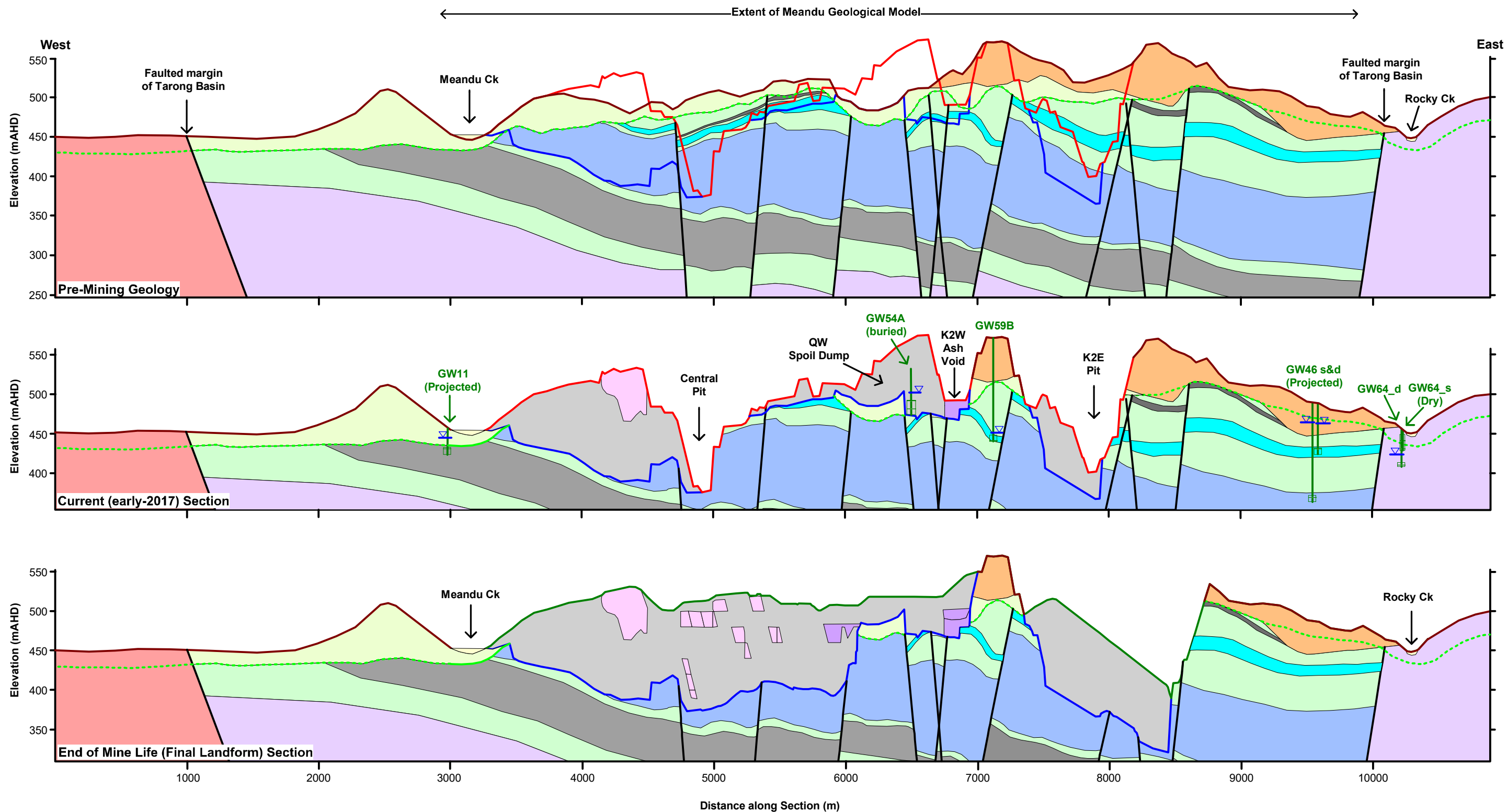
Horizontal scale 1:30,000 at A3
Vertical scale 1:5,000 at A3
6 x vertical exaggeration

100 m

600 m



CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Hydrogeological Sections West-East 1	
CHECKED	DATE		
SCALE As Shown		PROJECT No JBT01-012-059	FIGURE No 6



Legend

- | | | |
|--|---|--|
| Quaternary Alluvium | Queen Seam - multiple coal seams separated by interburden | Final Topographic Surface |
| Tertiary Basalt and residual soils | Prince and Lower Seams - Base uncertain | Deepest Mined Surface |
| Triassic Tarong beds (coal measures) - weathered | Triassic Boondooma Igneous Complex | Fault |
| Triassic Tarong beds (coal measures) - Fresh | Carboniferous Maronghi Creek beds | Waste (General Spoil) |
| Ace Seam - multiple coal seams separated by interburden | Base of Weathering | Rejects |
| King Seam - multiple coal seams separated by interburden | Original Topographic Surface | Tailings |
| | Current Topographic Surface | Ash |

- Existing Site Monitoring Bore**
- GW64_d
- Measured water level
- Screened interval

100 m

Horizontal scale 1:30,000 at A3

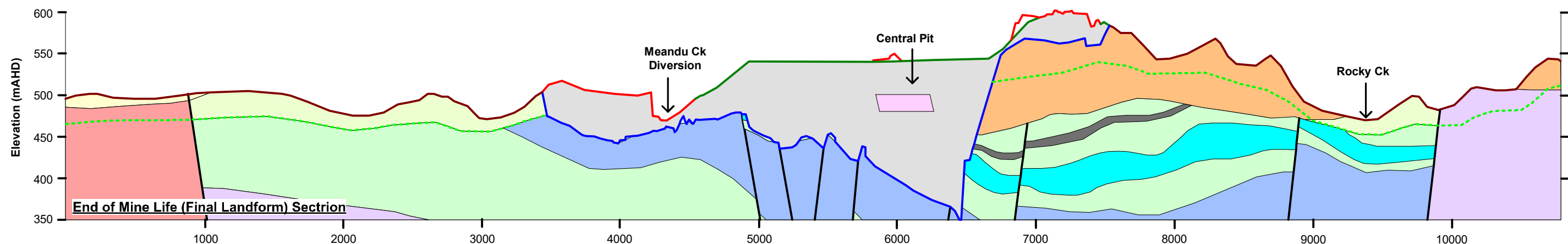
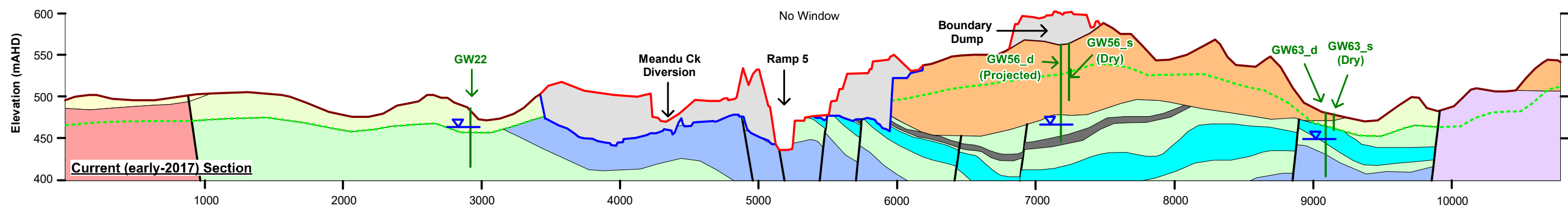
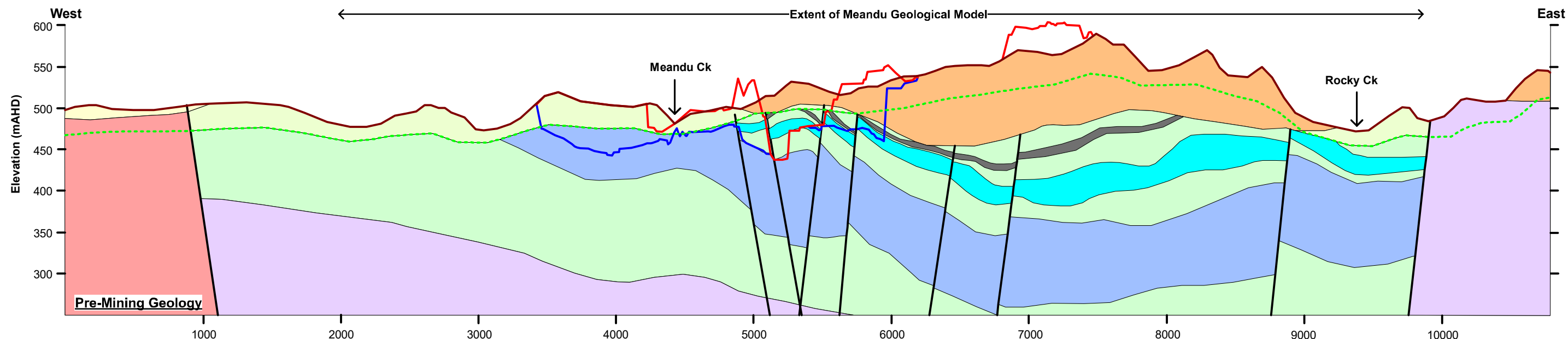
Vertical scale 1:5,000 at A3

6 x vertical exaggeration

600 m

Notes:
Meandu Geological Model extends to base of Queen Seam.
Geology below base of Queen Seam and beyond the lateral extent of the geological model is interpreted.

	CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
	DRAWN JWB	DATE Aug 2018	TITLE Hydrogeological Sections West-East 2	
	CHECKED	DATE		
	SCALE As Shown	A3	PROJECT No JBT01-012-059	FIGURE No 7



Legend

- | | |
|--|---|
| Quaternary Alluvium | Queen Seam - multiple coal seams separated by interburden |
| Tertiary Basalt and residual soils | Prince and Lower Seams - Base uncertain |
| Triassic Tarong beds (coal measures) - weathered | Triassic Boondooma Igneous Complex |
| Triassic Tarong beds (coal measures) - Fresh | Carboniferous Maronghi Creek beds |
| Ace Seam - multiple coal seams separated by interburden | Base of Weathering |
| King Seam - multiple coal seams separated by interburden | Original Topographic Surface |
| | Current Topographic Surface |

- | |
|---------------------------|
| Final Topographic Surface |
| Deepest Mined Surface |
| Fault |
| Waste (General Spoil) |
| Rejects |
| Tailings |
| Ash |

Distance along Section (m)

- | | |
|--------|--------------------------------------|
| GW63_d | Existing Site Monitoring Bore |
| | Measured water level |
| | Screened interval |

100 m

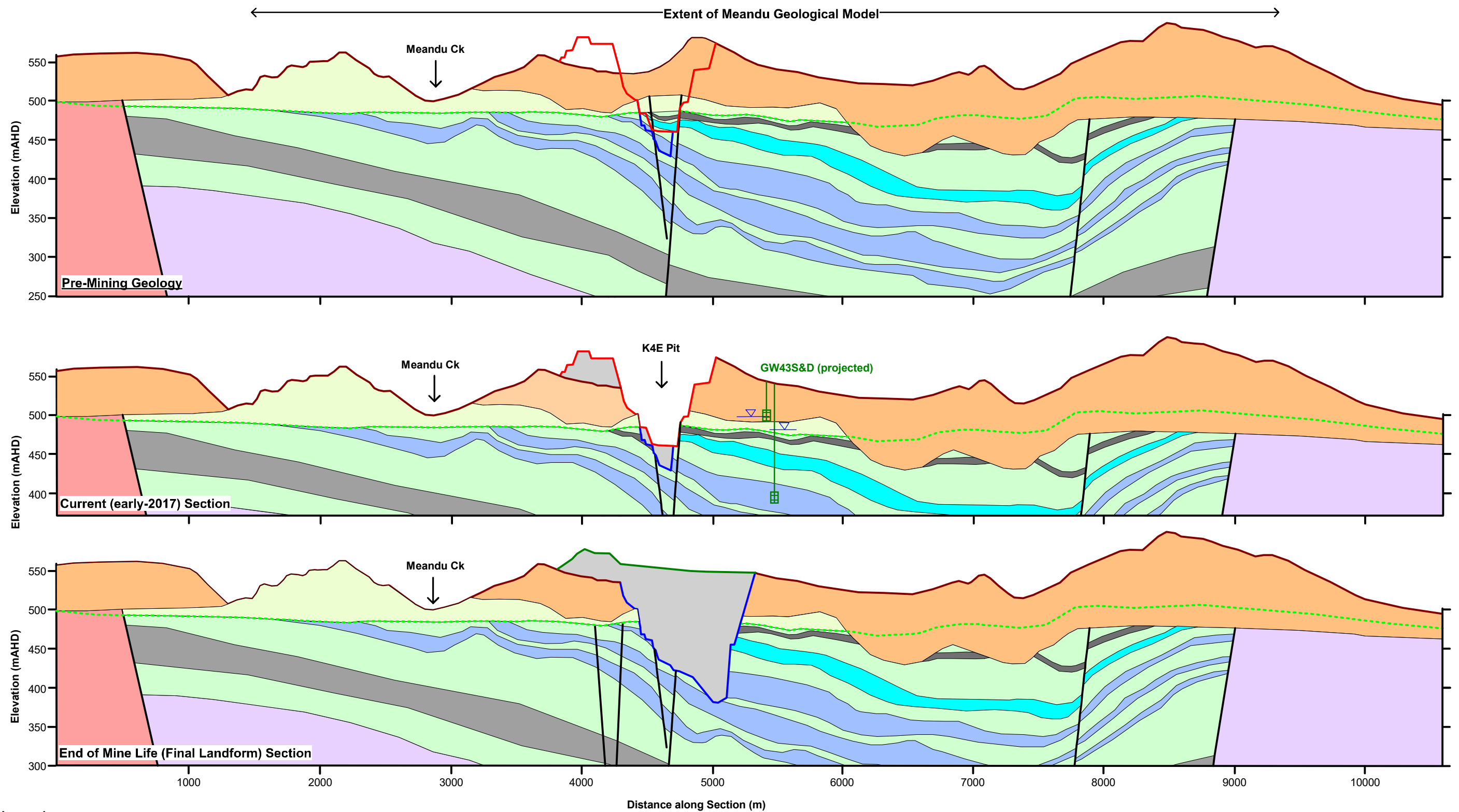
Horizontal scale 1:30,000 at A3
Vertical scale 1:5,000 at A3

6 x vertical exaggeration

600 m



CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Hydrogeological Sections West-East 3	
CHECKED	DATE		
SCALE As Shown		PROJECT No A3	FIGURE No 8
		JBT01-012-059	



Legend

- | | | |
|--|---|---------------------------|
| Quaternary Alluvium | Queen Seam - multiple coal seams separated by interburden | Final Topographic Surface |
| Tertiary Basalt and residual soils | Prince and Lower Seams - Base uncertain | Deepest Mined Surface |
| Triassic Tarong beds (coal measures) - weathered | Triassic Boondooma Igneous Complex | Fault |
| Triassic Tarong beds (coal measures) - Fresh | Carboniferous Maronghi Creek beds | Waste (General Spoil) |
| Ace Seam - multiple coal seams separated by interburden | Base of Weathering | Rejects |
| King Seam - multiple coal seams separated by interburden | Original Topographic Surface | Tailings |
| | Current Topographic Surface | Ash |

GW63_d Existing Site Monitoring Bore

Measured water level

Screened interval

100 m

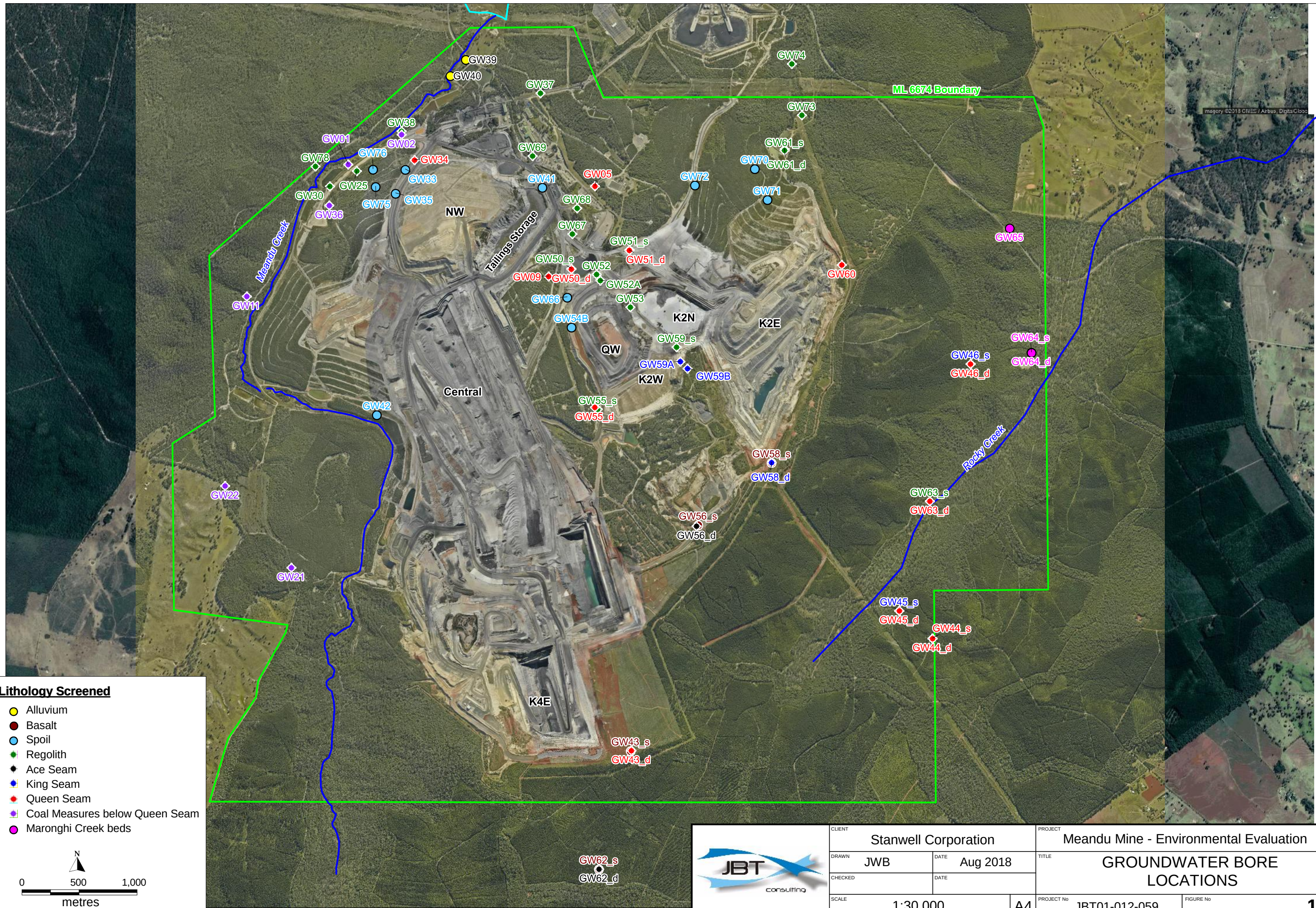
Horizontal scale 1:30,000 at A3

Vertical scale 1:5,000 at A3

6 x vertical exaggeration

600 m

	CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
	DRAWN JWB	DATE Aug 2018	TITLE Hydrogeological Sections West-East 4	
	CHECKED	DATE		
	SCALE As Shown		PROJECT No JBT01-012-059	FIGURE No 9

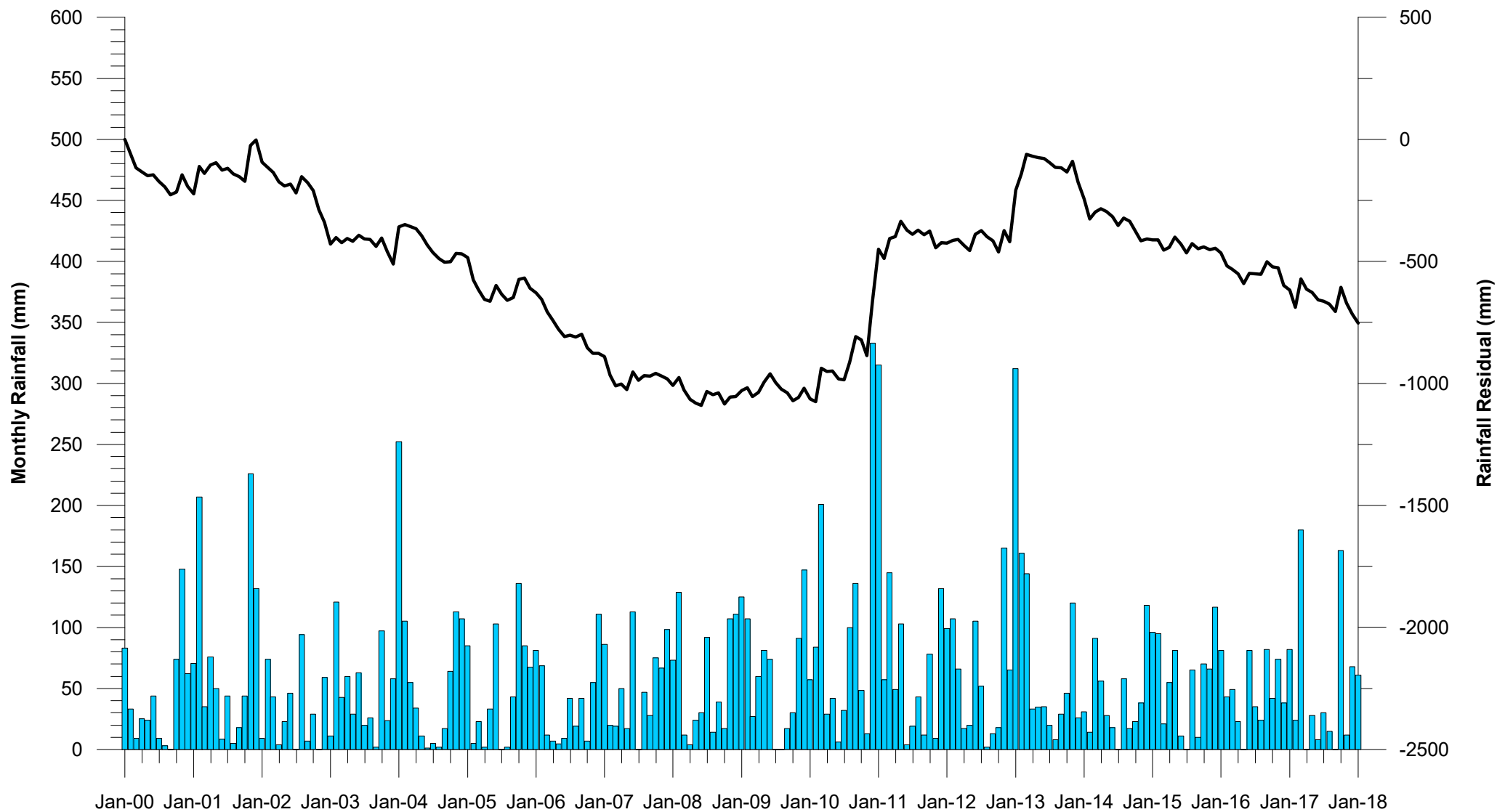


Lithology Screened

- Alluvium
- Basalt
- Spoil
- Regolith
- Ace Seam
- King Seam
- Queen Seam
- Coal Measures below Queen Seam
- Maronghi Creek beds

0 500 1,000 metres

JBT consulting		CLIENT	Stanwell Corporation		PROJECT	Meandu Mine - Environmental Evaluation	
		DRAWN	JWB	DATE	Aug 2018	TITLE	
		CHECKED		DATE		GROUNDWATER BORE LOCATIONS	
		SCALE	1:30,000		A4	PROJECT No	FIGURE No
						JBT01-012-059	10

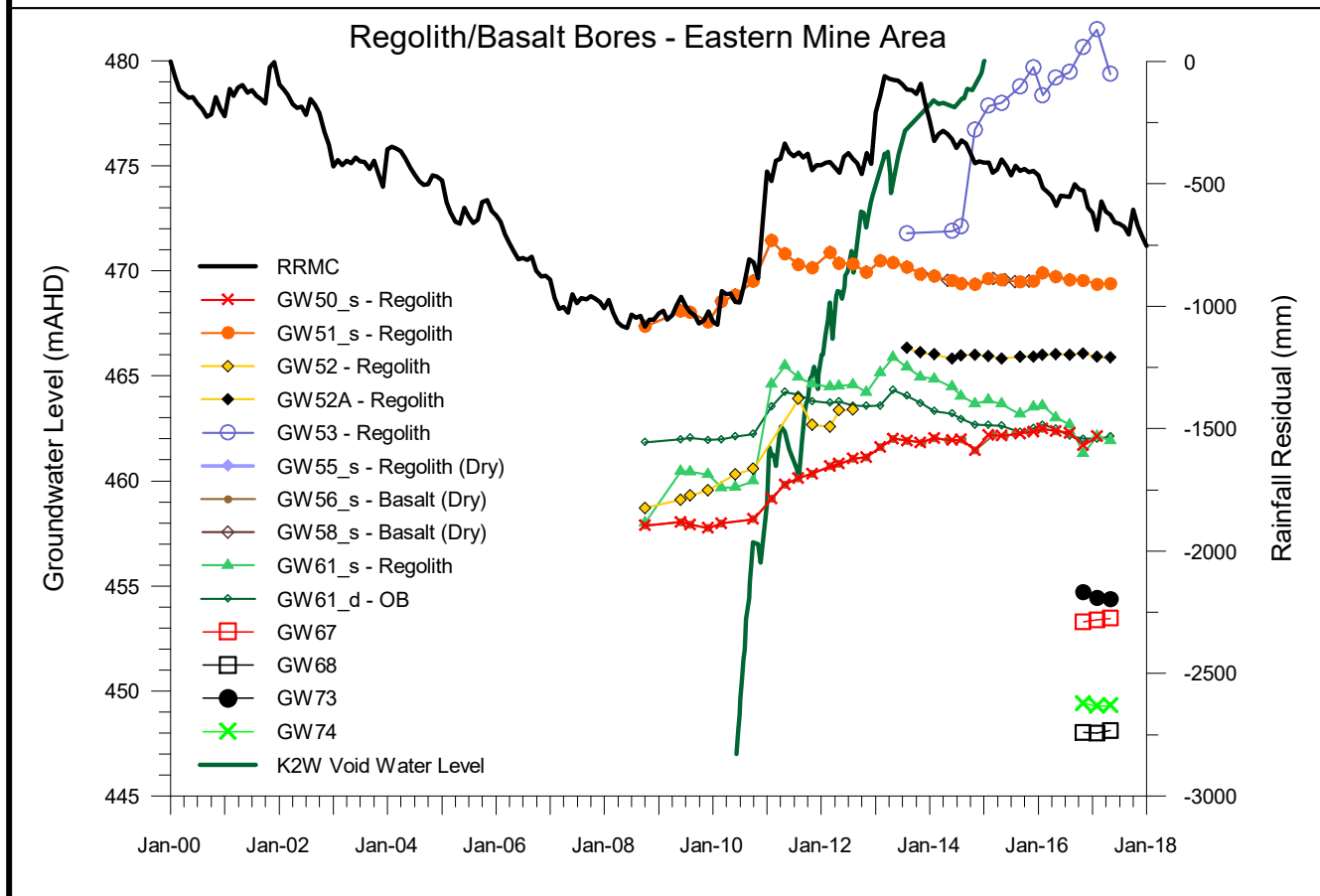
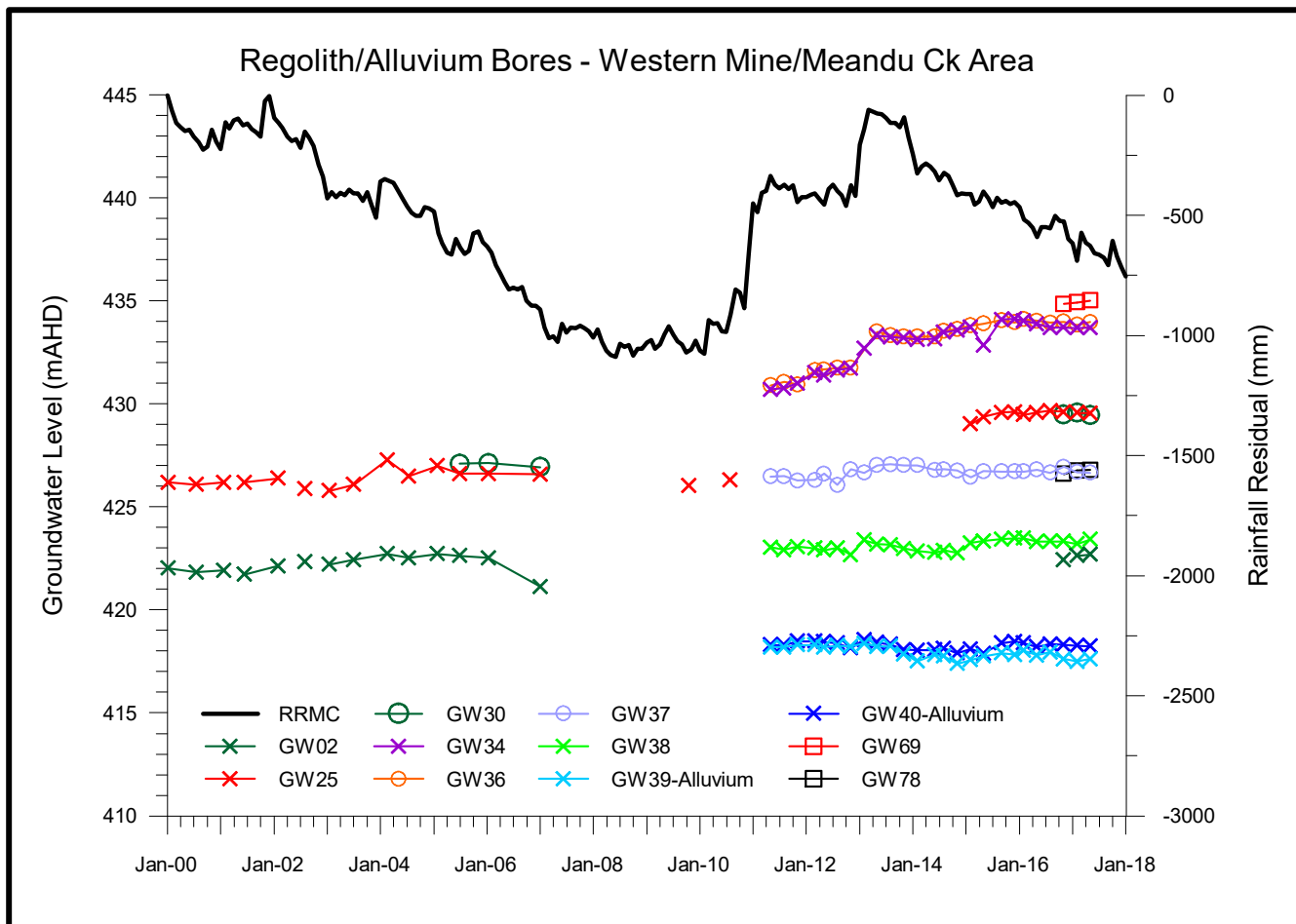


Tarong Rainfall Station No. 040199

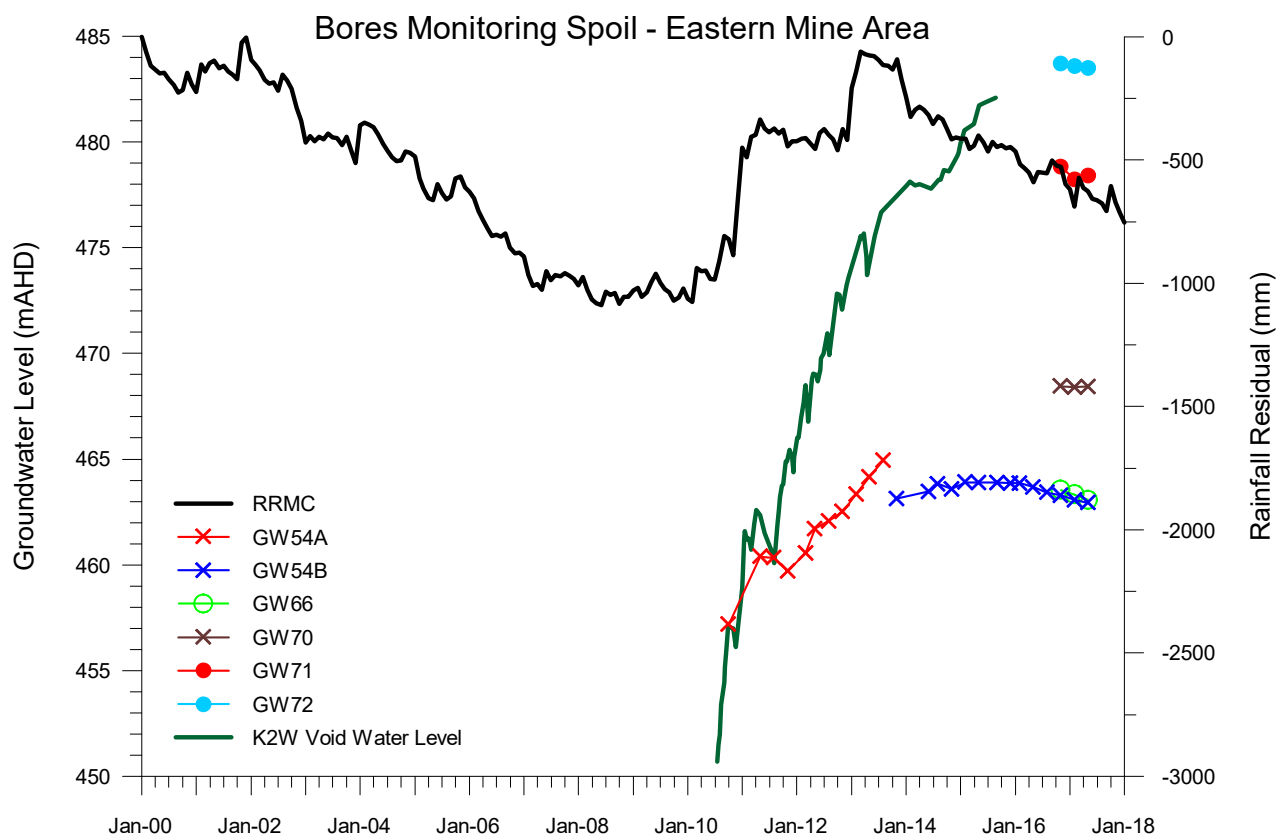
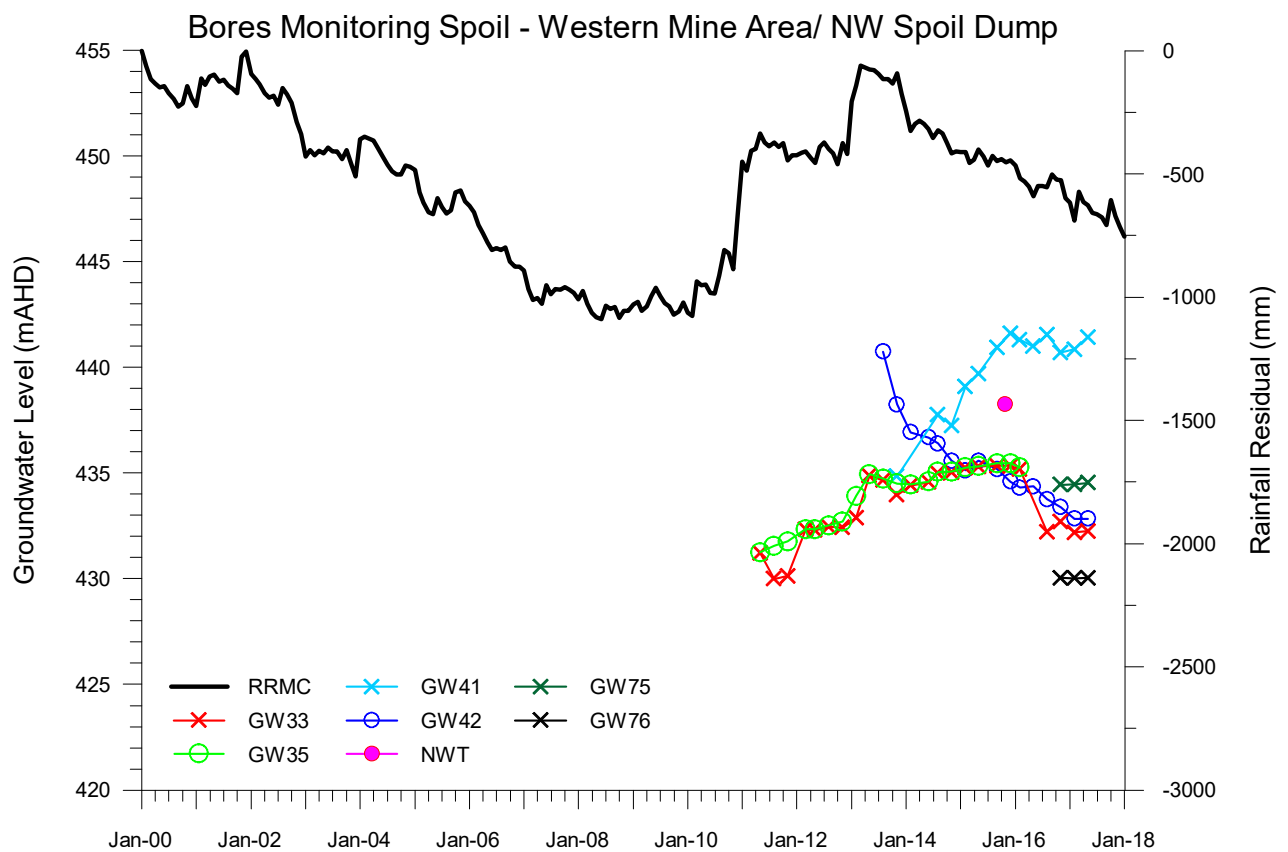
- Rainfall Residual Mass (RRM) Curve
- Monthly Rainfall - Station 040199 (Tarong)



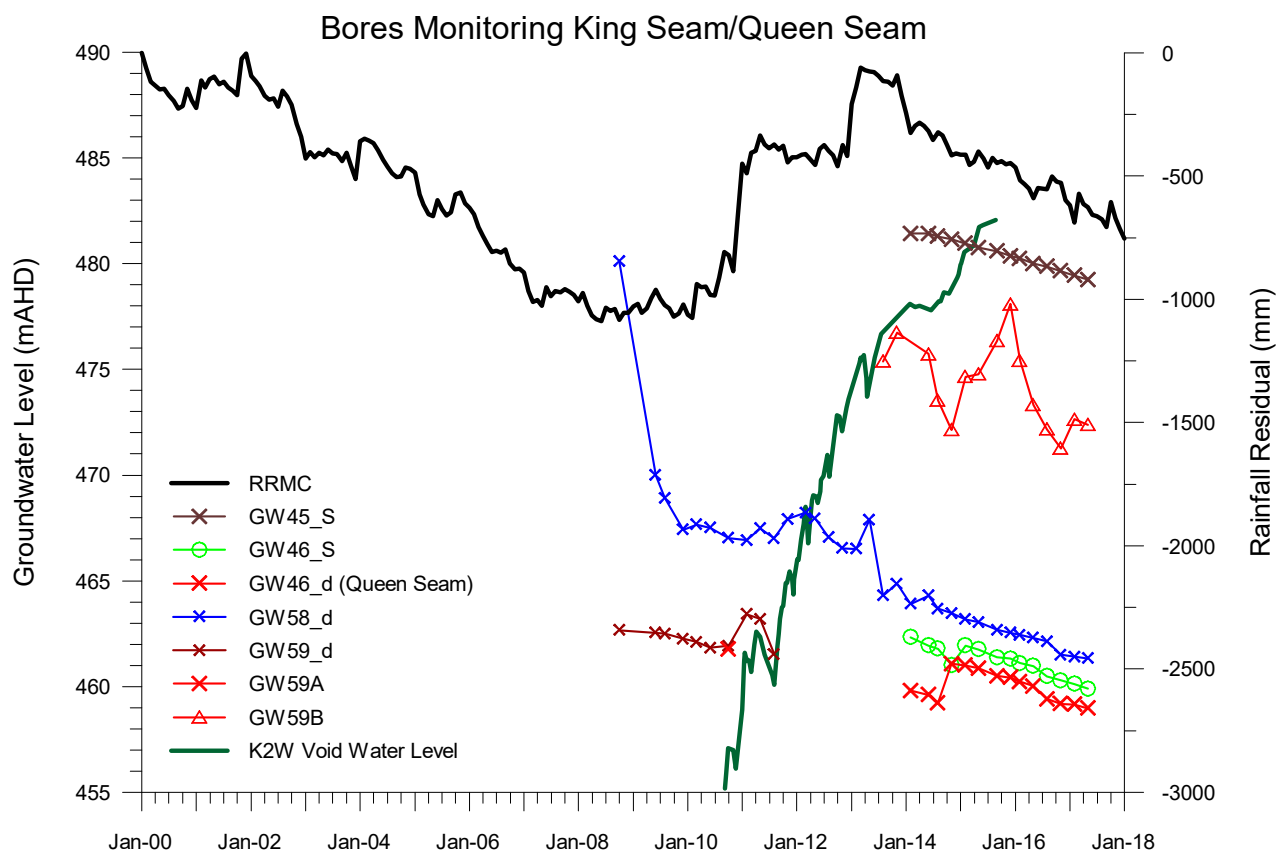
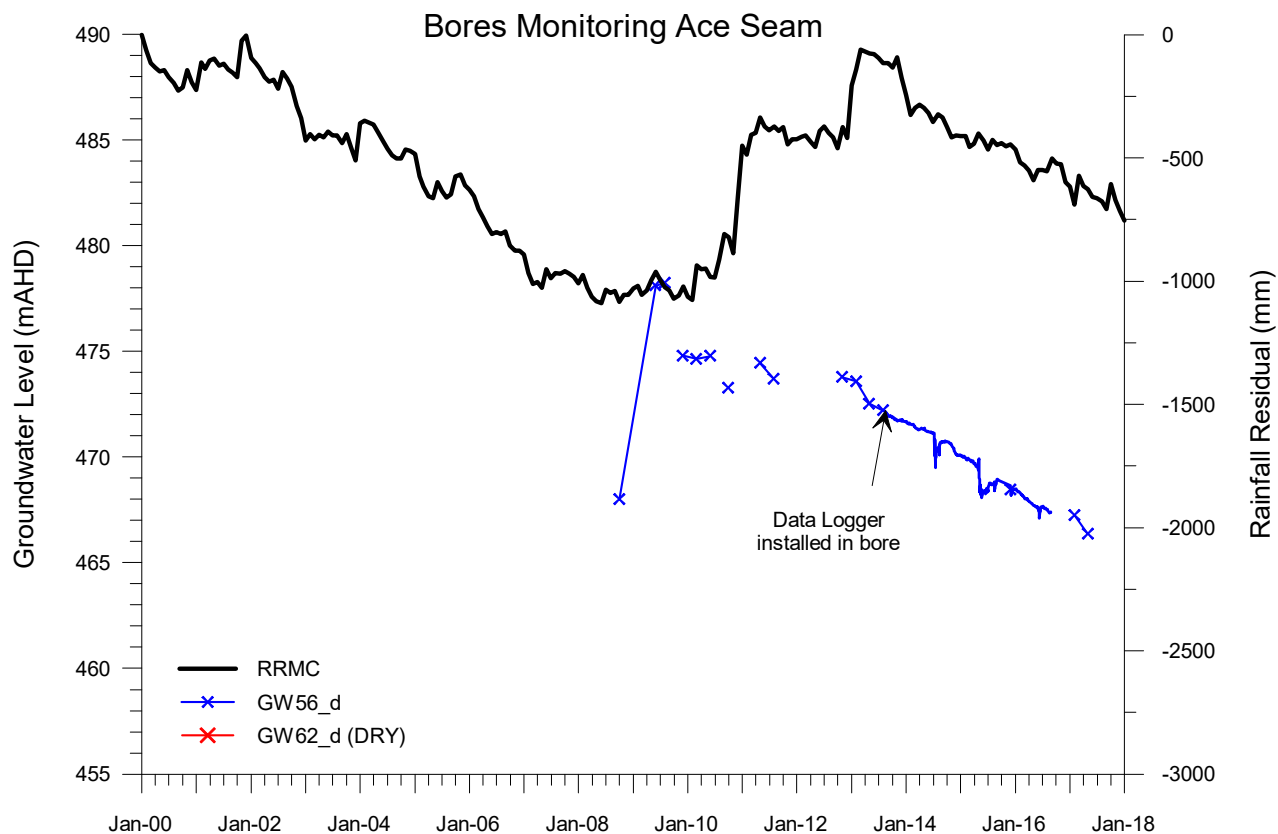
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Tarong Rainfall Data	
CHECKED	DATE		
SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 11



	CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
	DRAWN JWB	DATE Aug 2018	TITLE Groundwater Level Fluctuations Regolith/Basalt	
	CHECKED	DATE		
	SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 12



CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Groundwater Level Fluctuations Spoil Bores	
CHECKED	DATE		
SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 13



CLIENT **Stanwell Corporation**

PROJECT **Meandu Mine - Environmental Evaluation**

DRAWN **JWB**

DATE **Aug 2018**

TITLE **Groundwater Level Fluctuations
Ace Seam, King Seam & Queen Seam**

CHECKED

DATE

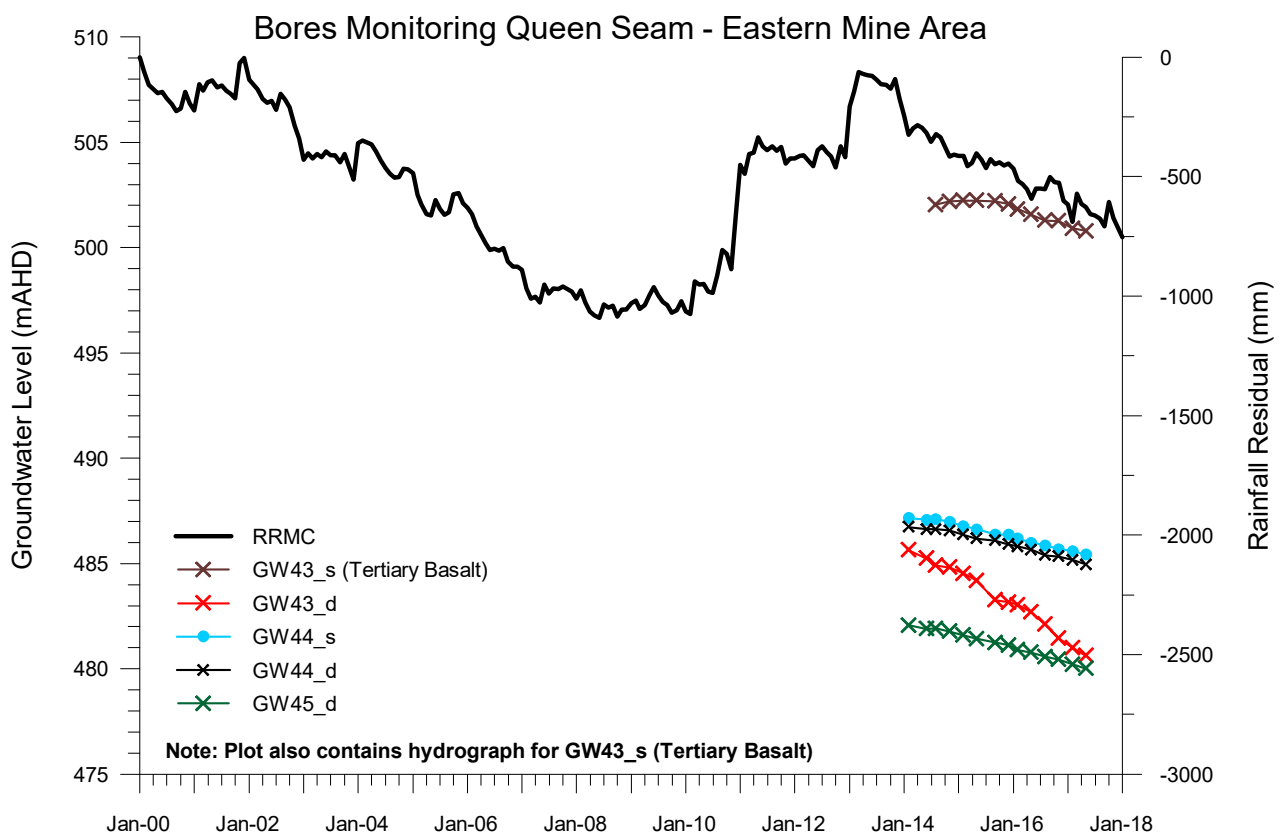
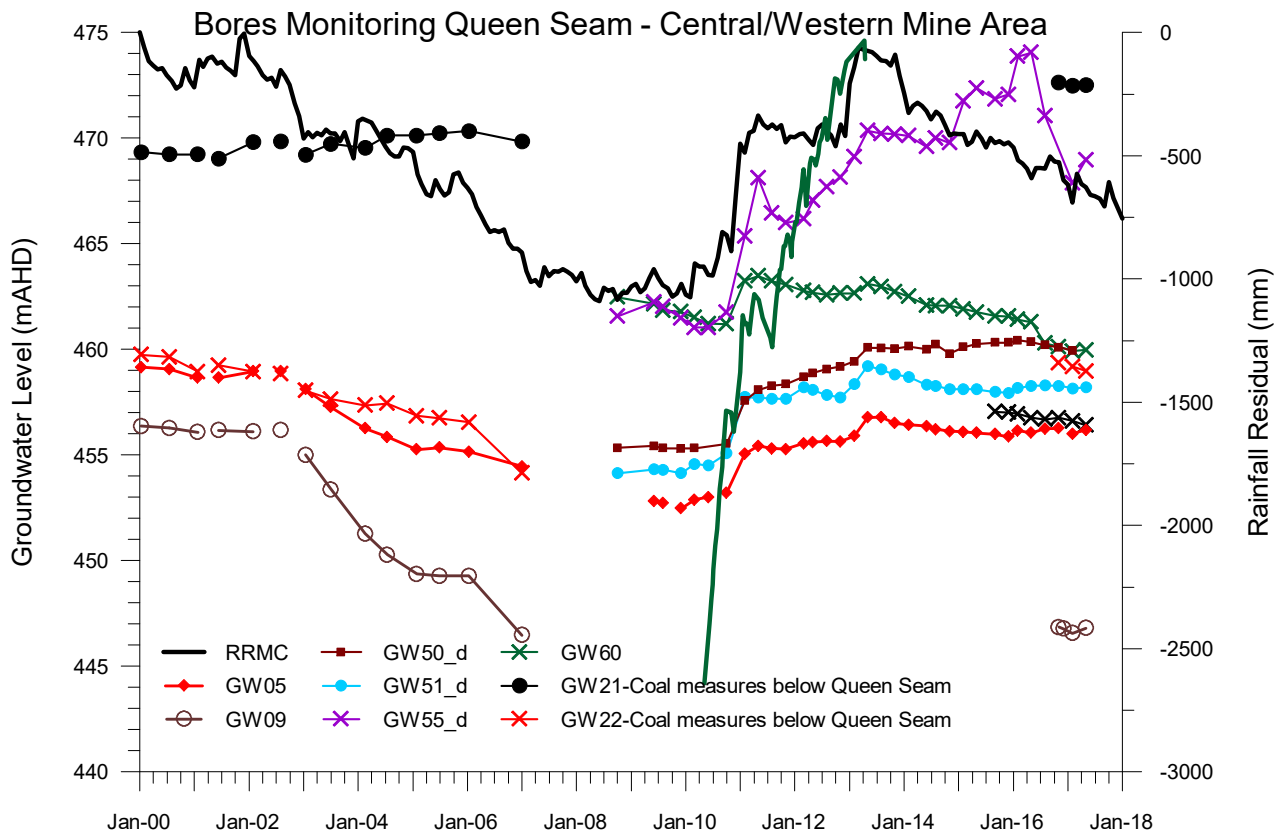
SCALE **As Shown**

A4

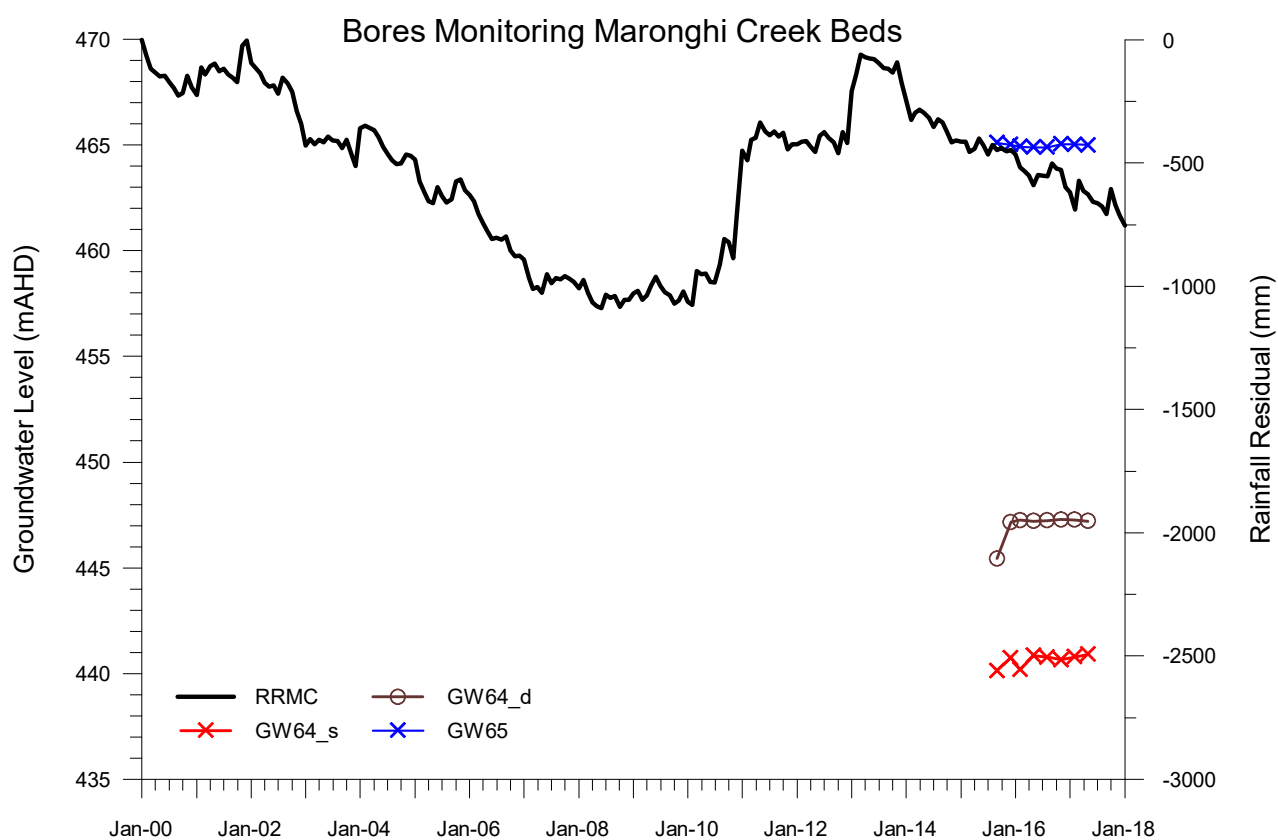
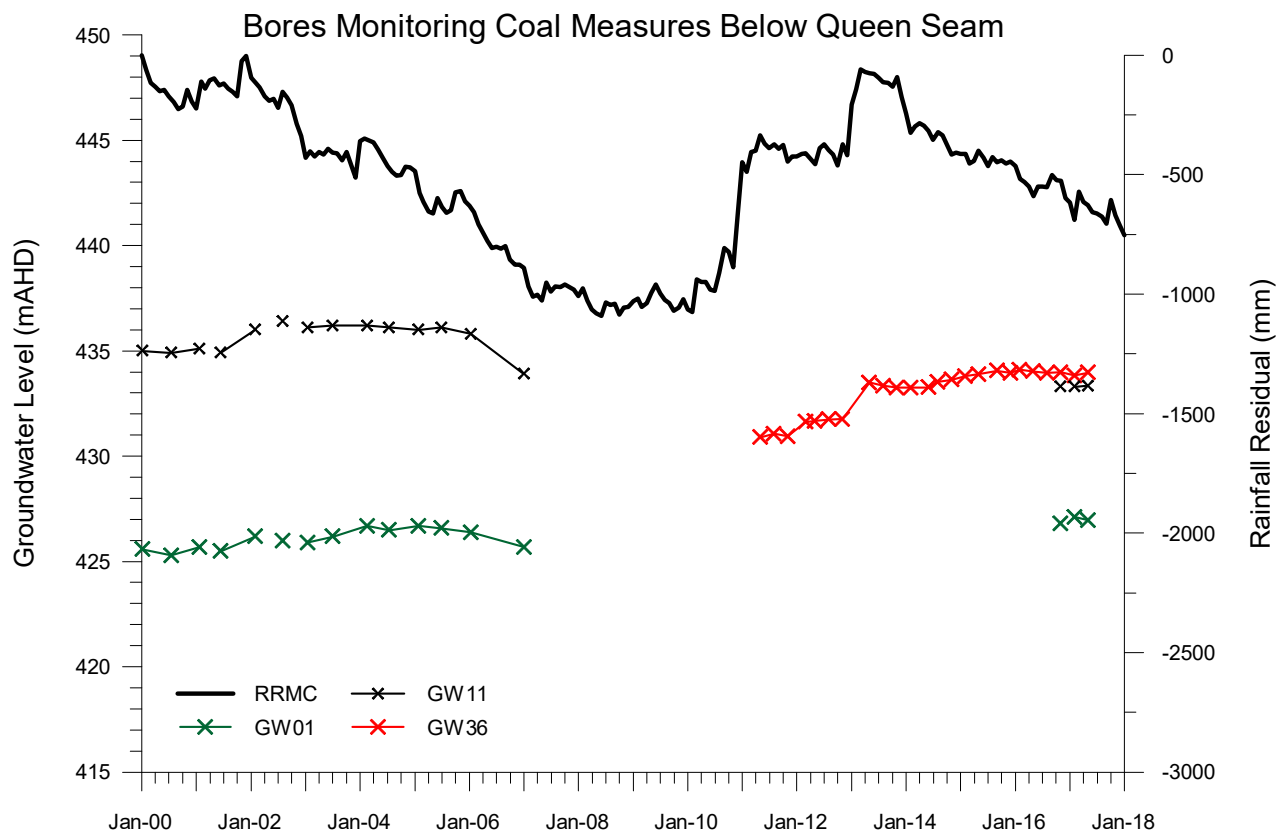
PROJECT No. **JBT01-012-059**

FIGURE No.

14

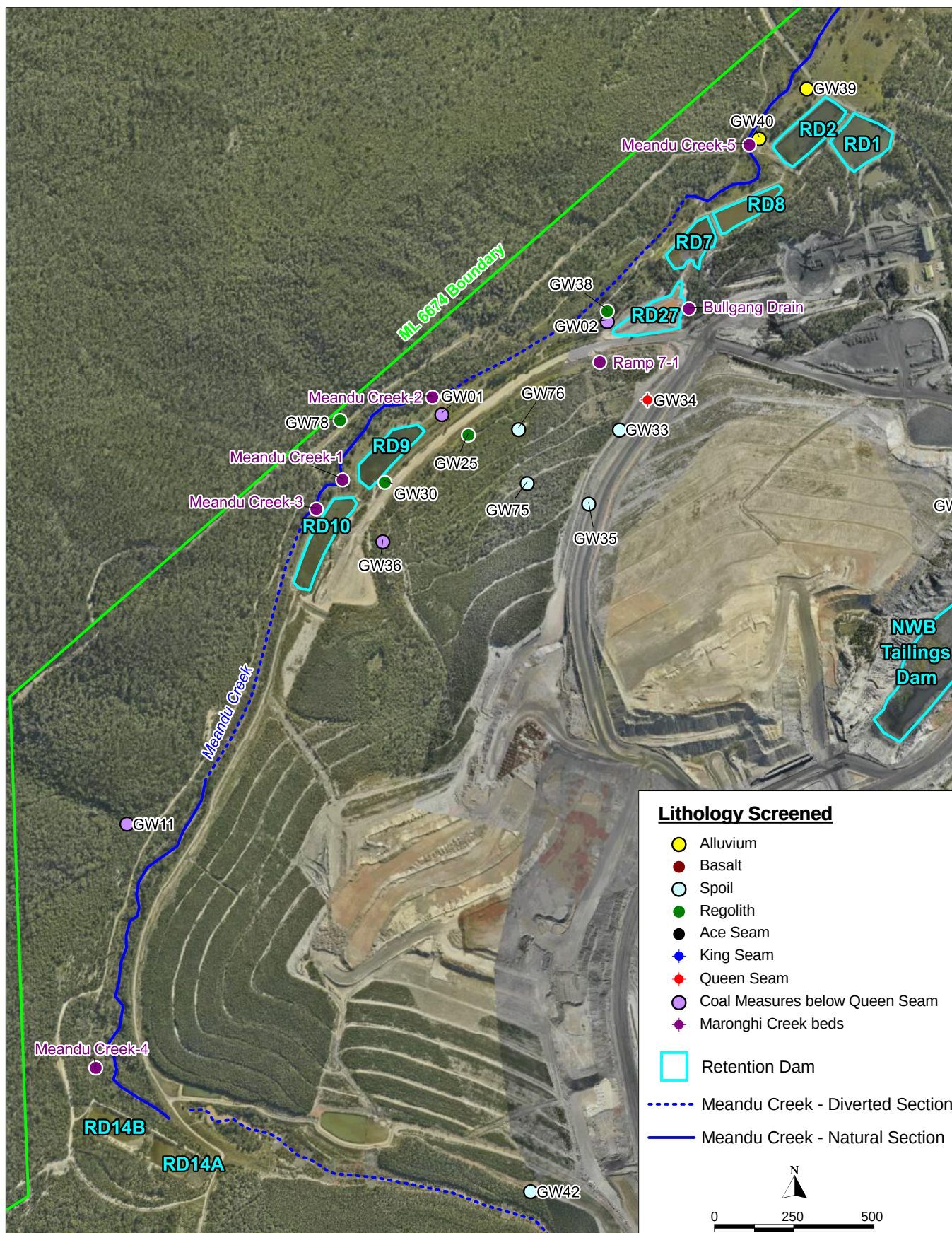


CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Groundwater Level Fluctuations Queen Seam	
CHECKED	DATE		
SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 15



CLIENT Stanwell Corporation	
DRAWN JWB	DATE Aug 2018
CHECKED	DATE
SCALE As Shown	A4

PROJECT Meandu Mine - Environmental Evaluation	
TITLE Groundwater Level Fluctuations Coal Measures & Maronghi Ck beds	
PROJECT No. JBT01-012-059	FIGURE No. 16



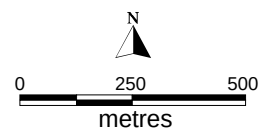
Lithology Screened

- Alluvium
- Basalt
- Spoil
- Regolith
- Ace Seam
- ◆ King Seam
- ◆ Queen Seam
- Coal Measures below Queen Seam
- ◆ Maronghi Creek beds

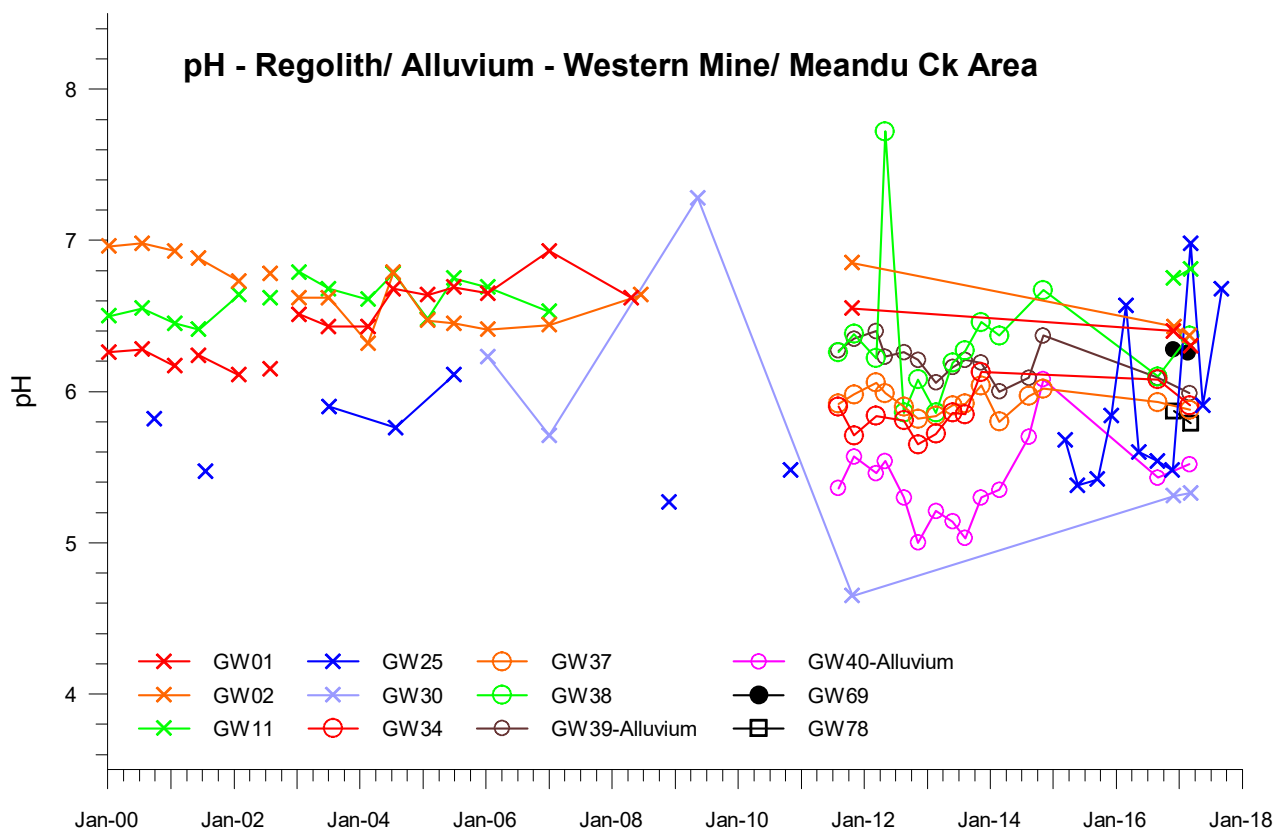
Retention Dam

--- Meandu Creek - Diverted Section

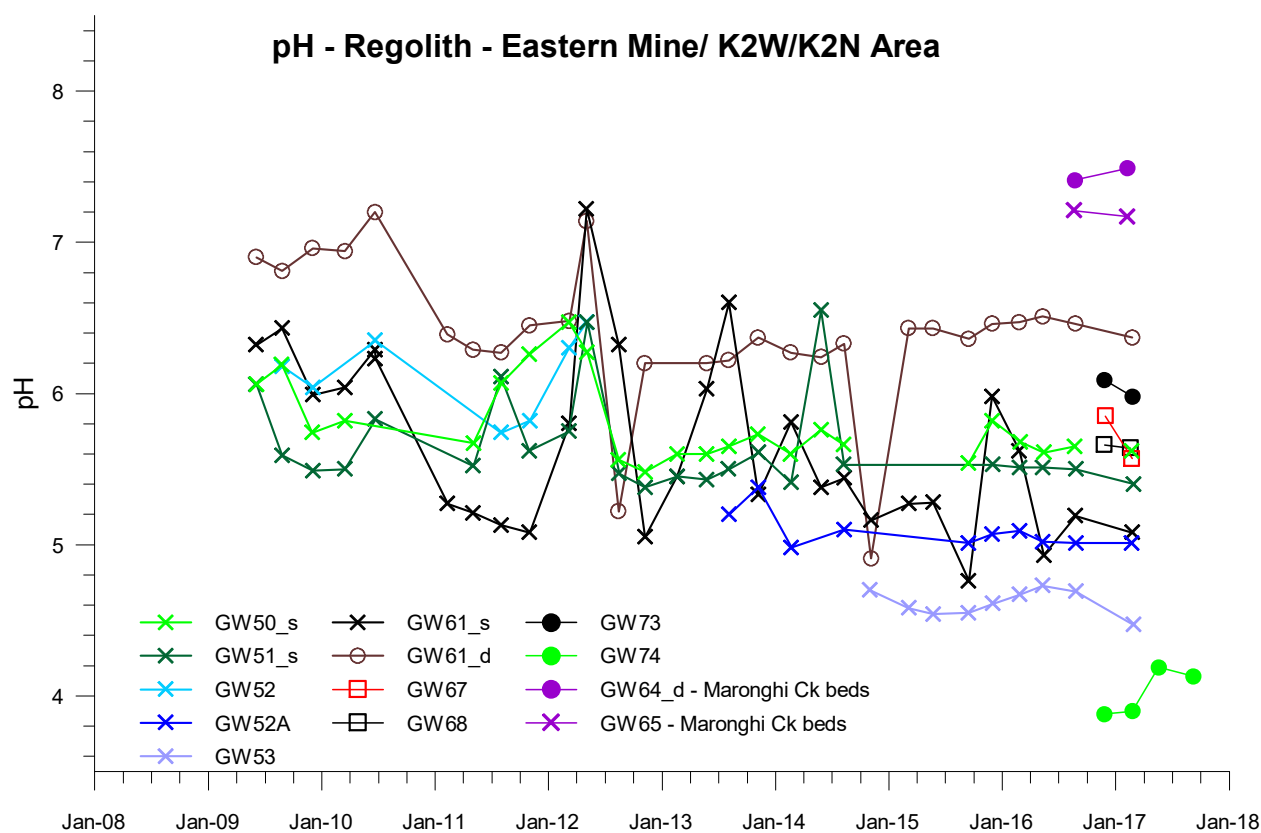
--- Meandu Creek - Natural Section



CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Monitoring Sites Near and Within Meandu Creek	
CHECKED	DATE		
SCALE 1:15,000	A4	PROJECT No JBT01-012-059	FIGURE No 17

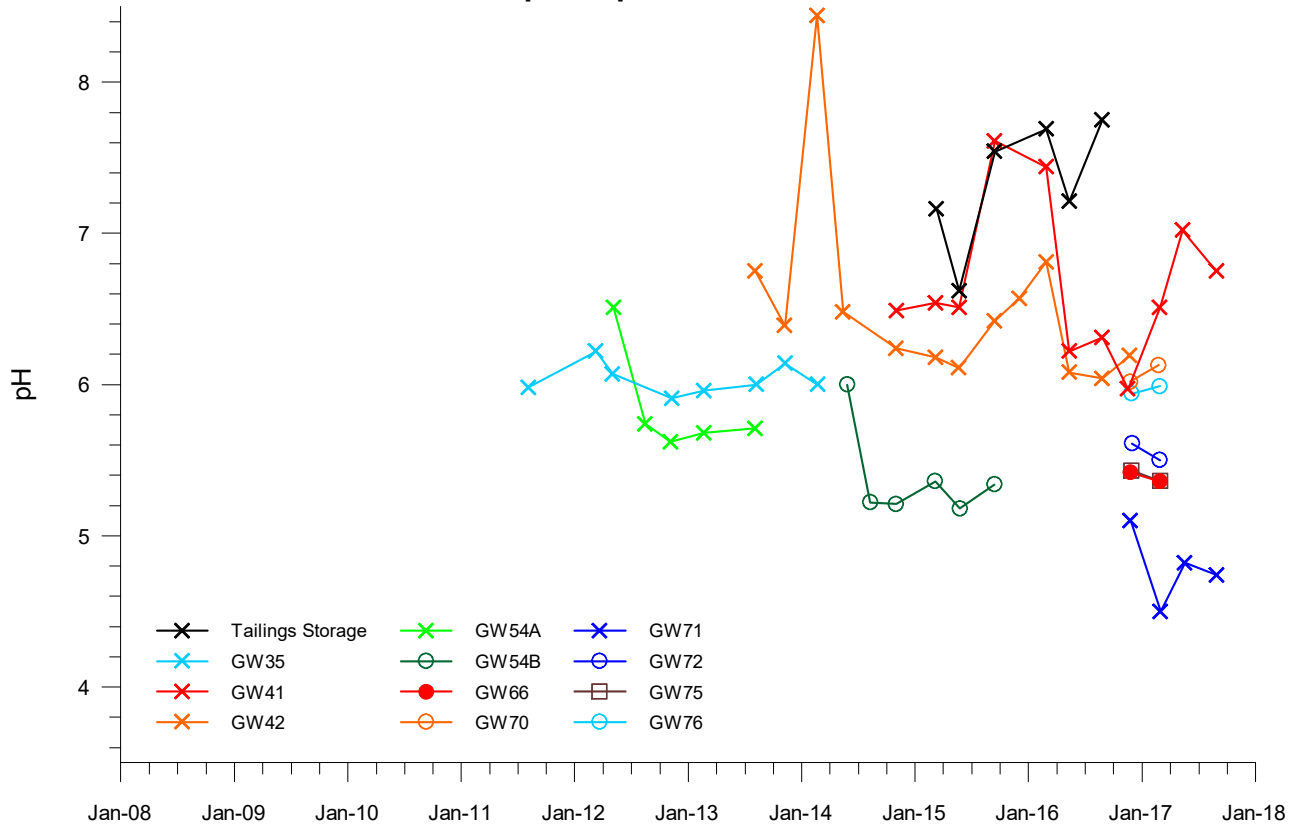


Note: Different horizontal scales between upper and lower plots



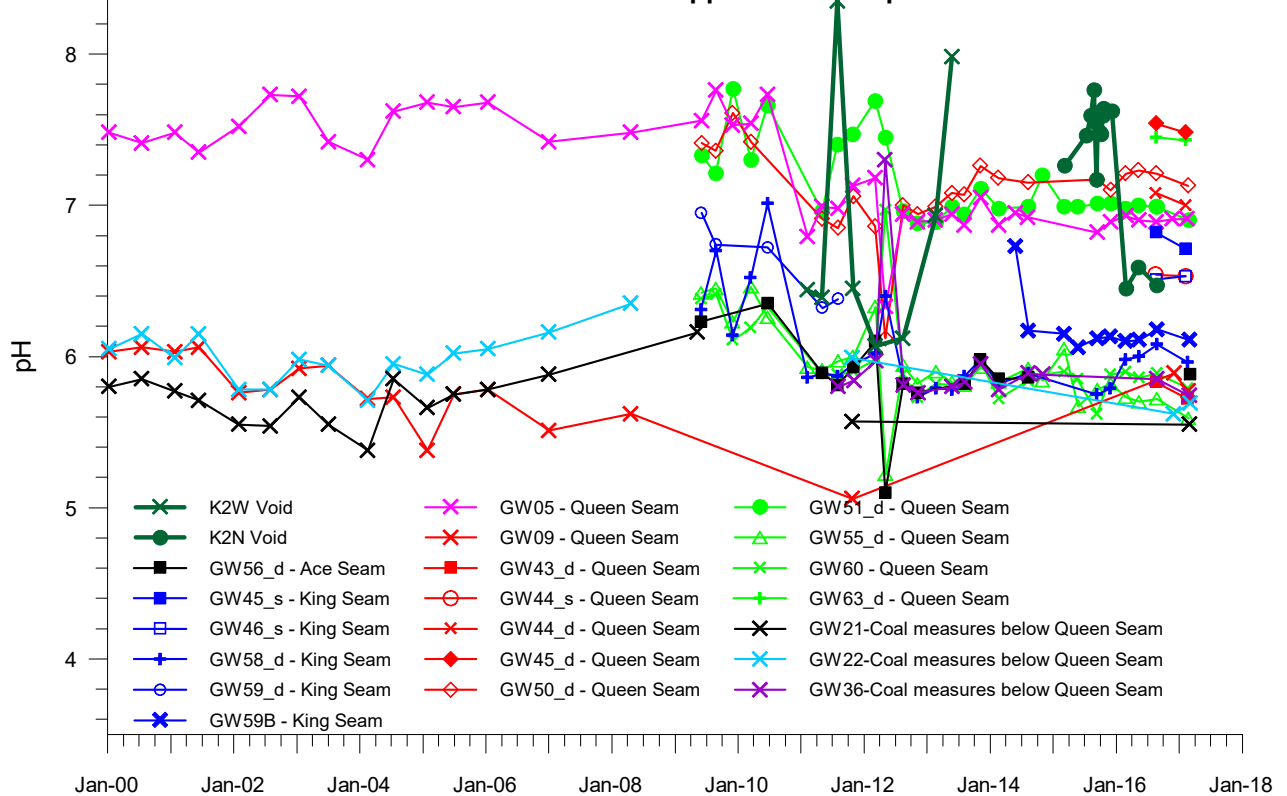
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE pH Data Regolith/ Alluvium Bores	
CHECKED	DATE		
SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 18

pH - Spoil Bores



pH - Coal Seam Bores/ Ash Water

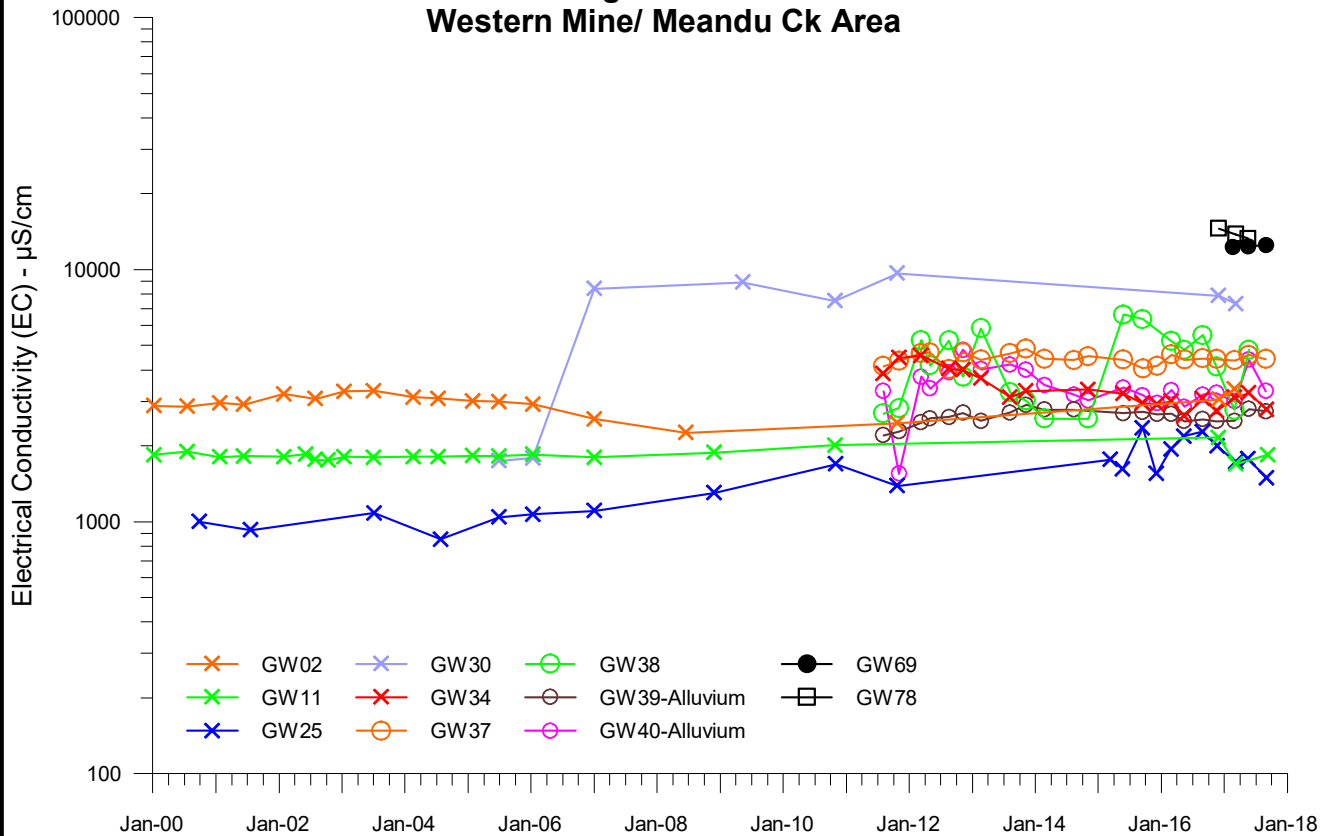
Note: Different horizontal scales between upper and lower plots



CLIENT	Stanwell Corporation	
DRAWN	JWB	DATE Aug 2018
CHECKED		DATE
SCALE	As Shown	A4

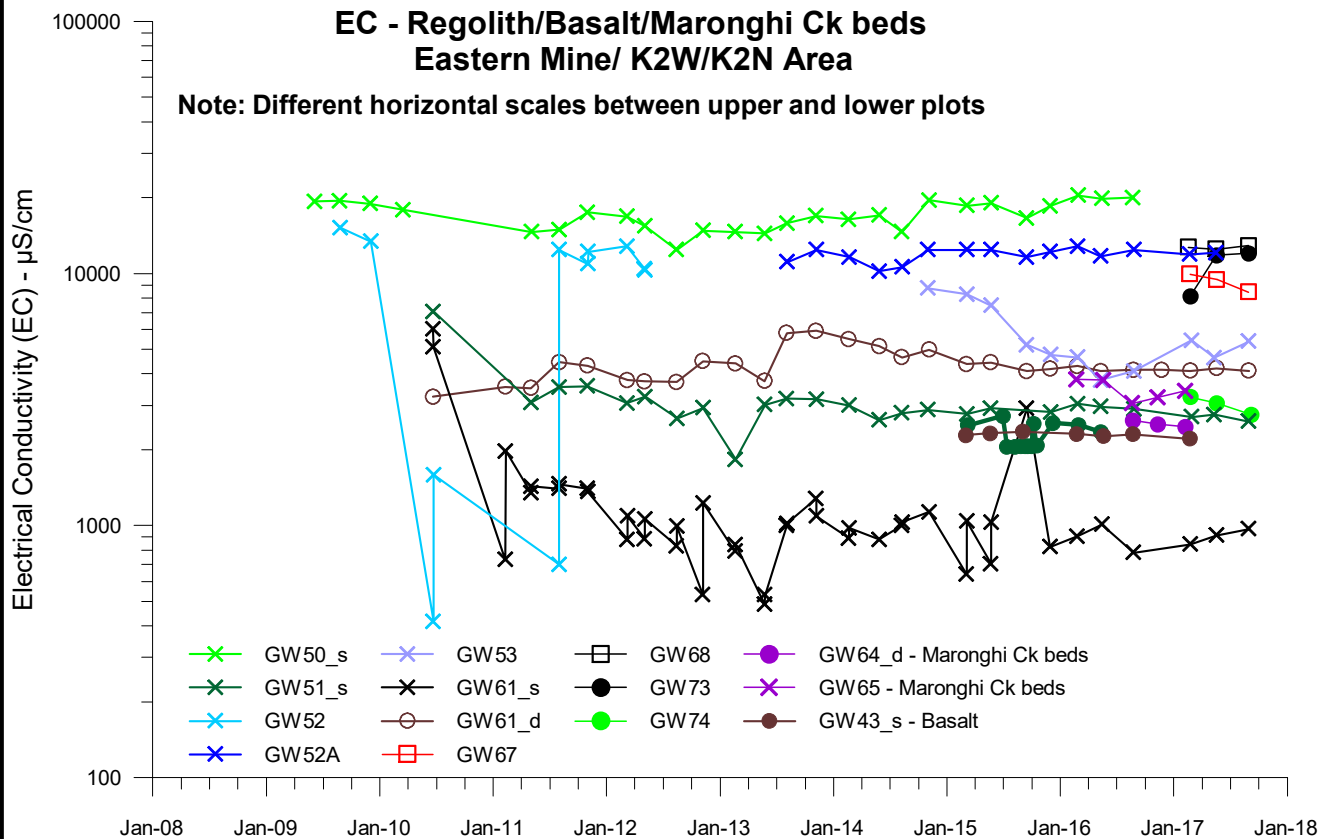
PROJECT	Meandu Mine - Environmental Evaluation	
TITLE	pH Data Spoil/ Coal Seam Bores & Ash Water	
PROJECT No.	JBT01-012-059	FIGURE No. 19

EC - Regolith/ Alluvium Western Mine/ Meandu Ck Area

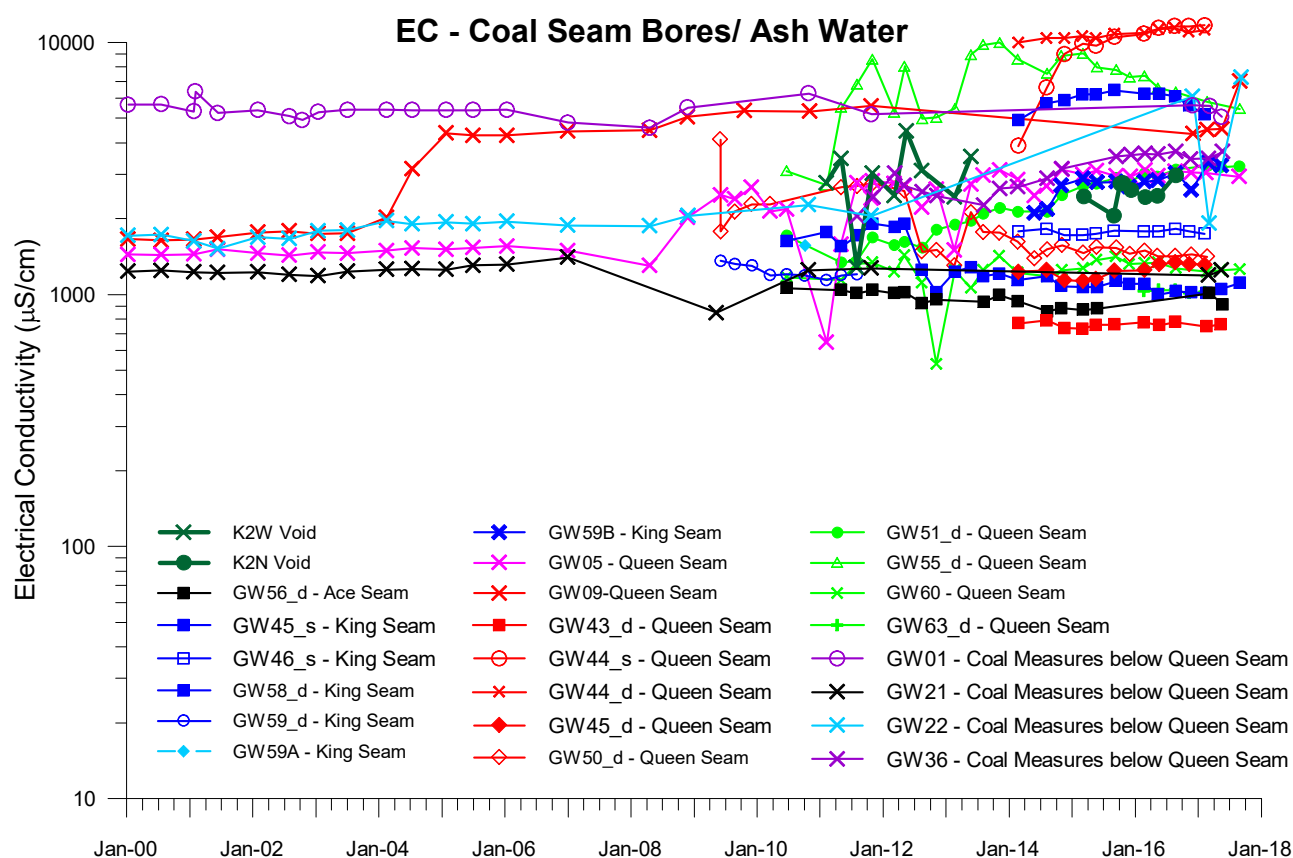
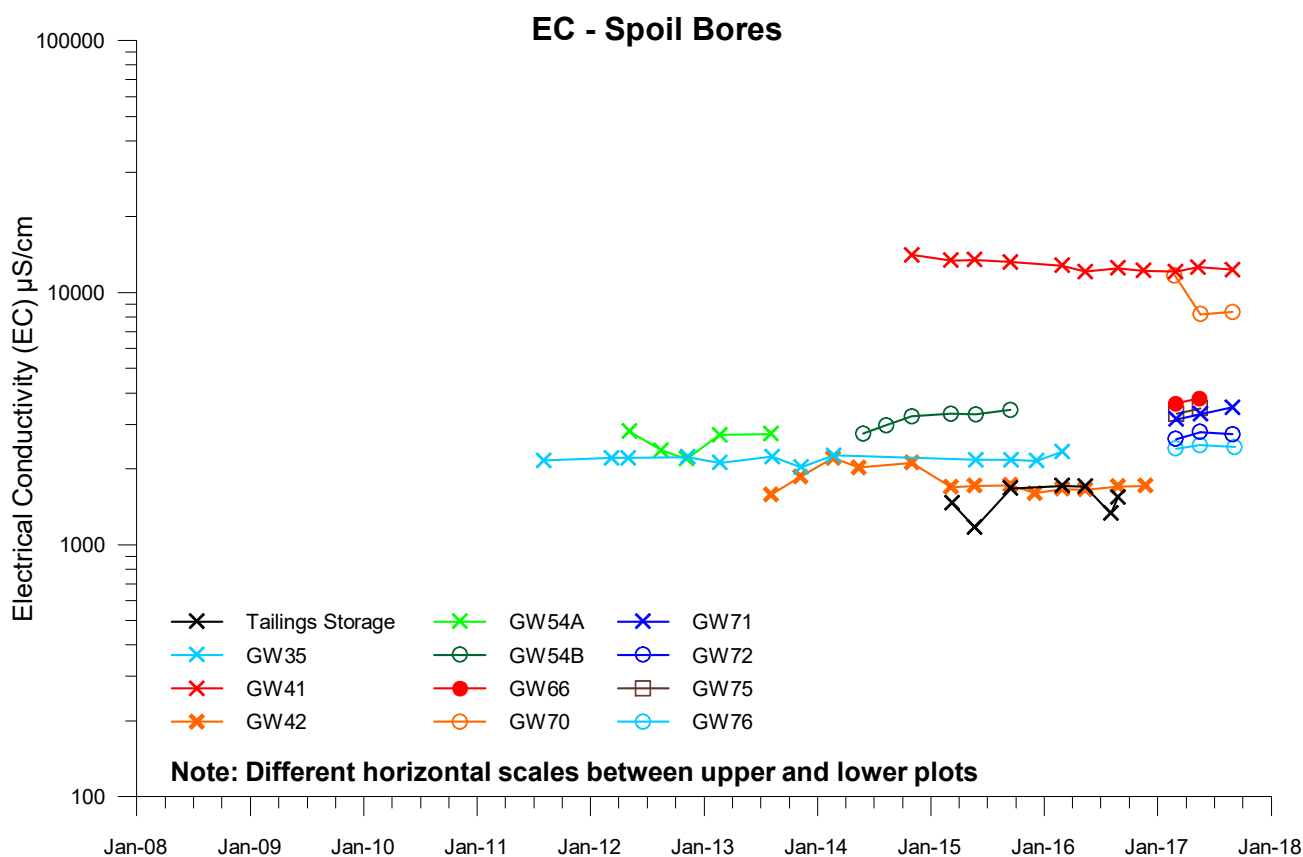


EC - Regolith/Basalt/Maronghi Ck beds Eastern Mine/ K2W/K2N Area

Note: Different horizontal scales between upper and lower plots



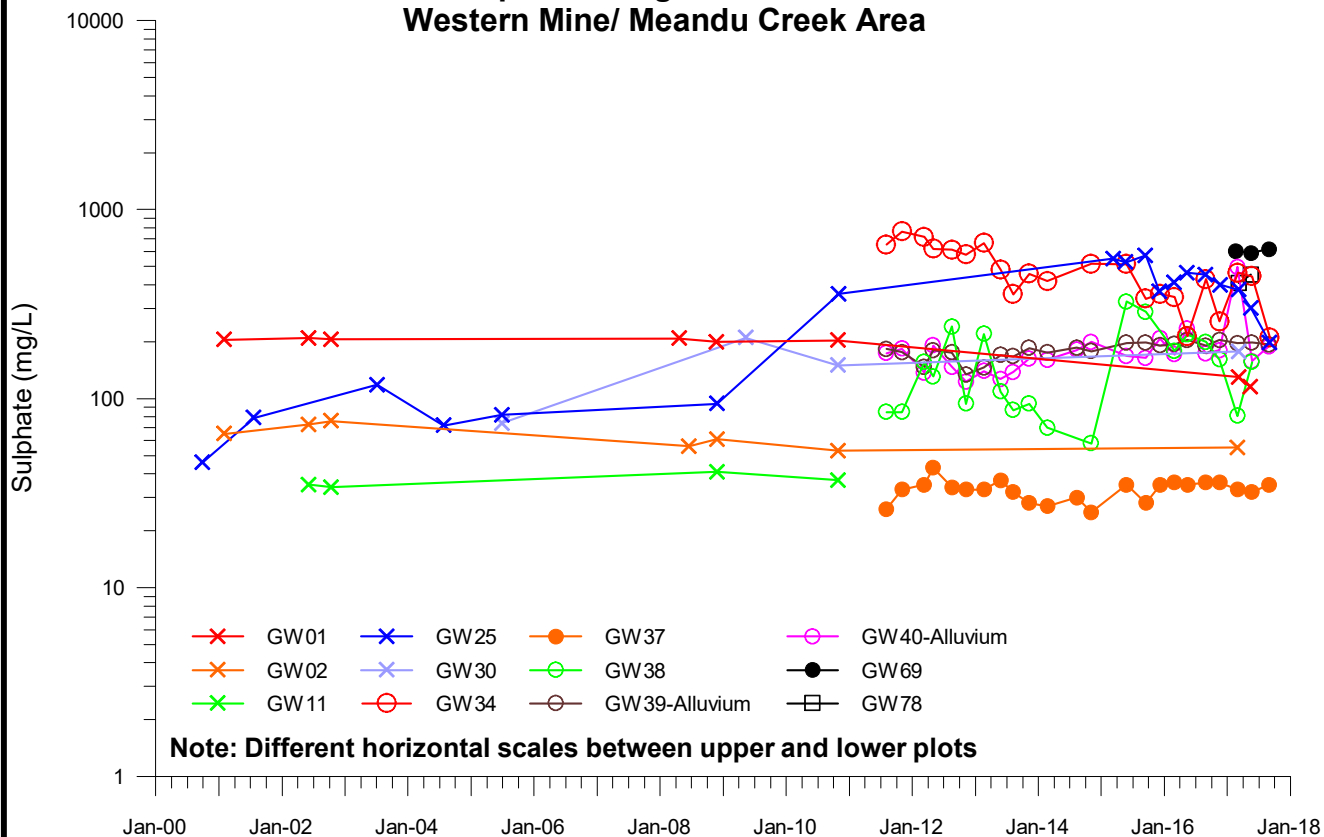
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Electrical Conductivity (EC) Data Regolith/Alluvium/Basalt/Maronghi Ck Bores	
CHECKED	DATE		
SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 20



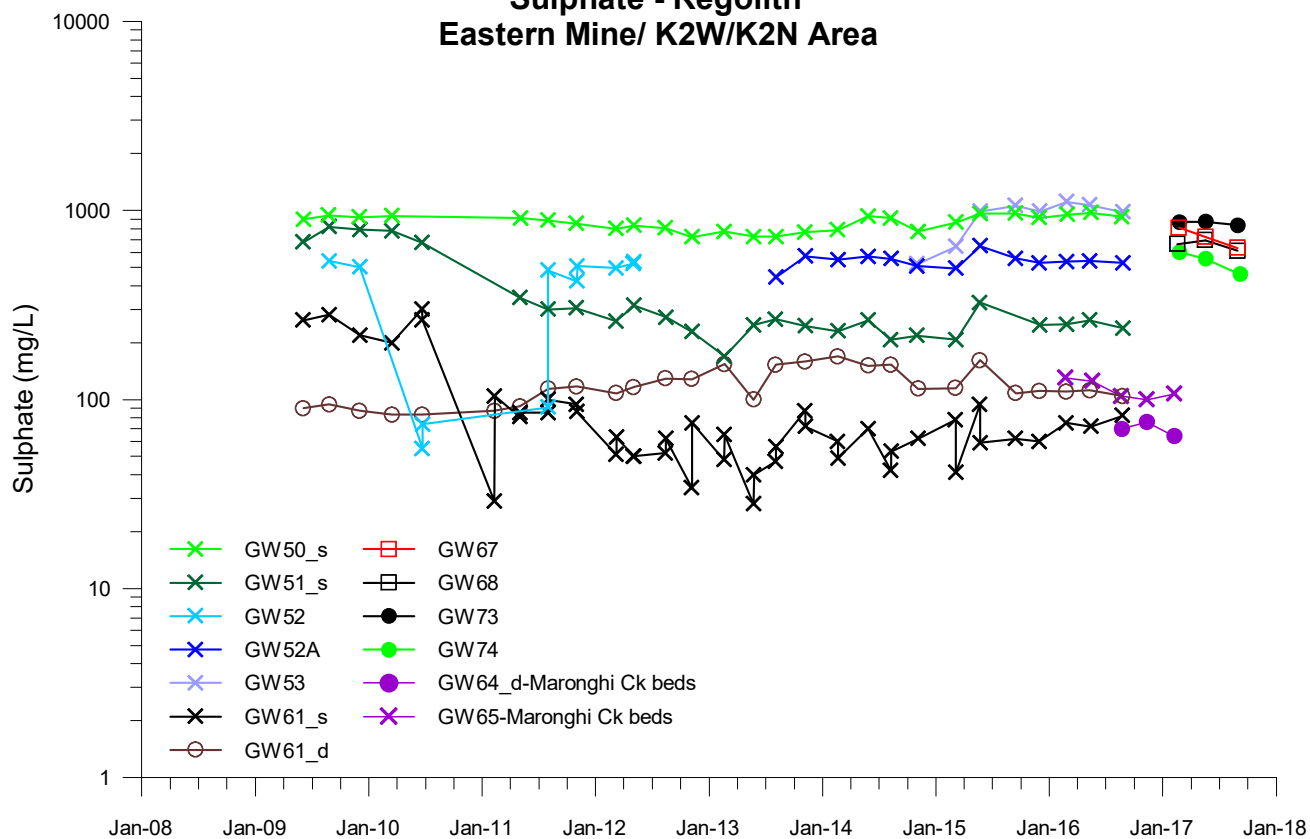
CLIENT Stanwell Corporation	
DRAWN JWB	DATE Aug 2018
CHECKED	DATE
SCALE As Shown	A4

PROJECT Meandu Mine - Environmental Evaluation	
TITLE Electrical Conductivity (EC) Data Spoil & Coal Seam/ Ash Water Samples	
PROJECT No. JBT01-012-059	FIGURE No. 21

Sulphate - Regolith/Alluvium Western Mine/ Meandu Creek Area



Sulphate - Regolith Eastern Mine/ K2W/K2N Area



CLIENT	Stanwell Corporation	
DRAWN	JWB	DATE Aug 2018
CHECKED		DATE
SCALE	As Shown	A4

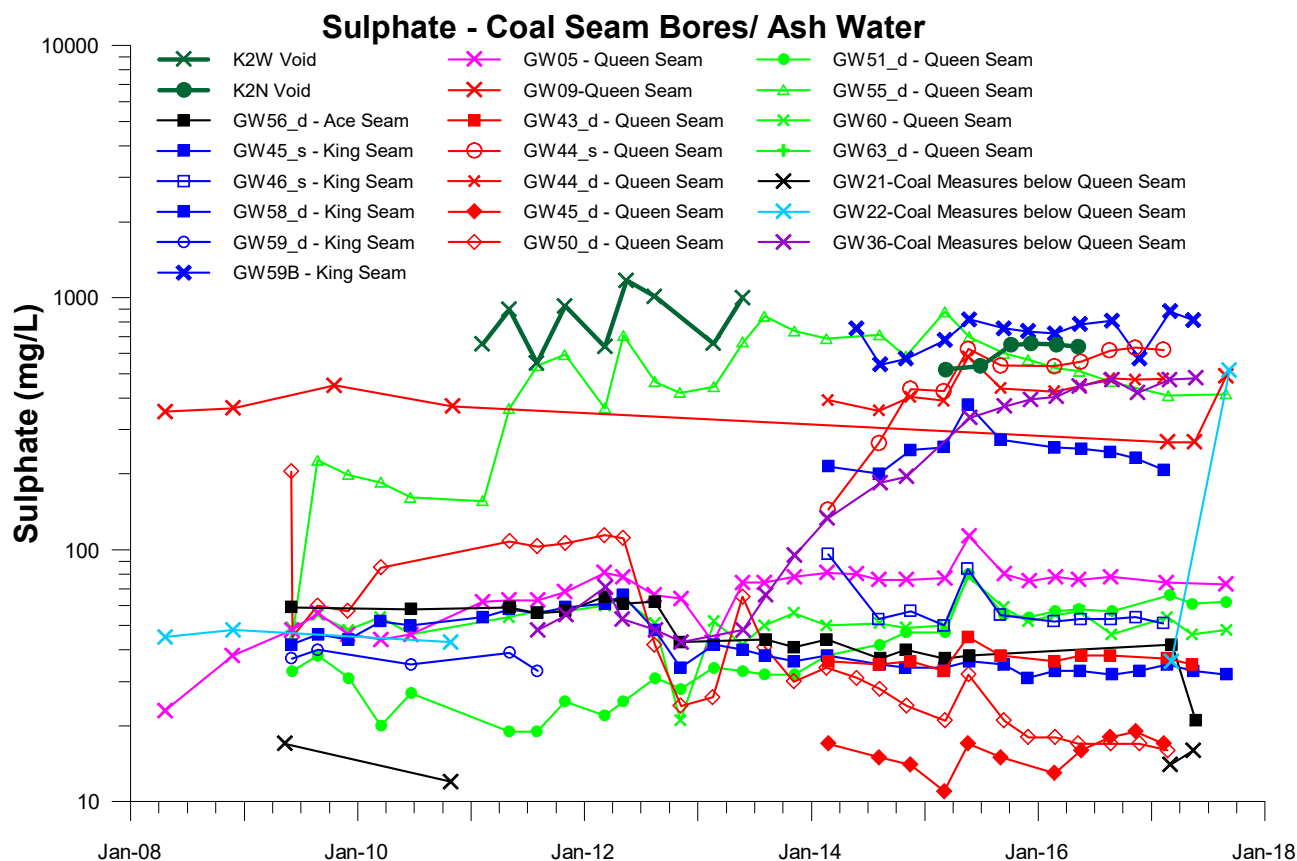
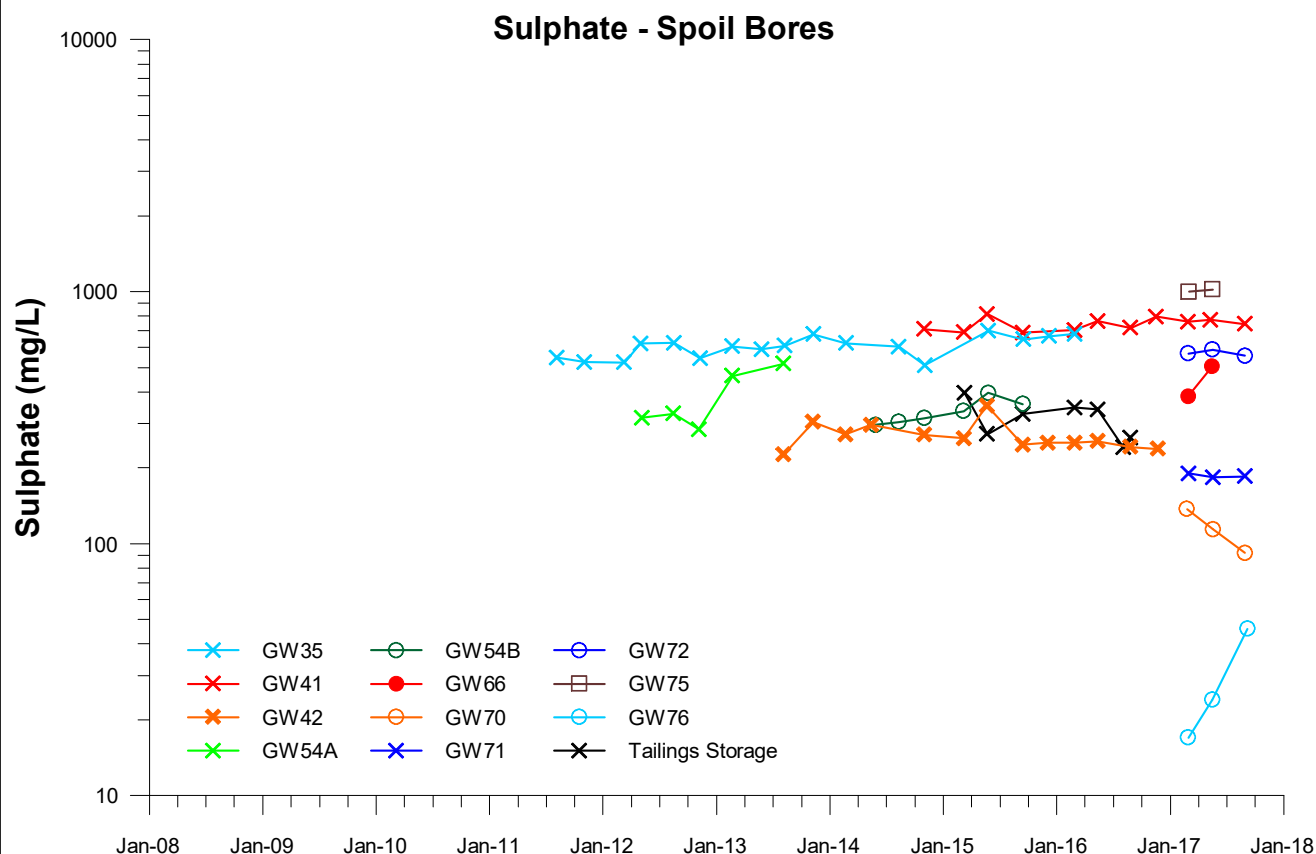
PROJECT Meandu Mine - Environmental Evaluation

TITLE Sulphate Concentration
Regolith/ Alluvium Bores

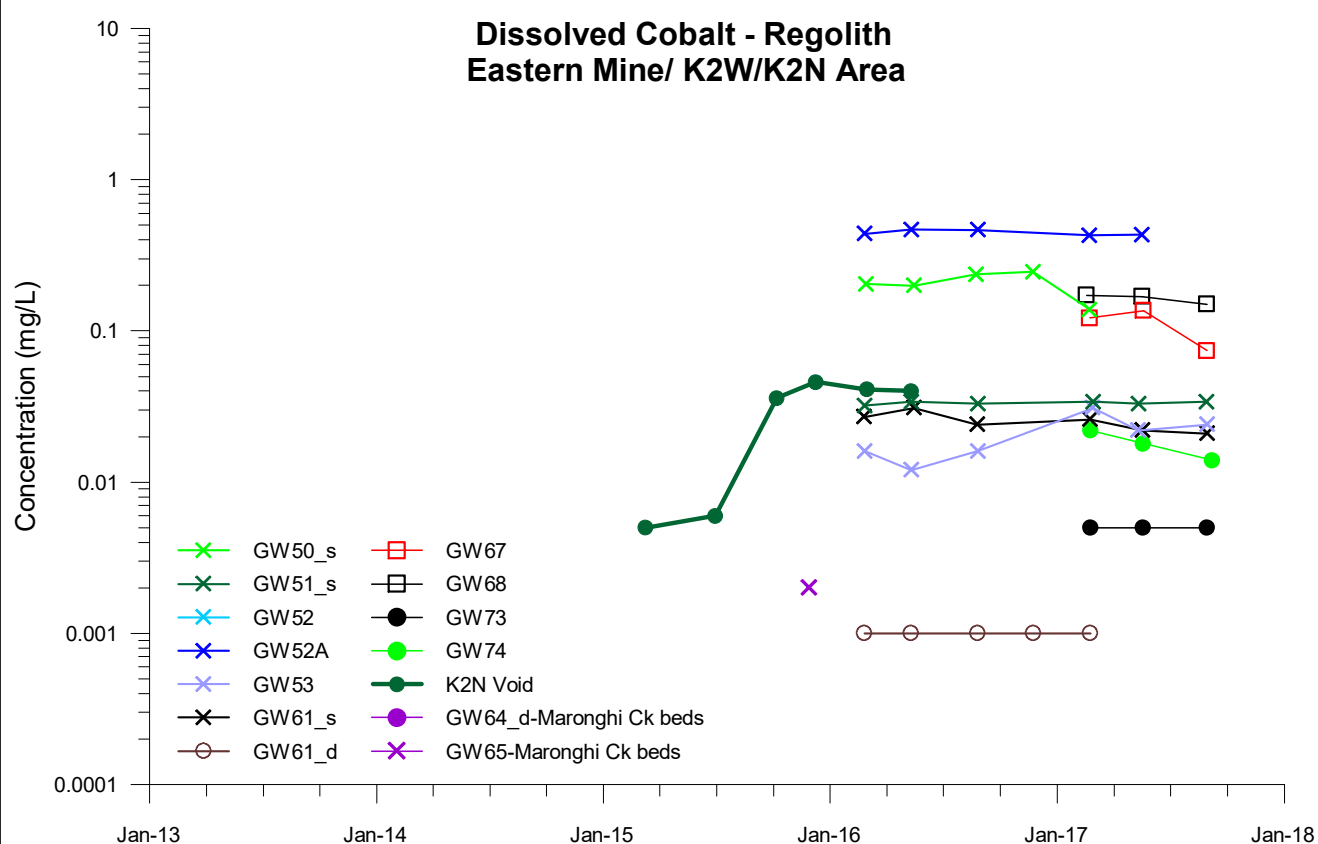
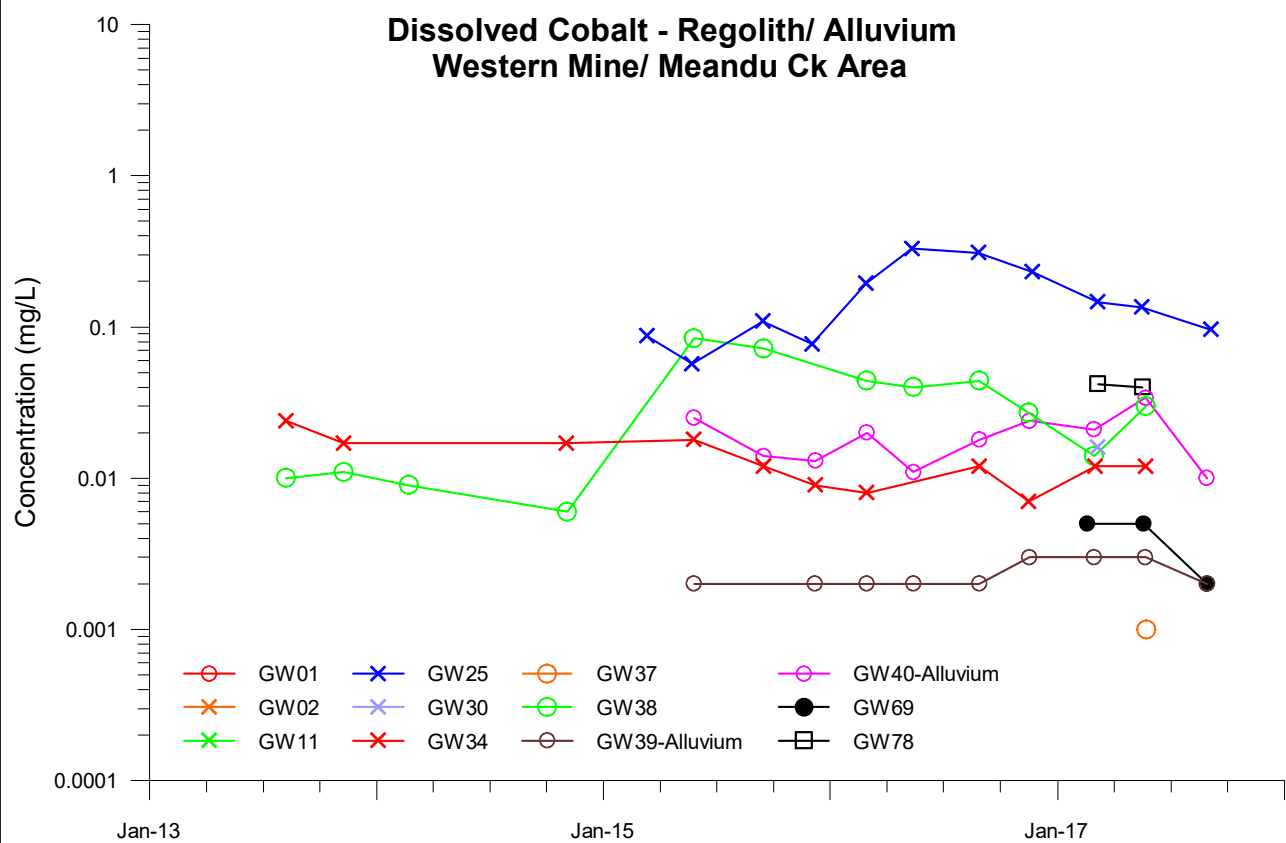
PROJECT No. JBT01-012-059

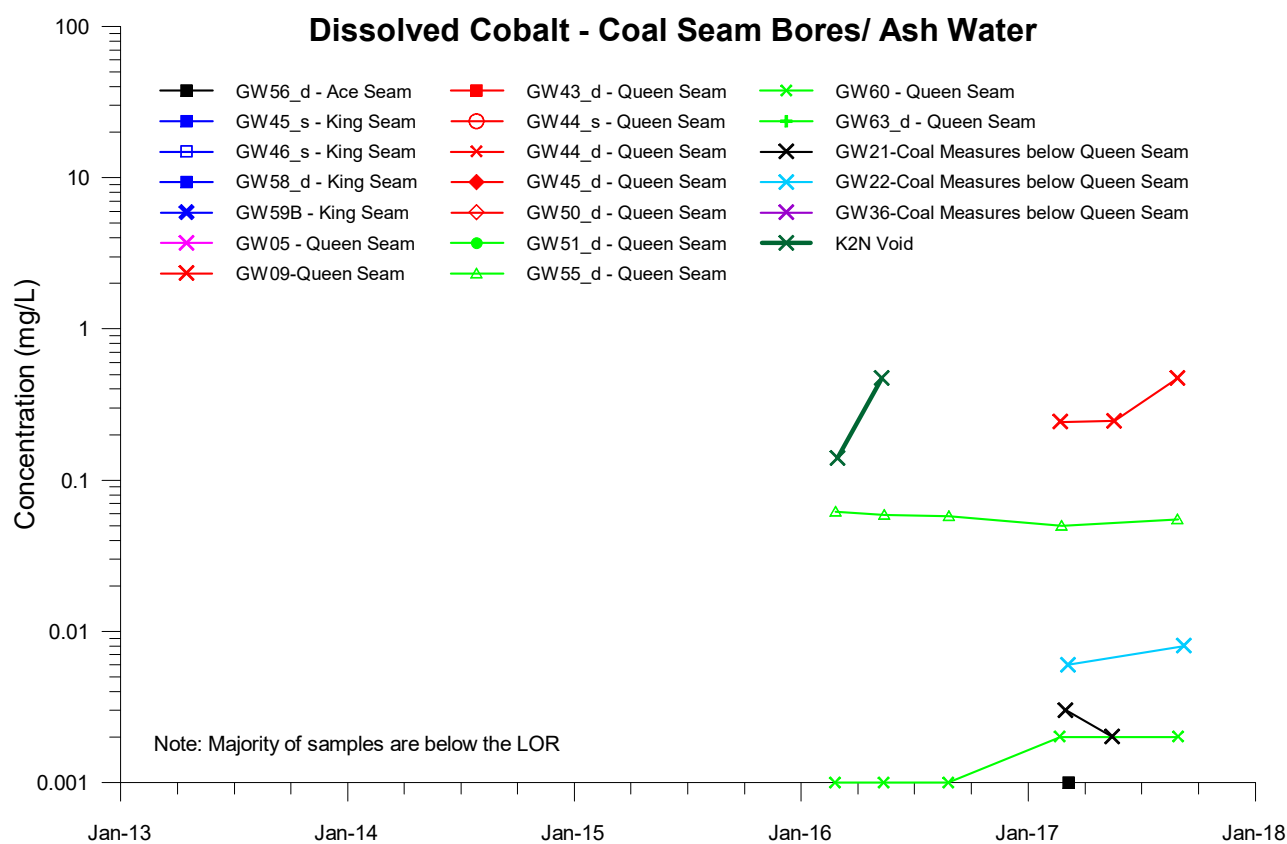
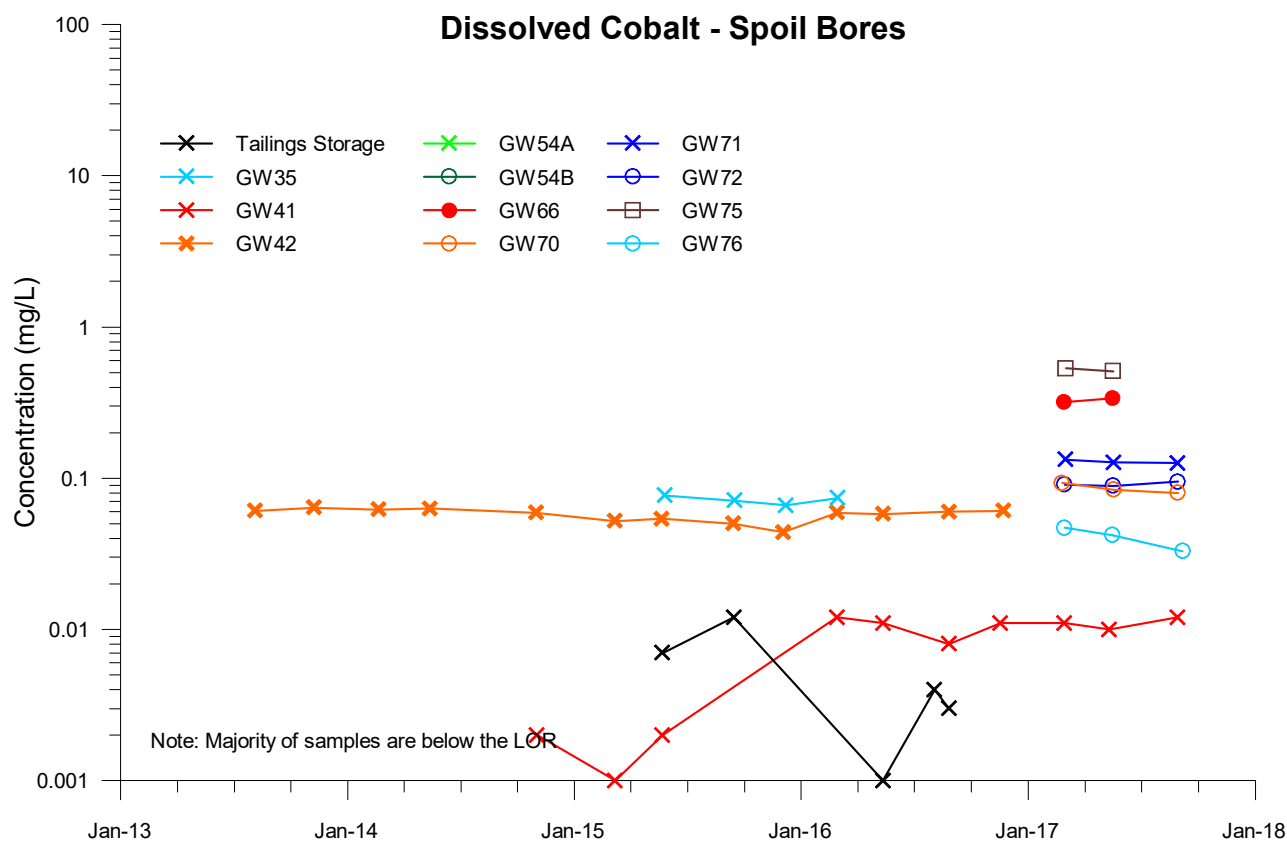
FIGURE No.

22

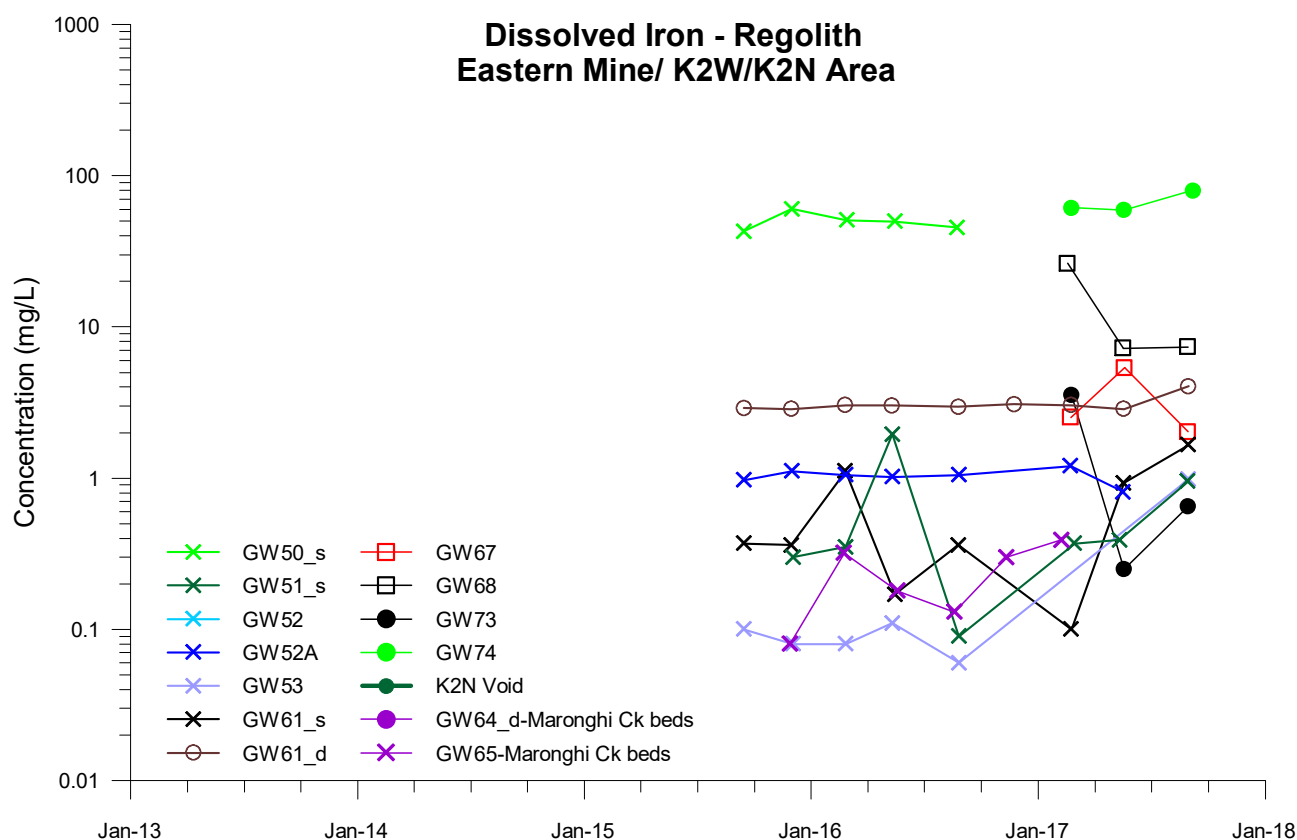
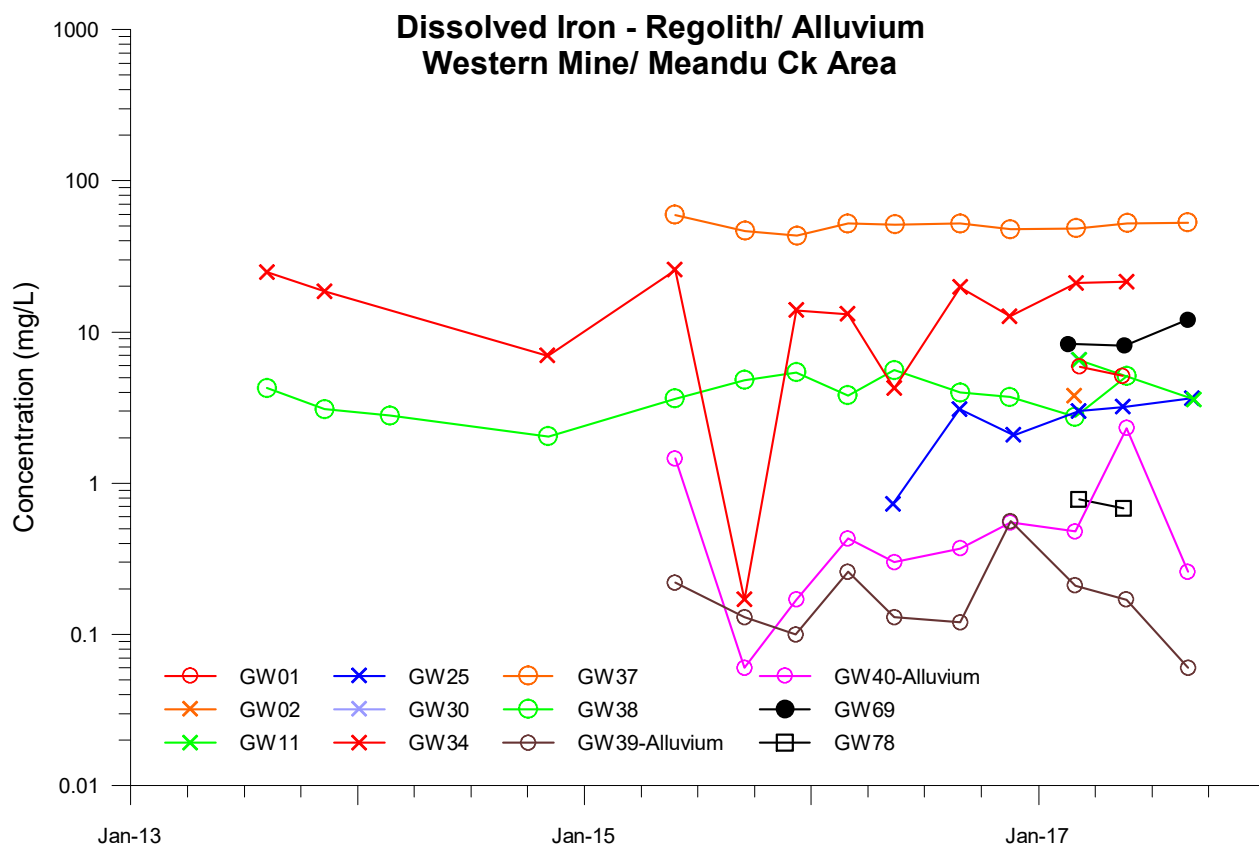


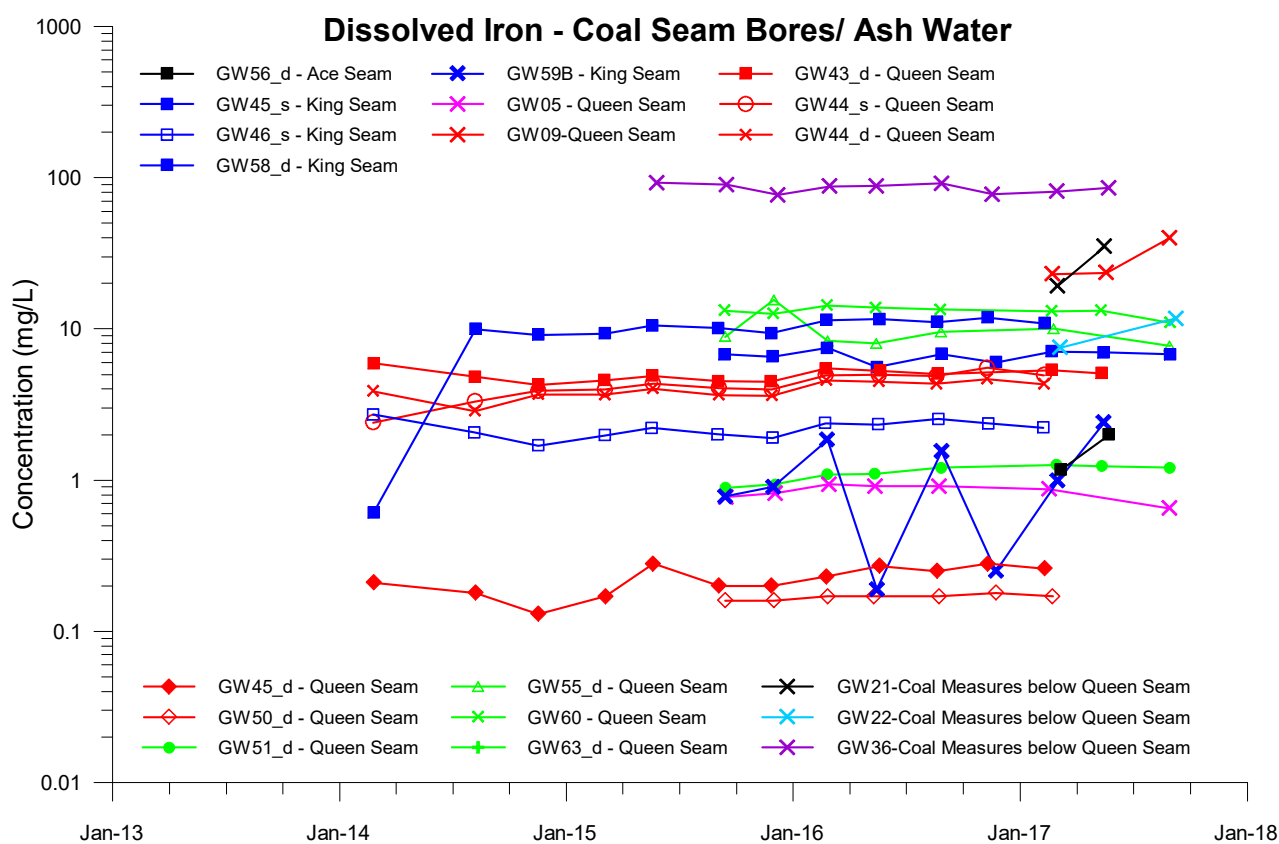
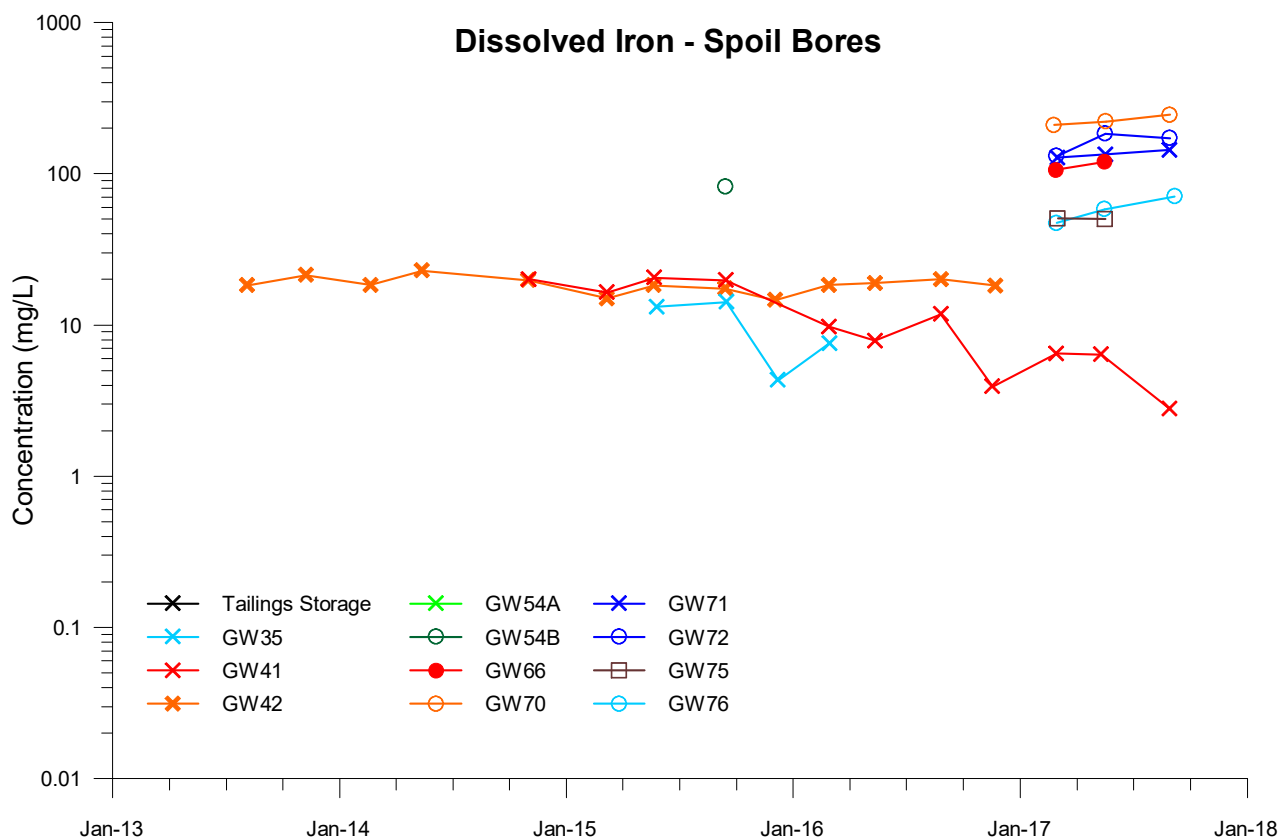
	CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
	DRAWN JWB	DATE Aug 2018	TITLE Sulphate Concentration Coal Seam & Ash Water Samples	
	CHECKED	DATE		
	SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 23





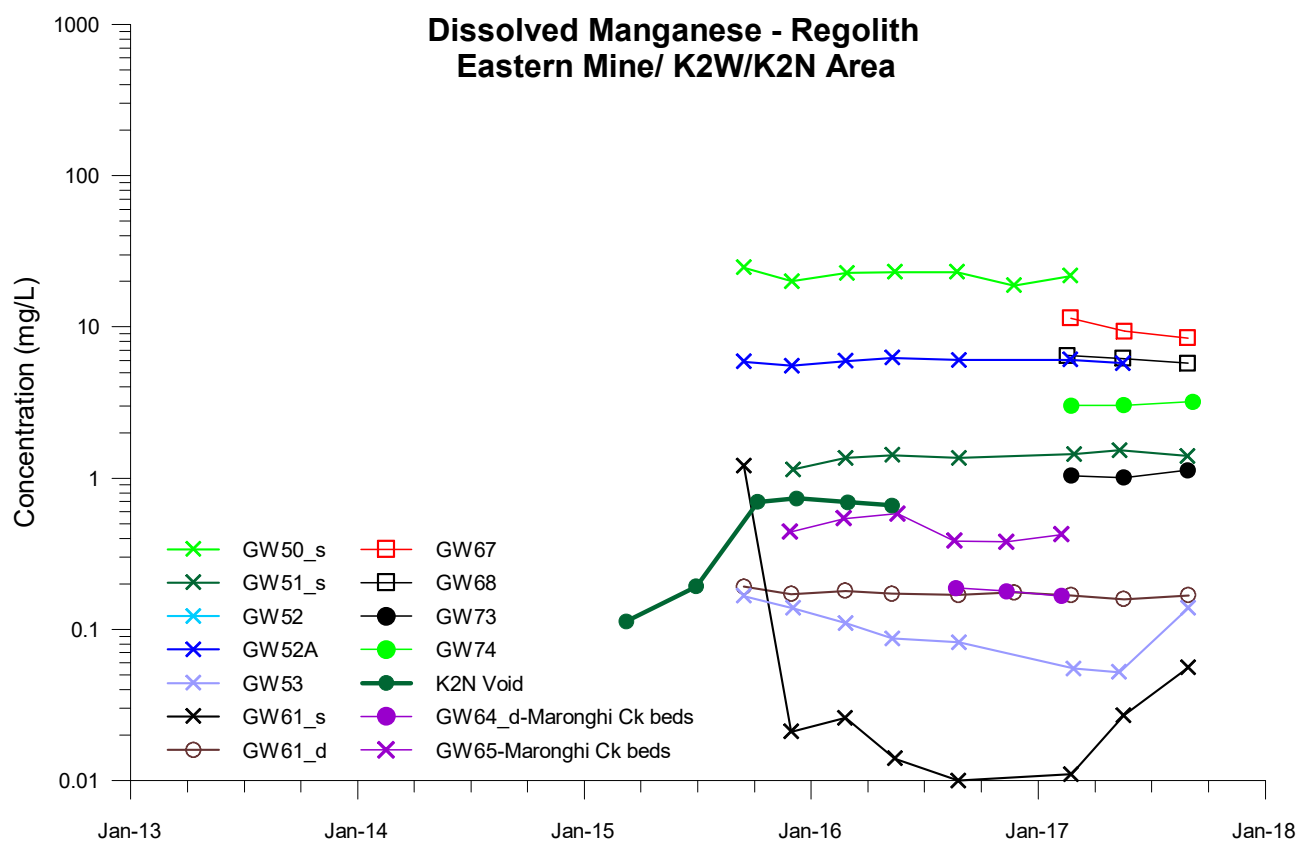
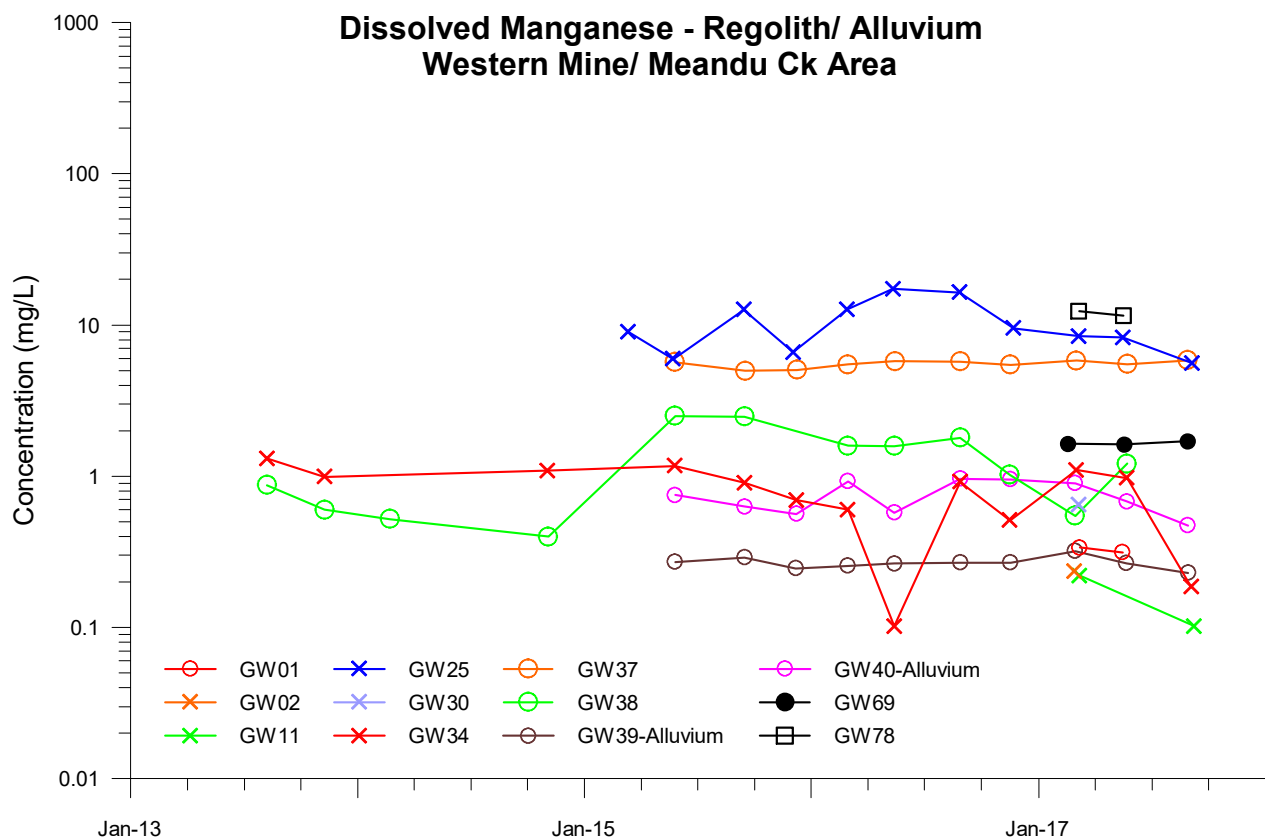
	CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
	DRAWN JWB	DATE Aug 2018	TITLE Dissolved Cobalt Concentration Spoil & Coal Seam/ Ash Water Samples	
	CHECKED	DATE		
	SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 25

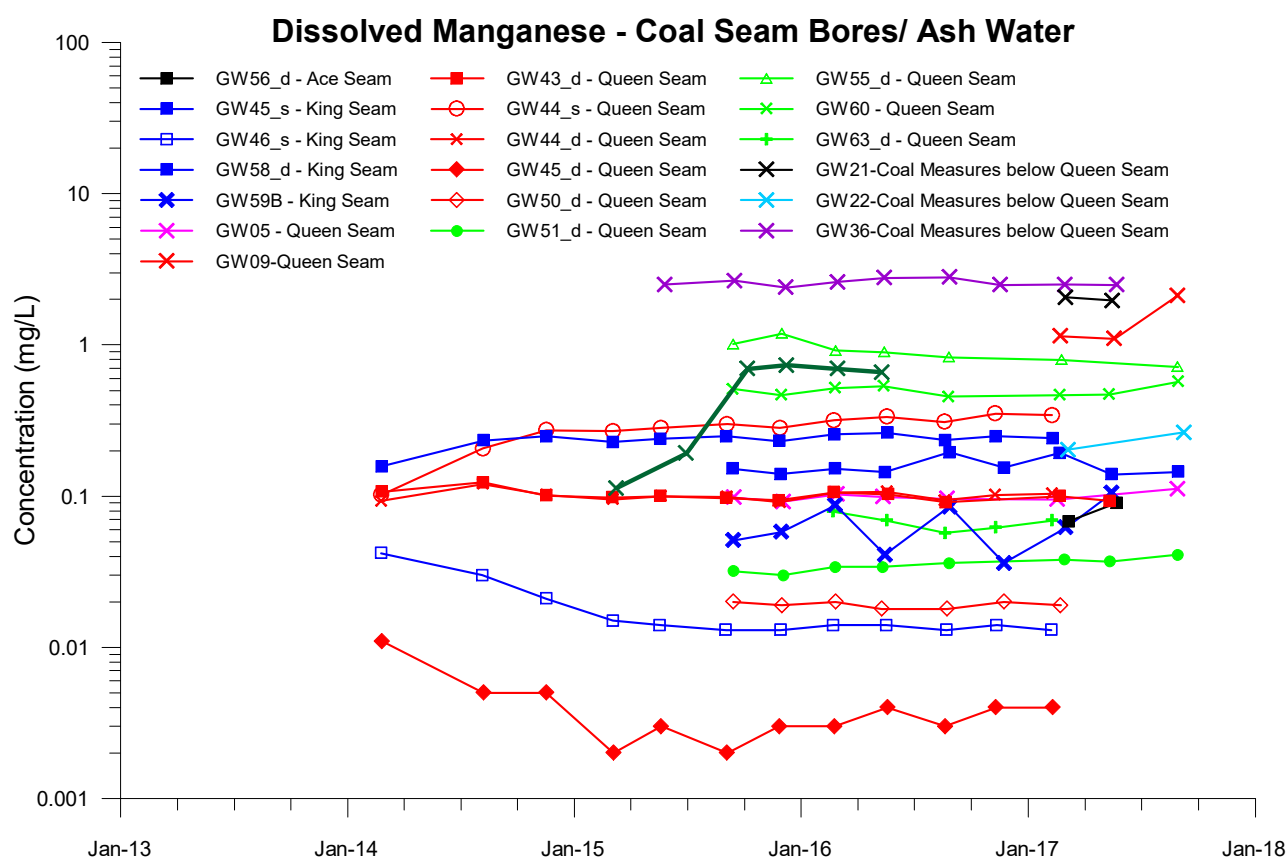
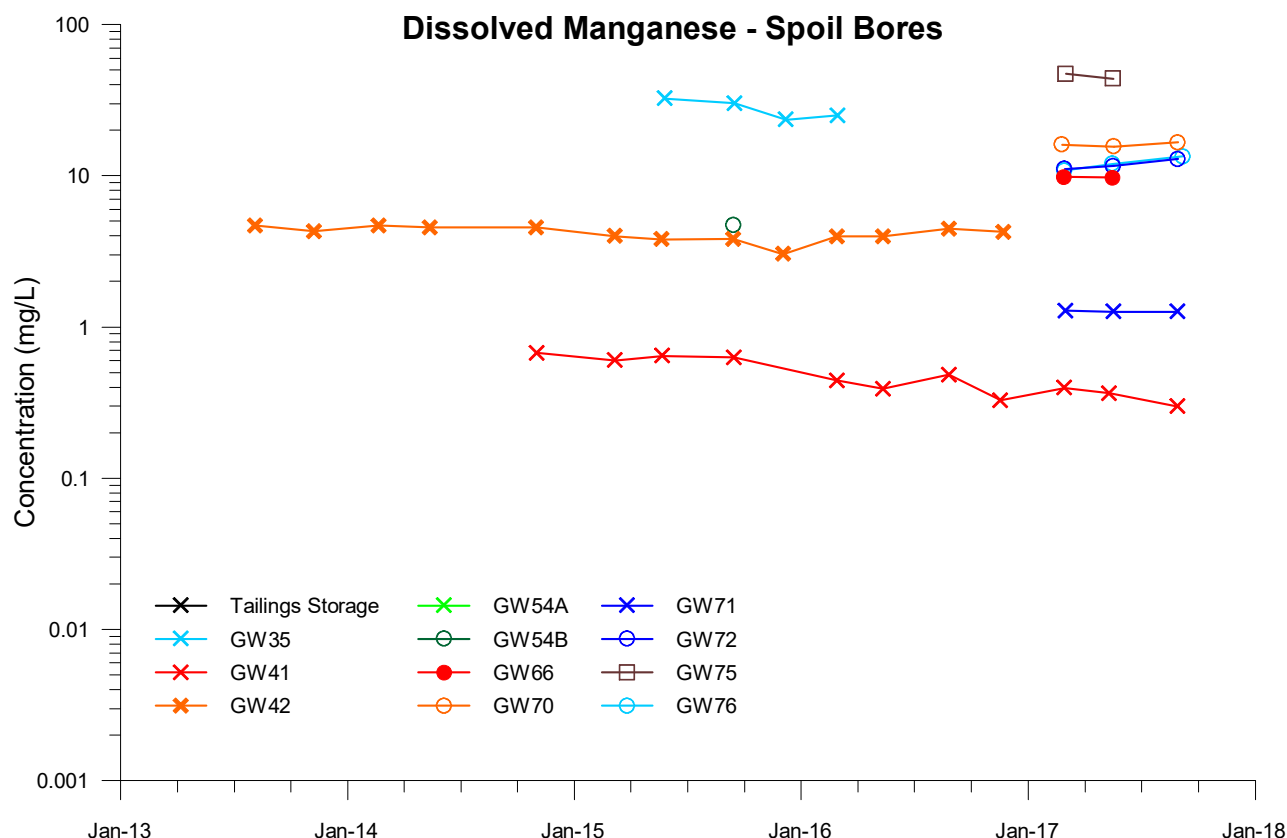




CLIENT Stanwell Corporation	
DRAWN JWB	DATE Aug 2018
CHECKED	DATE
SCALE As Shown	A4

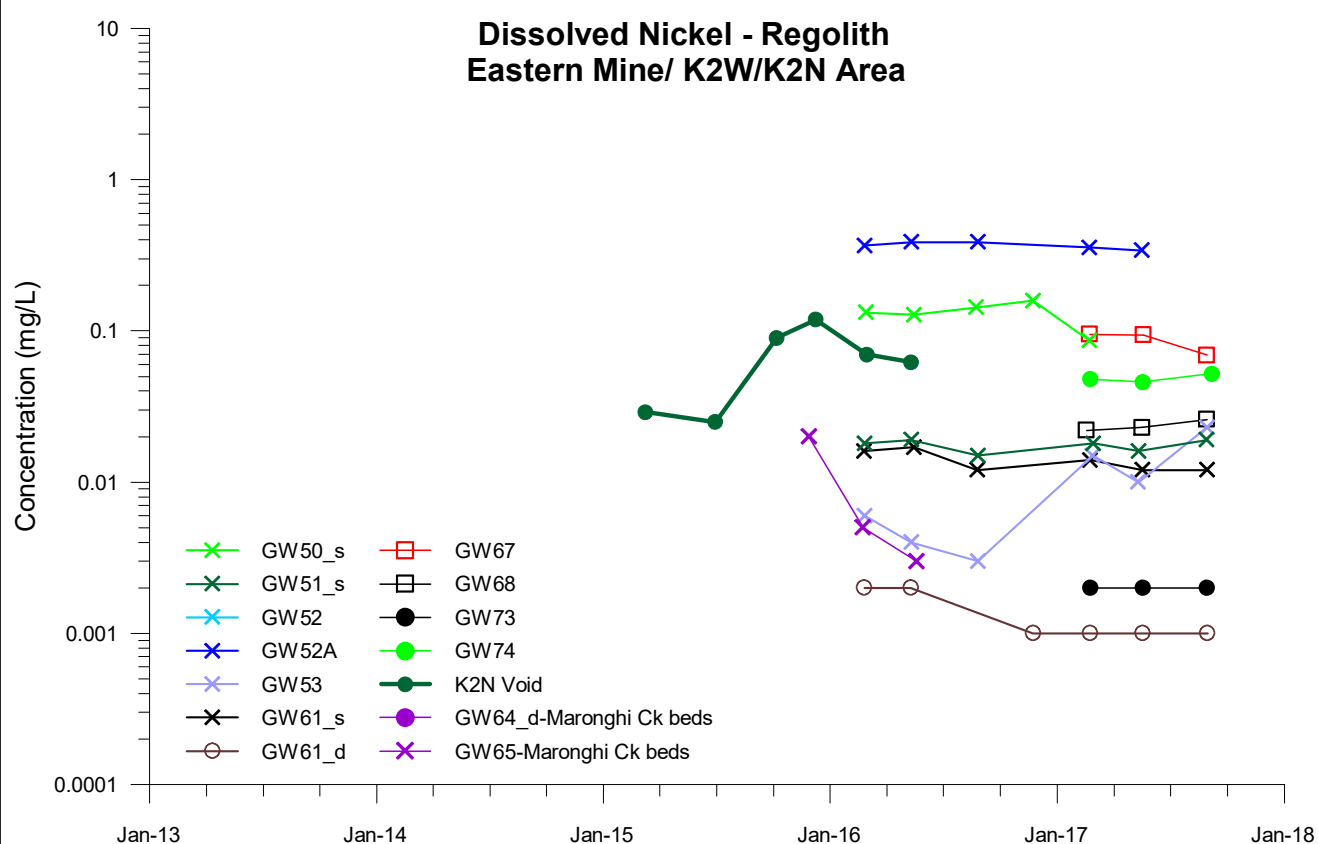
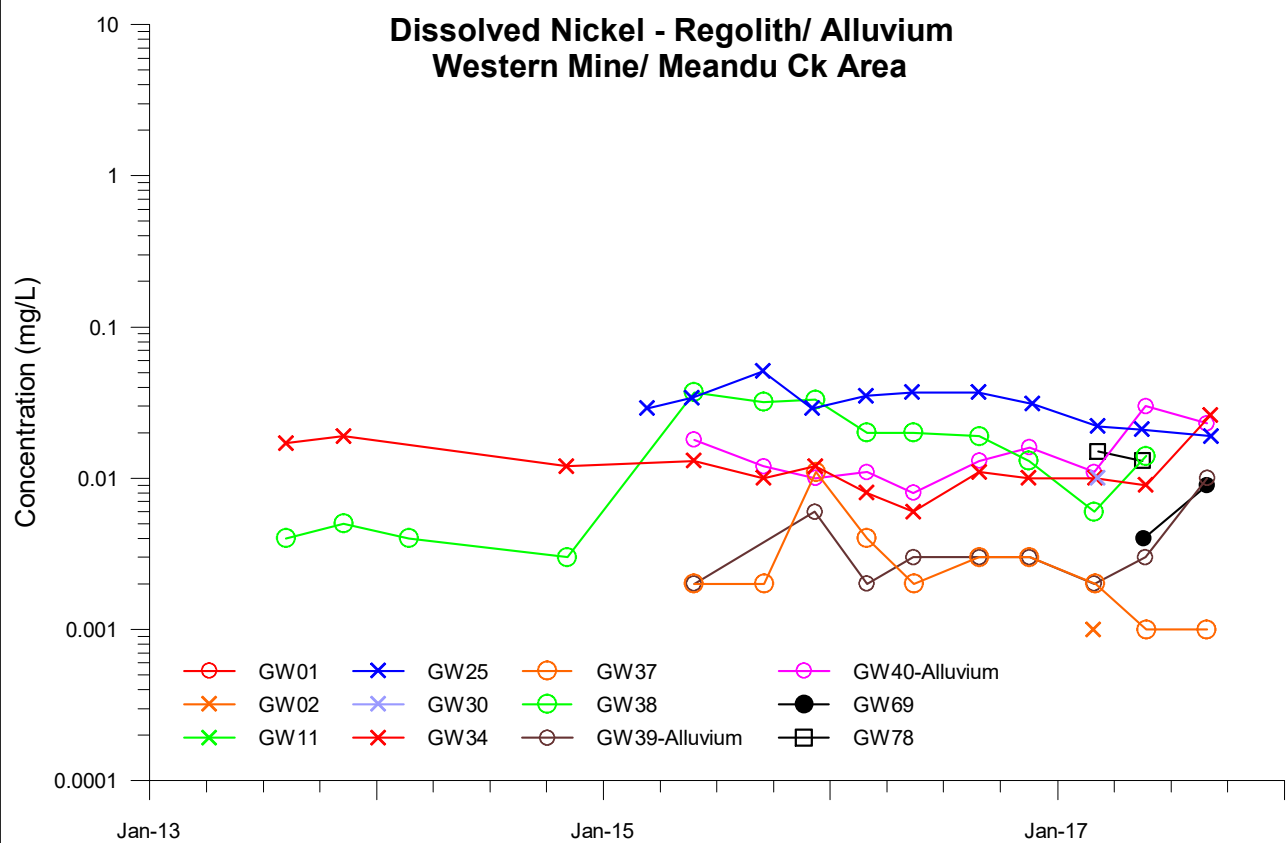
PROJECT Meandu Mine - Environmental Evaluation	
TITLE Dissolved Iron Concentration Spoil & Coal Seam/ Ash Water Samples	
PROJECT No. JBT01-012-059	FIGURE No. 27



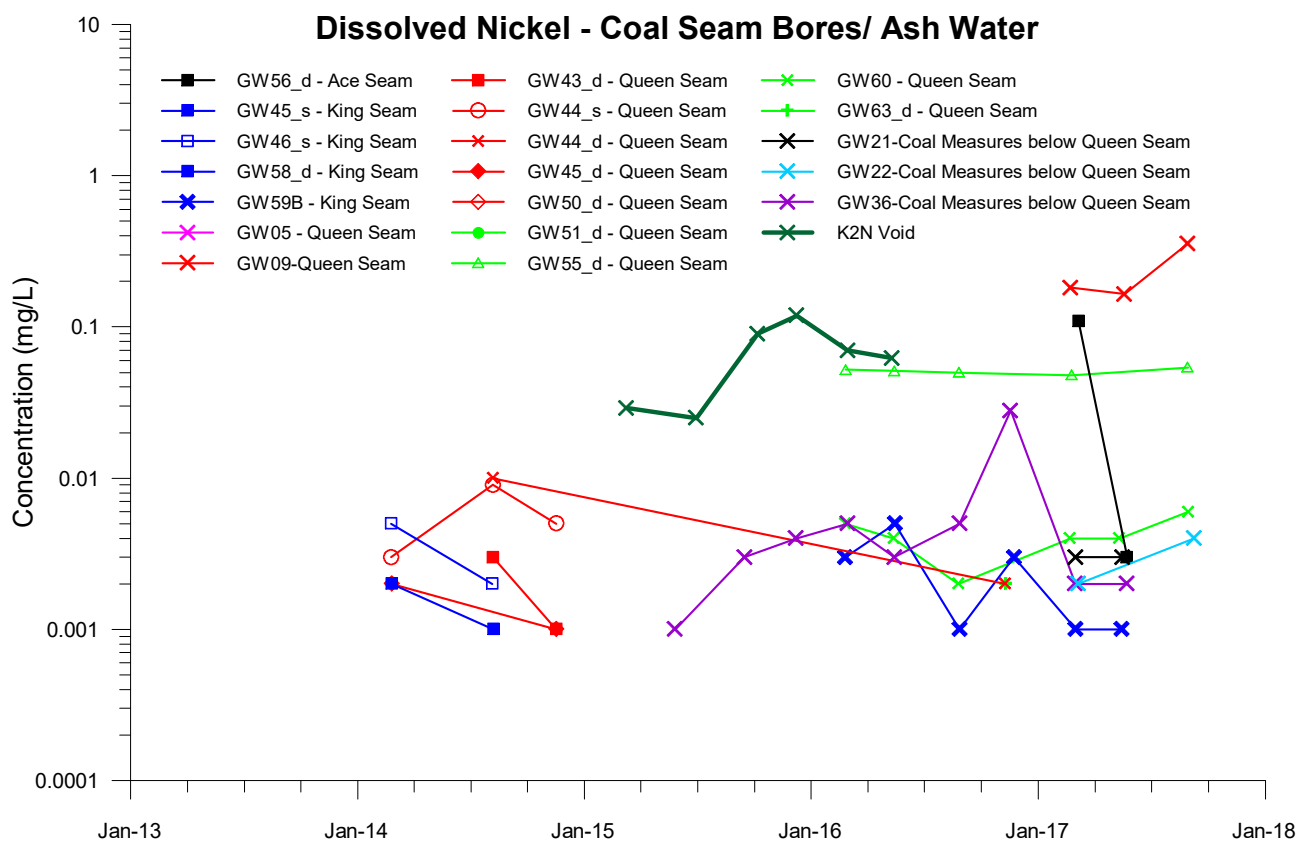
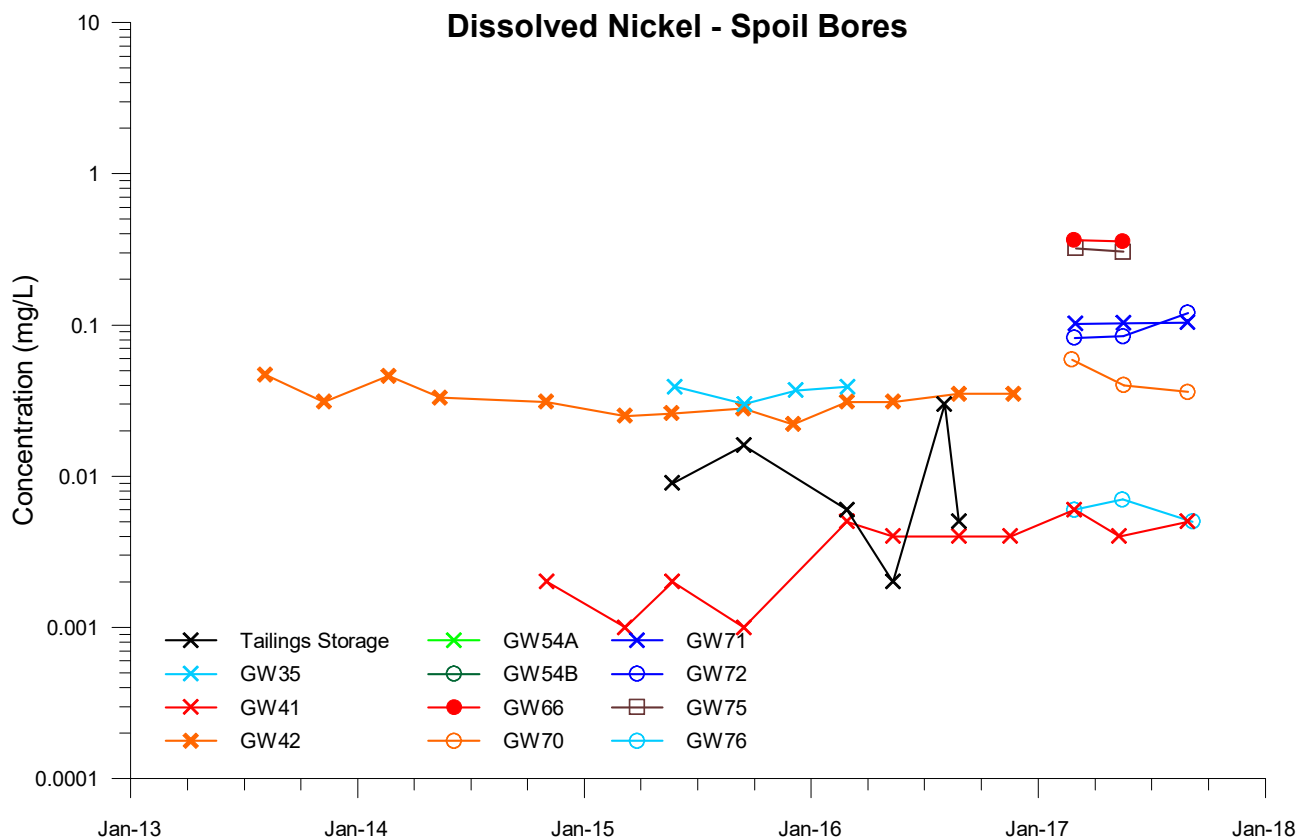


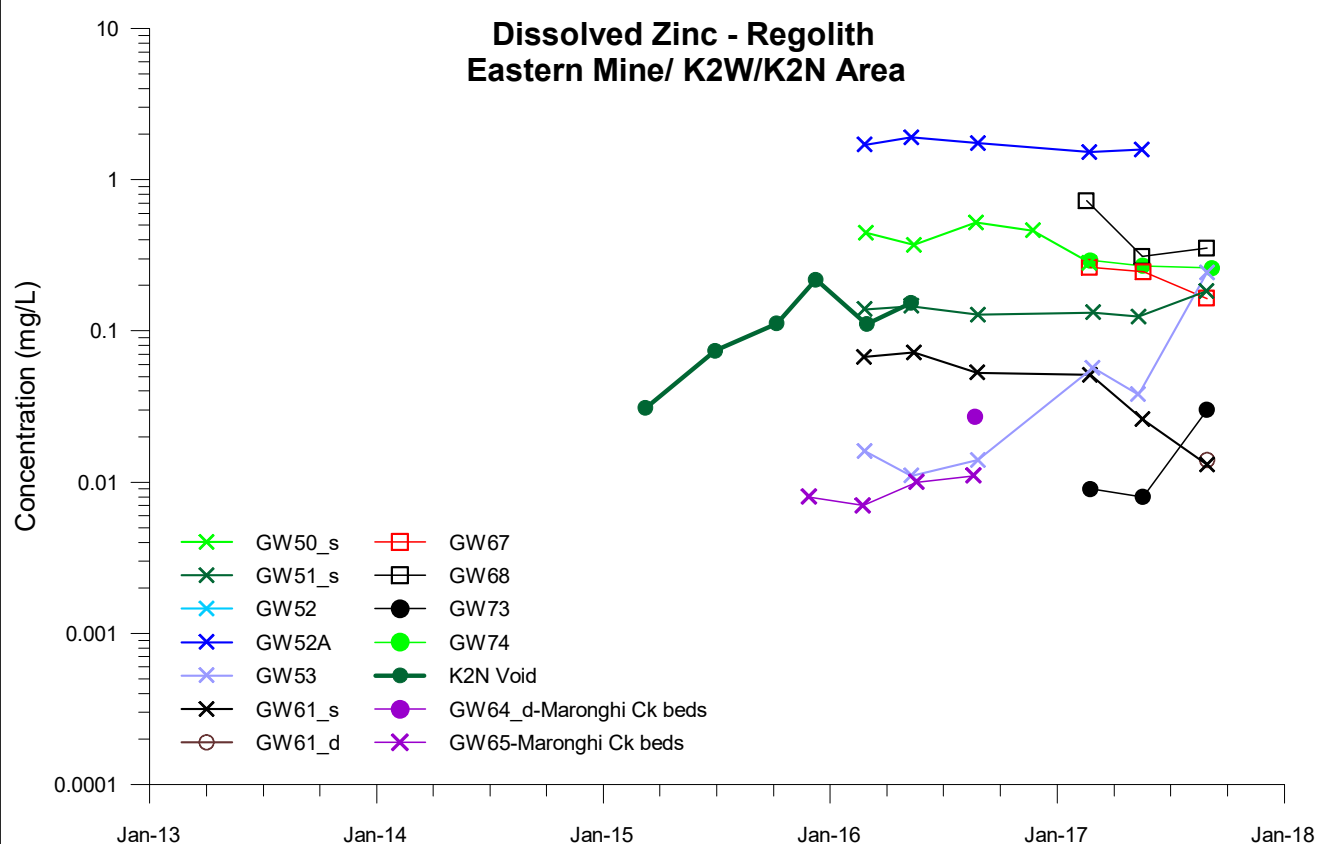
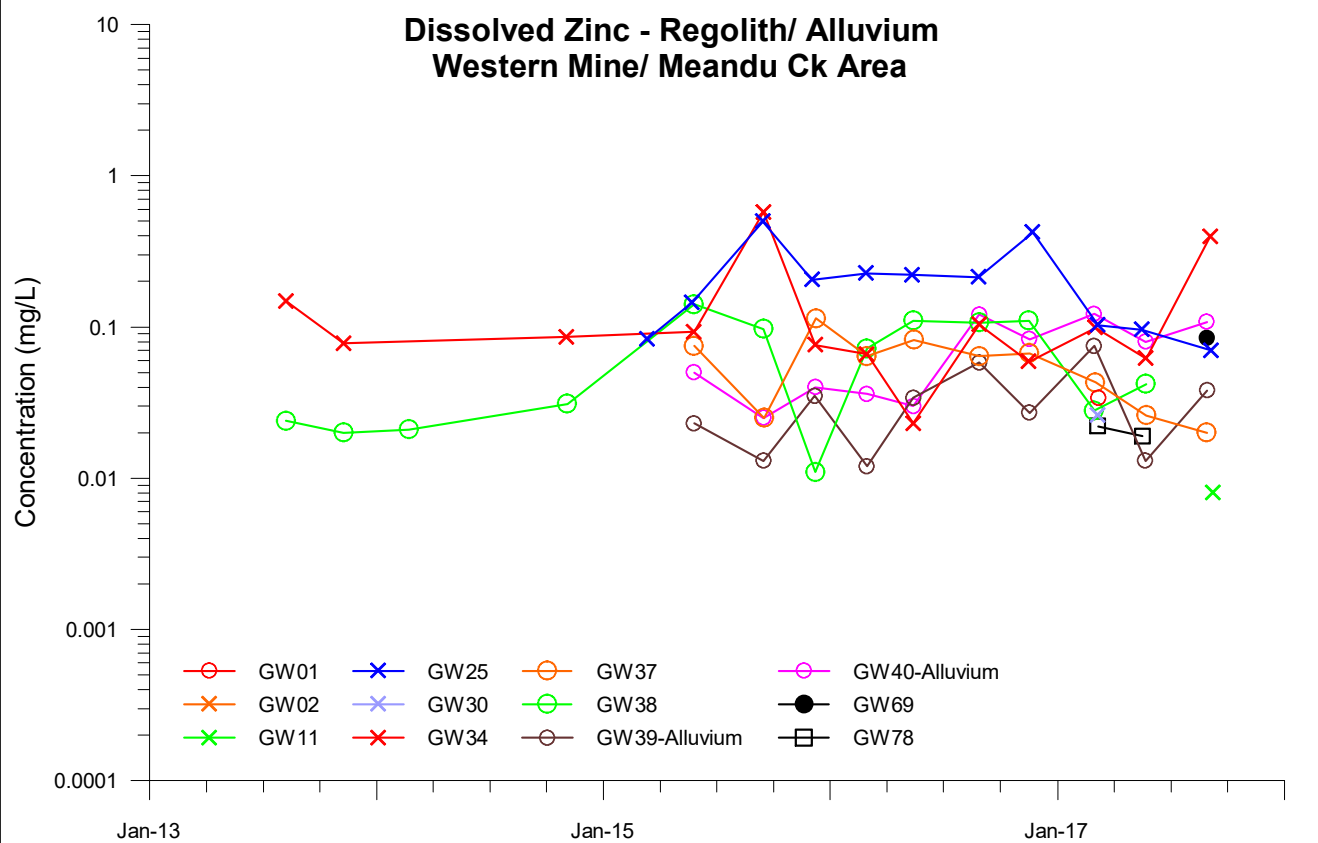
CLIENT	Stanwell Corporation	
DRAWN	JWB	DATE Aug 2018
CHECKED		DATE
SCALE	As Shown	A4

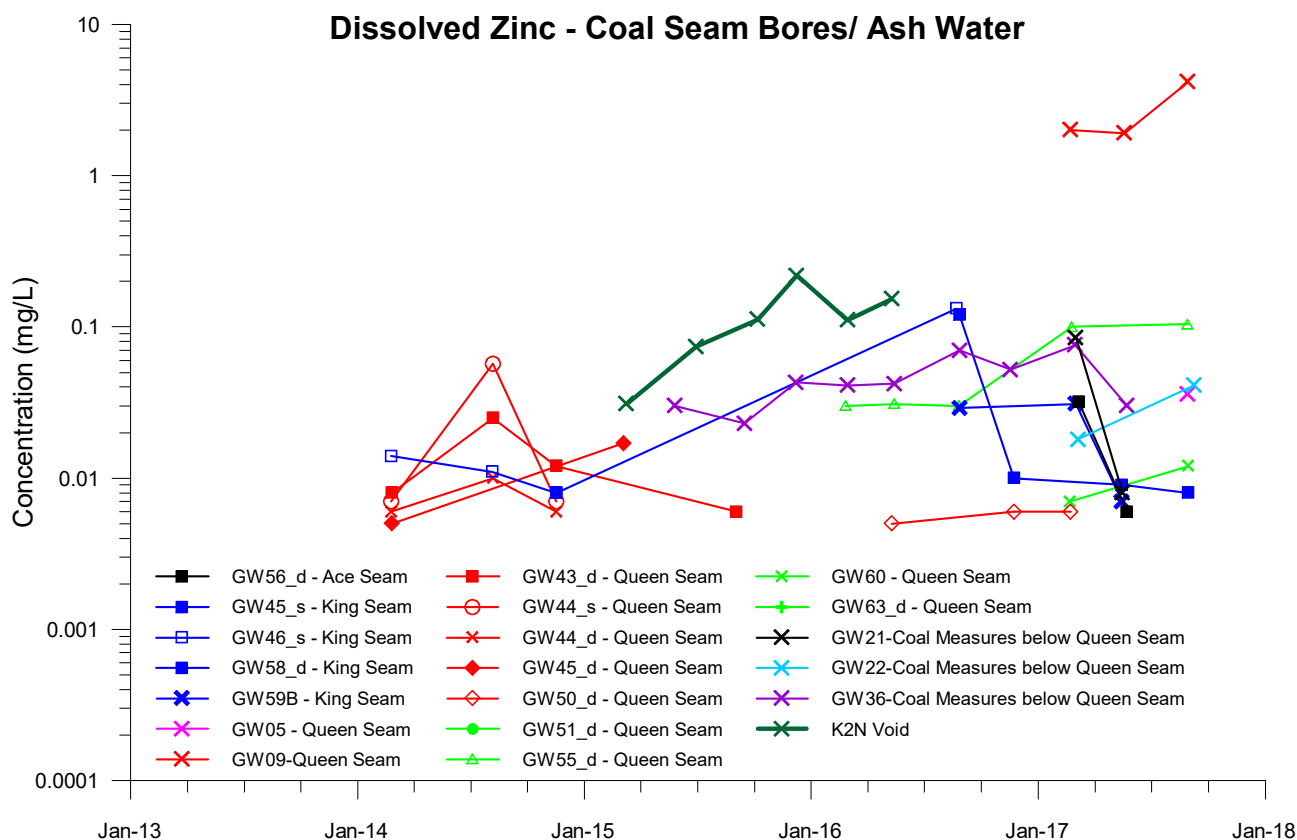
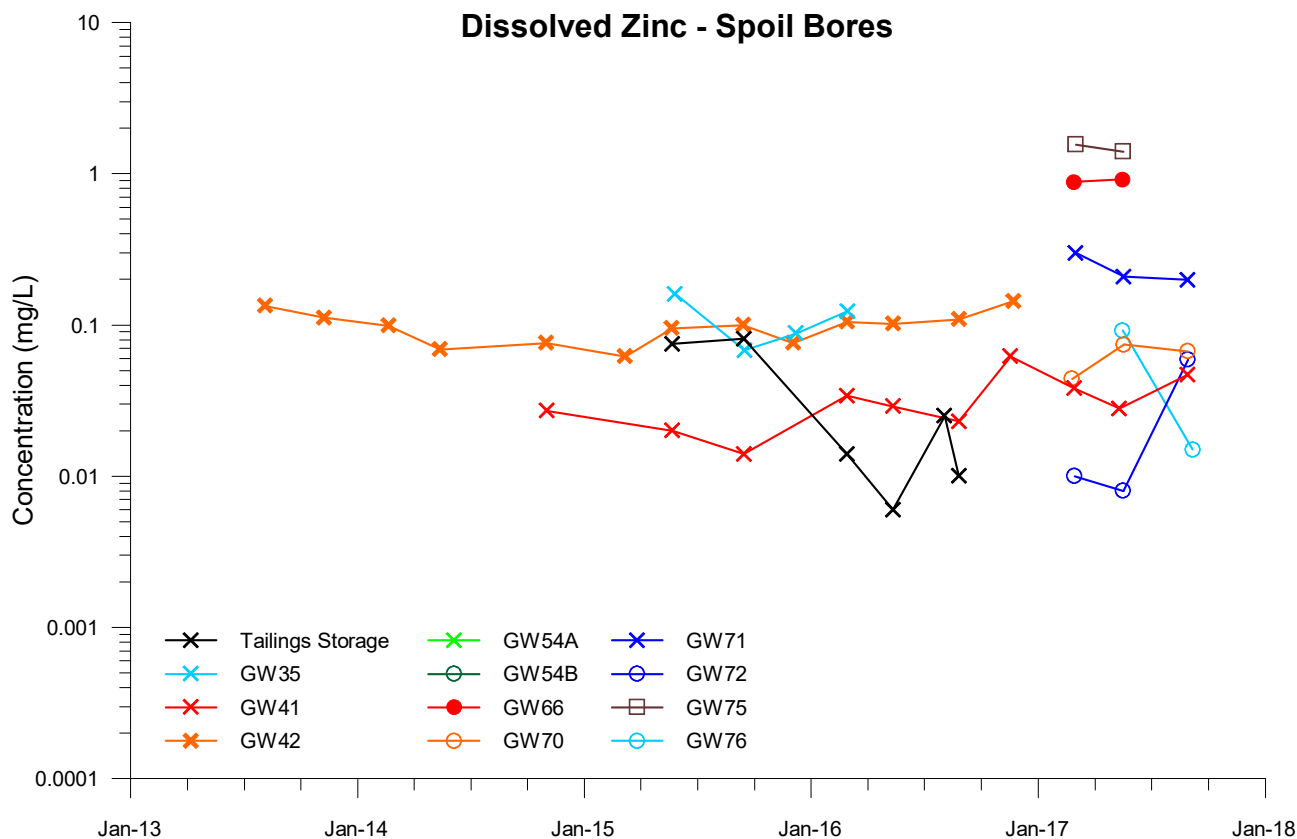
PROJECT	Meandu Mine - Environmental Evaluation	
TITLE	Dissolved Manganese Concentration Spoil & Coal Seam/ Ash Water Samples	
PROJECT No.	JBT01-012-059	FIGURE No. 29



	CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
	DRAWN JWB	DATE Aug 2018	TITLE Dissolved Nickel Concentration Regolith/ Alluvium Bores	
	CHECKED	DATE		
	SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 30





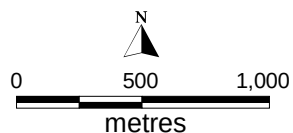


Electrical Conductivity (EC) Data

Site	Groundwater Unit	EC - Lab $\mu\text{S}/\text{cm}$	Sample Date
GW01	Regolith	5600	Nov-2016
GW02	Regolith	3350	Dec-2016
GW05	Queen Seam	3040	Aug-2016
GW09	Regolith	4510	Dec-2016
GW11	Regolith	2030	Nov-2016
GW22	Regolith	2000	Dec-2016
GW25	Regolith	1720	Aug-2016
GW30	Regolith	7400	Nov-2016
GW34	Regolith	3370	Aug-2016
GW35	Spoil	2340	Feb-2016
GW36	Regolith	3760	Aug-2016
GW37	Regolith	4790	Aug-2016
GW38	Regolith	2980	Mar-2017
GW39	Alluvium	2700	Mar-2017
GW40	Alluvium	3260	Mar-2017
GW41	Spoil	13100	Feb-2017
GW42	Spoil	1700	Nov-2016
GW48 (NW1)	NW Spoil	3450	Sep-2016
GW50_D	Queen Seam	1460	Feb-2017
GW50_S	Regolith	20620	Feb-2017
GW51_D	Queen Seam	3530	Feb-2017
GW51_S	Regolith	2910	Feb-2017
GW52A	Regolith	12400	Feb-2017
GW53	Regolith	5710	Feb-2017
GW54A	Spoil	2750	Aug-2013
GW54B	Spoil	3420	Sep-2015
GW55_D	Queen Seam	6100	Feb-2017
GW56_d	Ace Seam	1000	Mar-2017
GW58_D	King Seam	1040	Feb-2017
GW59B	King Seam	3640	Mar-2017
GW60	Queen Seam	1270	Feb-2017
GW61_D	Regolith	4360	Feb-2017
GW61_S	Regolith	935	Feb-2017
GW66	Spoil	3830	Feb-2017
GW67	Regolith	10340	Feb-2017
GW68	Regolith	12760	Feb-2017
GW69	Regolith	12520	Feb-2017
GW70	Spoil	8730	Feb-2017
GW71	Spoil	3420	Mar-2017
GW72	Spoil	2930	Feb-2017
GW73	Regolith	12390	Feb-2017
GW74	Regolith	3400	Feb-2017
GW75	Spoil	3600	Mar-2017
GW76	Spoil	2740	Feb-2017
GW78	Regolith	13820	Mar-2017
K2N Ash	Ash Void	2973	Oct-2016
K2W Ash Void	Ash Void	3530	May-2013
Tailings Void	Tailings Void	1540	Dec-2016
Bullgang Drain	Bullgang Drain	2950	Feb-2017
Ramp 7-1	Ramp 7-1	3190	Feb-2017

EC Data Range

- >2,000 $\mu\text{S}/\text{cm}$
- 2,000 to <5,000 $\mu\text{S}/\text{cm}$
- 5,000 to <10,000 $\mu\text{S}/\text{cm}$
- >10,000 $\mu\text{S}/\text{cm}$



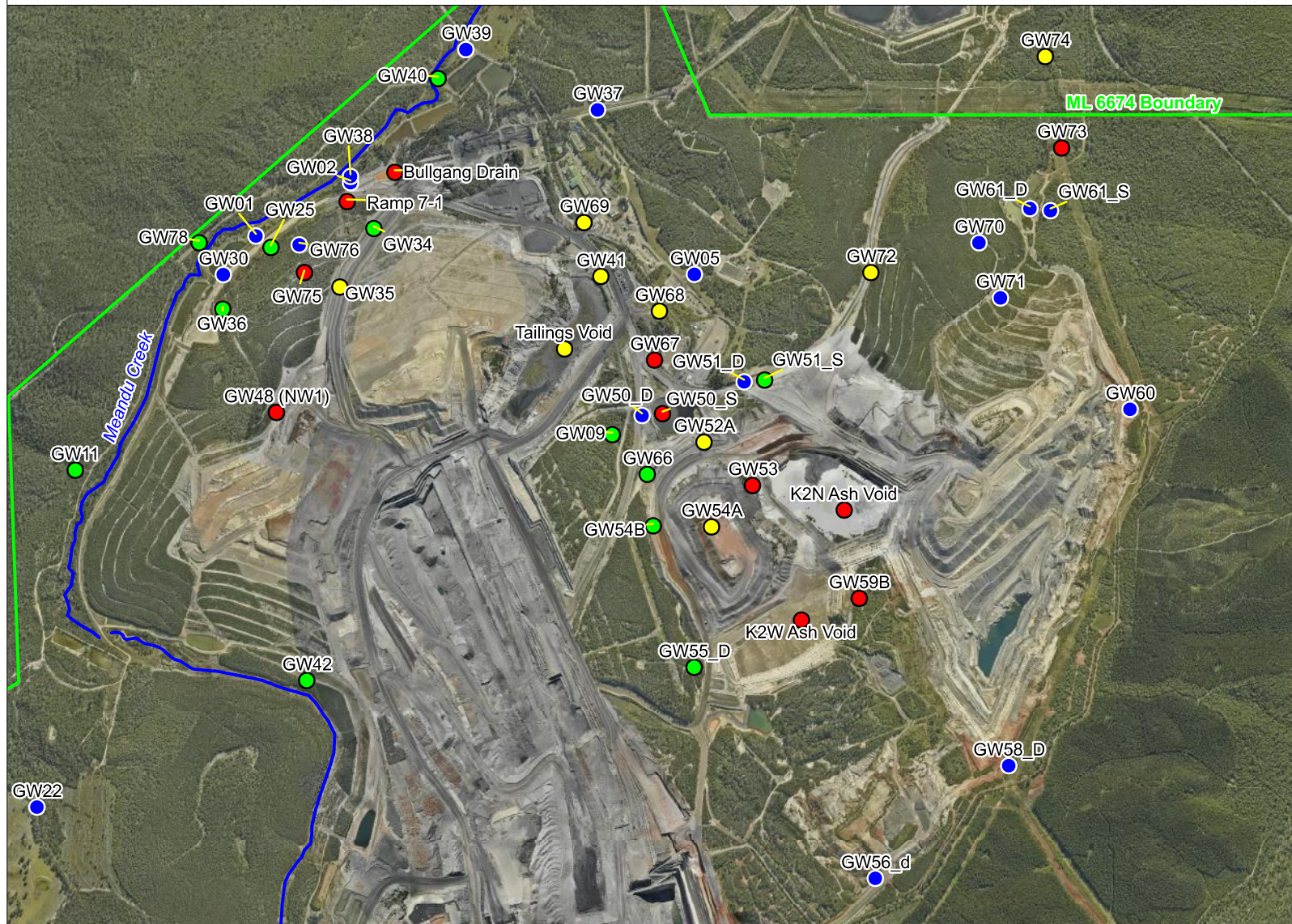
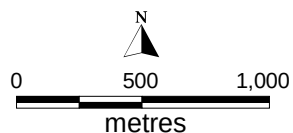
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Groundwater Electrical Conductivity (EC) Data	
CHECKED	DATE		
SCALE 1:30,000	A4	PROJECT No JBT01-012-059	FIGURE No 34

Sulphate (SO4) Data

Site	Groundwater Unit	Sulphate (SO4) mg/L	Sample Date
GW01	Regolith	130	Nov-2016
GW02	Regolith	55	Dec-2016
GW05	Queen Seam	74	Aug-2016
GW09	Regolith	267	Dec-2016
GW11	Regolith	291	Nov-2016
GW22	Regolith	36	Dec-2016
GW25	Regolith	376	Aug-2016
GW30	Regolith	177	Nov-2016
GW34	Regolith	462	Aug-2016
GW35	Spoil	680	Feb-2016
GW36	Regolith	473	Aug-2016
GW37	Regolith	33	Aug-2016
GW38	Regolith	81	Mar-2017
GW39	Alluvium	196	Mar-2017
GW40	Alluvium	497	Mar-2017
GW41	Spoil	758	Feb-2017
GW42	Spoil	238	Nov-2016
GW48 (NW1)	NW Spoil	966	Sep-2016
GW50_D	Queen Seam	16	Feb-2017
GW50_S	Regolith	1150	Feb-2017
GW51_D	Queen Seam	66	Feb-2017
GW51_S	Regolith	240	Feb-2017
GW52A	Regolith	527	Feb-2017
GW53	Regolith	974	Feb-2017
GW54A	Spoil	518	Aug-2013
GW54B	Spoil	358	Sep-2015
GW55_D	Queen Seam	408	Feb-2017
GW56_d	Ace Seam	42	Mar-2017
GW58_D	King Seam	35	Feb-2017
GW59B	King Seam	880	Mar-2017
GW60	Queen Seam	54	Feb-2017
GW61_D	Regolith	109	Feb-2017
GW61_S	Regolith	68	Feb-2017
GW66	Spoil	384	Feb-2017
GW67	Regolith	811	Feb-2017
GW68	Regolith	665	Feb-2017
GW69	Regolith	603	Feb-2017
GW70	Spoil	137	Feb-2017
GW71	Spoil	190	Mar-2017
GW72	Spoil	568	Feb-2017
GW73	Regolith	869	Feb-2017
GW74	Regolith	603	Feb-2017
GW75	Spoil	1000	Mar-2017
GW76	Spoil	17	Feb-2017
GW78	Regolith	409	Mar-2017
K2N Ash	Ash Void	834	Oct-2016
K2W Ash Void	Ash Void	1000	May-2013
Tailings Void	Tailings Void	696	Dec-2016
Bullgang Drain	Bullgang Drain	870	Feb-2017
Ramp 7-1	Ramp 7-1	970	Feb-2017

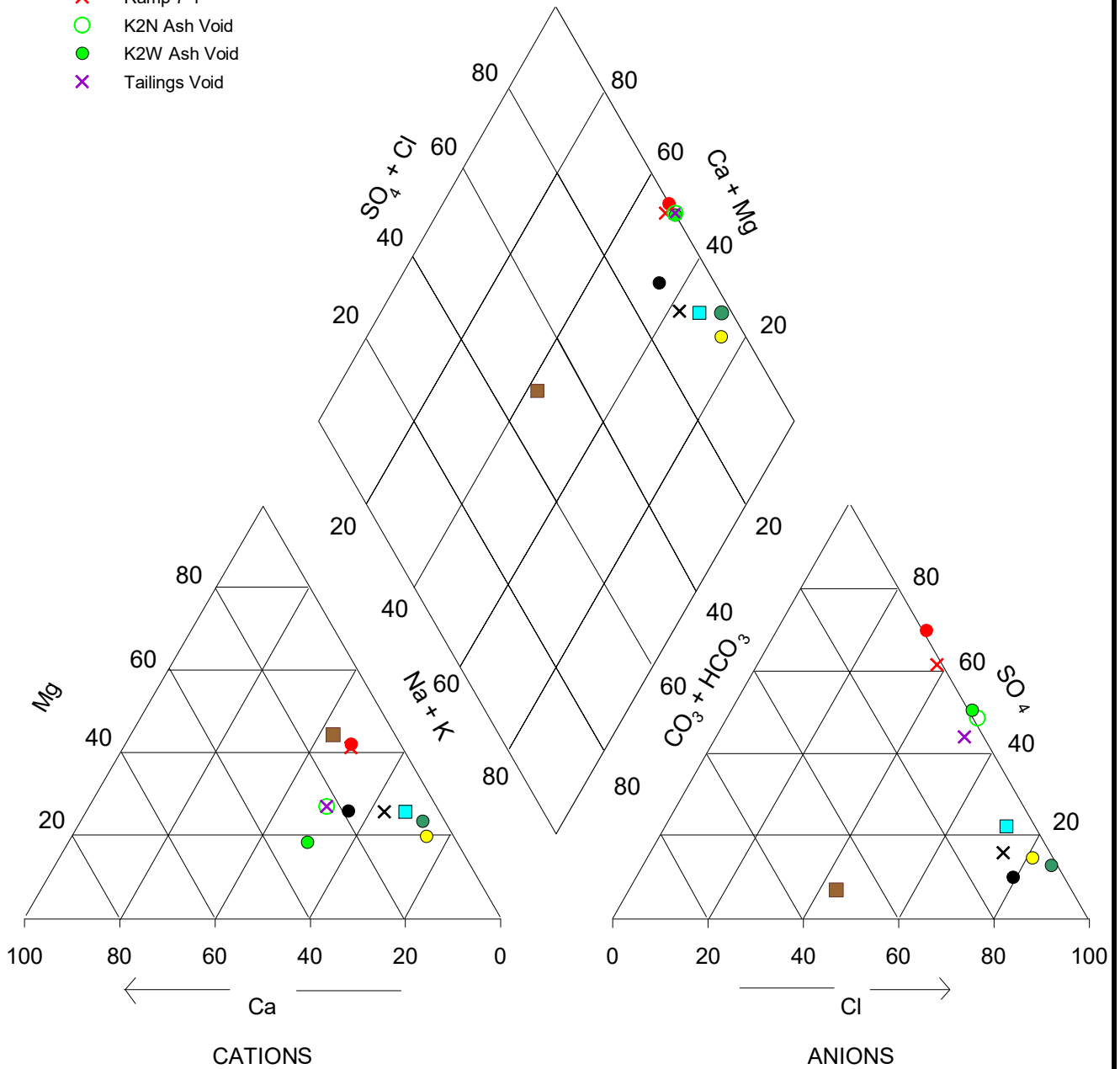
Sulphate Data Range

- < 200 mg/L
- 200 to < 500 mg/L
- 500 to < 800 mg/L
- >800 mg/L



CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Groundwater Sulphate (SO4) Data	
CHECKED	DATE		
SCALE 1:30,000	A4	PROJECT No JBT01-012-059	FIGURE No 35

- Alluvium
- Basalt
- Regolith
- Spoil
- Coal Measures - Background
- ✕ Coal Measures - Mine Affected
- Bullgang Drain
- ✕ Ramp 7-1
- K2N Ash Void
- K2W Ash Void
- ✕ Tailings Void



CLIENT Stanwell Corporation	
DRAWN JWB	DATE Aug 2018
CHECKED	DATE
SCALE As Shown	A4

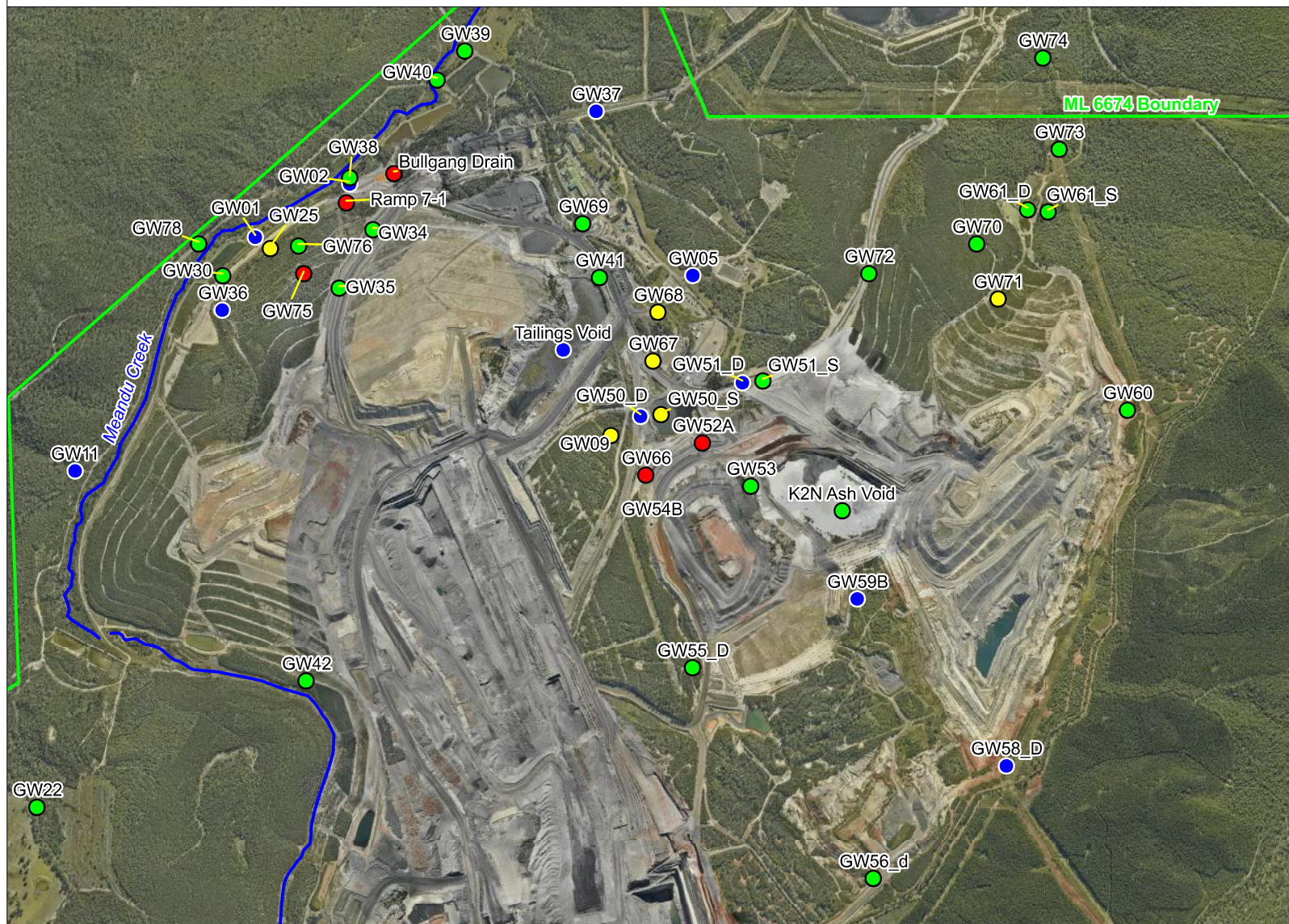
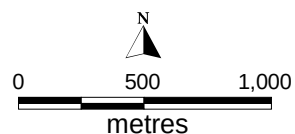
PROJECT Meandu Mine - Environmental Assessment	
TITLE Piper Trilinear Plot Groundwater Units & Surface Water Sites	
PROJECT No. JBT01-012-059	FIGURE No. 36

Dissolved Cobalt (Co) Data

Site	Groundwater Unit	Co (Dissolved) mg/L	Sample Date
GW01	Regolith	<0.001	Nov-2016
GW02	Regolith	<0.001	Dec-2016
GW05	Queen Seam	<0.001	Aug-2016
GW09	Regolith	0.243	Dec-2016
GW11	Regolith	<0.001	Nov-2016
GW22	Regolith	0.006	Dec-2016
GW25	Regolith	0.146	Aug-2016
GW30	Regolith	0.016	Nov-2016
GW34	Regolith	0.012	Aug-2016
GW35	Spoil	0.074	Feb-2016
GW36	Regolith	<0.001	Aug-2016
GW37	Regolith	<0.001	Aug-2016
GW38	Regolith	0.014	Mar-2017
GW39	Alluvium	0.003	Mar-2017
GW40	Alluvium	0.021	Mar-2017
GW41	Spoil	0.011	Feb-2017
GW42	Spoil	0.061	Nov-2016
GW50_D	Queen Seam	<0.001	Feb-2017
GW50_S	Regolith	0.138	Feb-2017
GW51_D	Queen Seam	<0.001	Feb-2017
GW51_S	Regolith	0.034	Feb-2017
GW52A	Regolit	0.429	Feb-2017
GW53	Regolith	0.031	Feb-2017
GW55_D	Queen Seam	0.05	Feb-2017
GW56_d	Ace Seam	0.001	Mar-2017
GW58_D	King Seam	<0.001	Feb-2017
GW59B	King Seam	<0.001	Mar-2017
GW60	Queen Seam	0.002	Feb-2017
GW61_D	Regolith	0.001	Feb-2017
GW61_S	Regolith	0.026	Feb-2017
GW66	Spoil	0.32	Feb-2017
GW67	Regolith	0.122	Feb-2017
GW68	Regolith	0.172	Feb-2017
GW69	Regolith	0.005	Feb-2017
GW70	Spoil	0.093	Feb-2017
GW71	Spoil	0.133	Mar-2017
GW72	Spoil	0.091	Feb-2017
GW73	Regolith	0.005	Feb-2017
GW74	Regolith	0.022	Feb-2017
GW75	Spoil	0.532	Mar-2017
GW76	Spoil	0.047	Feb-2017
GW78	Regolith	0.042	Mar-2017
K2N Ash	Ash Void	0.022	Oct-2016
Tailings Void	Tailings Void	<0.001	Dec-2016
Bullgang Drain	Bullgang Drain	0.602	Feb-2017
Ramp 7-1	Ramp 7-1	0.647	Feb-2017

Dissolved Cobalt Range

- <LOR
- >LOR to <0.1 mg/L
- 0.1 to <0.25mg/L
- >0.25mg/L



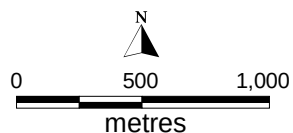
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Groundwater Dissolved Cobalt (Co) Data	
CHECKED	DATE		
SCALE 1:30,000	A4	PROJECT No JBT01-012-059	FIGURE No 37

Dissolved Iron (Fe) Data

Site	Groundwater Unit	Fe (Dissolved) mg/L	Sample Date
GW01	Regolith	5.91	Nov-2016
GW02	Regolith	3.77	Dec-2016
GW05	Queen Seam	0.87	Aug-2016
GW09	Regolith	23	Dec-2016
GW11	Regolith	6.5	Nov-2016
GW22	Regolith	7.5	Dec-2016
GW25	Regolith	3	Aug-2016
GW30	Regolith	6.54	Nov-2016
GW34	Regolith	21	Aug-2016
GW35	Spoil	7.55	Feb-2016
GW36	Regolith	81.2	Aug-2016
GW37	Regolith	48.5	Aug-2016
GW38	Regolith	2.75	Mar-2017
GW39	Alluvium	0.21	Mar-2017
GW40	Alluvium	0.48	Mar-2017
GW41	Spoil	6.46	Feb-2017
GW42	Spoil	18.2	Nov-2016
GW50_D	Queen Seam	0.17	Feb-2017
GW50_S	Regolith	43.7	Feb-2017
GW51_D	Queen Seam	1.26	Feb-2017
GW51_S	Regolith	<0.05	Feb-2017
GW52A	Regolith	0.85	Feb-2017
GW53	Regolith	<0.05	Feb-2017
GW54B	Spoil	82.6	Sep-2015
GW55_D	Queen Seam	10	Feb-2017
GW56_d	Ace Seam	1.17	Mar-2017
GW58_D	King Seam	7.1	Feb-2017
GW59B	King Seam	0.99	Mar-2017
GW60	Queen Seam	13.1	Feb-2017
GW61_D	Regolith	2.87	Feb-2017
GW61_S	Regolith	<0.05	Feb-2017
GW66	Spoil	106	Feb-2017
GW67	Regolith	1.79	Feb-2017
GW68	Regolith	1.22	Feb-2017
GW69	Regolith	8.34	Feb-2017
GW70	Spoil	210	Feb-2017
GW71	Spoil	128	Mar-2017
GW72	Spoil	131	Feb-2017
GW73	Regolith	0.24	Feb-2017
GW74	Regolith	53	Feb-2017
GW75	Spoil	50.5	Mar-2017
GW76	Spoil	47.3	Feb-2017
GW78	Regolith	0.78	Mar-2017
K2N Ash	Ash Void	<0.05	Oct-2016
Tailings Void	Tailings Void	<0.05	Dec-2016
Bullgang Drain	Bullgang Drain	91.5	Feb-2017
Ramp 7-1	Ramp 7-1	81.8	Feb-2017

Dissolved Iron Range

- < LOR
- >LOR to < 5 mg/L
- 5 to <10 mg/L
- 10 to <20 mg/L
- 20 to <50 mg/L
- >50 mg/L



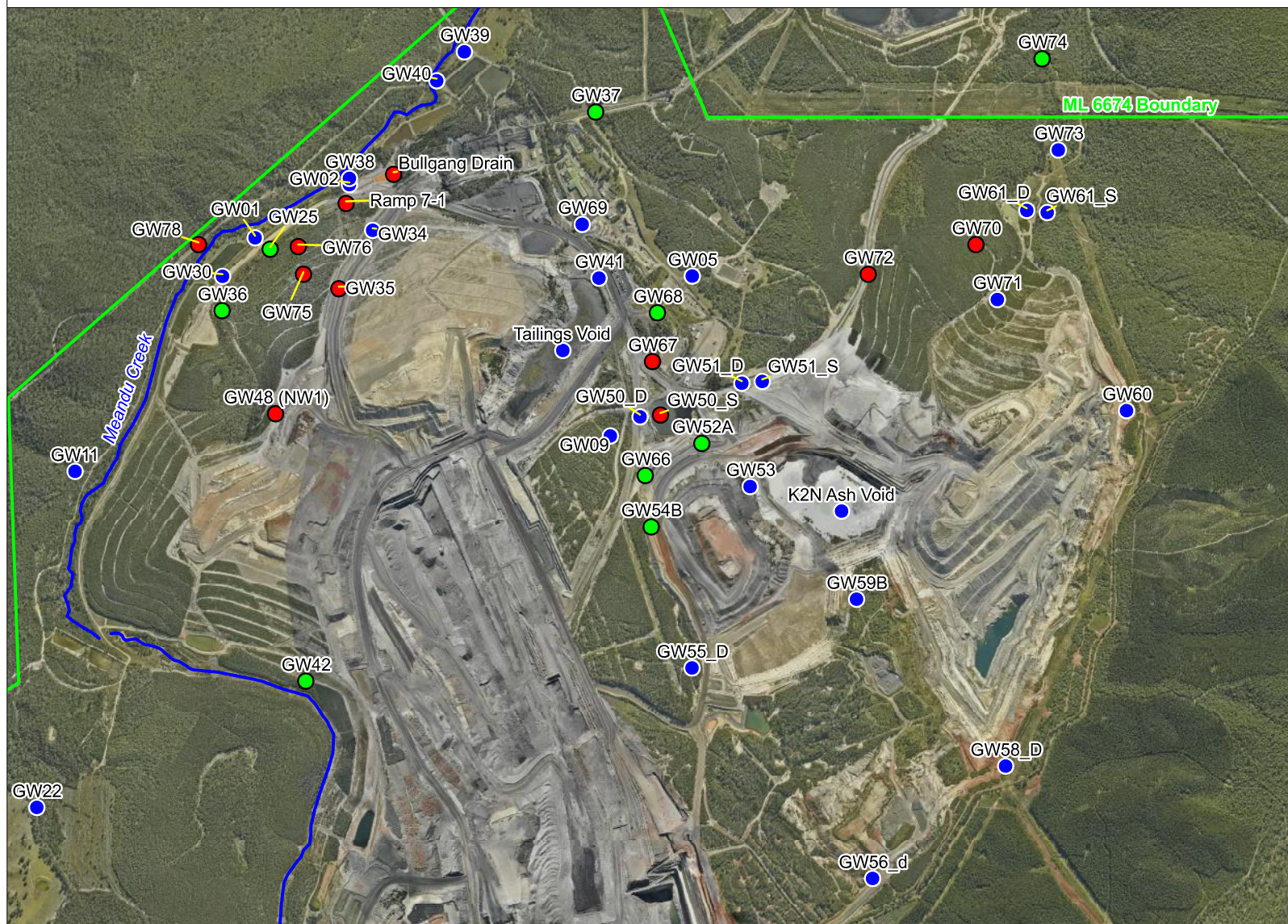
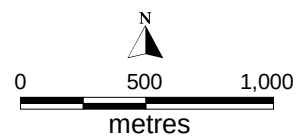
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Groundwater Dissolved Iron (Fe) Data	
CHECKED	DATE		
SCALE 1:30,000	A4	PROJECT No JBT01-012-059	FIGURE No 38

Dissolved Manganese (Mn) Data

Site	Groundwater Unit	Mn (Dissolved) mg/L	Sample Date
GW01	Regolith	0.338	Nov-2016
GW02	Regolith	0.235	Dec-2016
GW05	Queen Seam	0.095	Aug-2016
GW09	Regolith	1.14	Dec-2016
GW11	Regolith	0.22	Nov-2016
GW22	Regolith	0.203	Dec-2016
GW25	Regolith	8.4	Aug-2016
GW30	Regolith	0.649	Nov-2016
GW34	Regolith	1.1	Aug-2016
GW35	Spoil	25	Feb-2016
GW36	Regolith	2.51	Aug-2016
GW37	Regolith	5.82	Aug-2016
GW38	Regolith	0.547	Mar-2017
GW39	Alluvium	0.32	Mar-2017
GW40	Alluvium	0.898	Mar-2017
GW41	Spoil	0.395	Feb-2017
GW42	Spoil	4.25	Nov-2016
GW48 (NW1)	NW Spoil	13.5	Sep-2016
GW50_D	Queen Seam	0.019	Feb-2017
GW50_S	Regolith	21.7	Feb-2017
GW51_D	Queen Seam	0.038	Feb-2017
GW51_S	Regolith	1.44	Feb-2017
GW52A	Regolith	6.05	Feb-2017
GW53	Regolith	0.055	Feb-2017
GW54B	Spoil	4.71	Sep-2015
GW55_D	Queen Seam	0.796	Feb-2017
GW56_d	Ace Seam	0.068	Mar-2017
GW58_D	King Seam	0.193	Feb-2017
GW59B	King Seam	0.062	Mar-2017
GW60	Queen Seam	0.466	Feb-2017
GW61_D	Regolith	0.168	Feb-2017
GW61_S	Regolith	0.011	Feb-2017
GW66	Spoil	9.81	Feb-2017
GW67	Regolith	11.4	Feb-2017
GW68	Regolith	6.45	Feb-2017
GW69	Regolith	1.64	Feb-2017
GW70	Spoil	16.1	Feb-2017
GW71	Spoil	1.28	Mar-2017
GW72	Spoil	11.1	Feb-2017
GW73	Regolith	1.04	Feb-2017
GW74	Regolith	3.02	Feb-2017
GW75	Spoil	47.3	Mar-2017
GW76	Spoil	10.8	Feb-2017
GW78	Regolith	12.3	Mar-2017
K2N Ash	Ash Void	0.484	Oct-2016
Tailings Void	Tailings Void	0.004	Dec-2016
Bullgang Drain	Bullgang Drain	26.2	Feb-2017
Ramp 7-1	Ramp 7-1	34.2	Feb-2017

Dissolved Manganese Range

- <2.5 mg/L
- 2.5 to <10mg/L
- >10mg/L



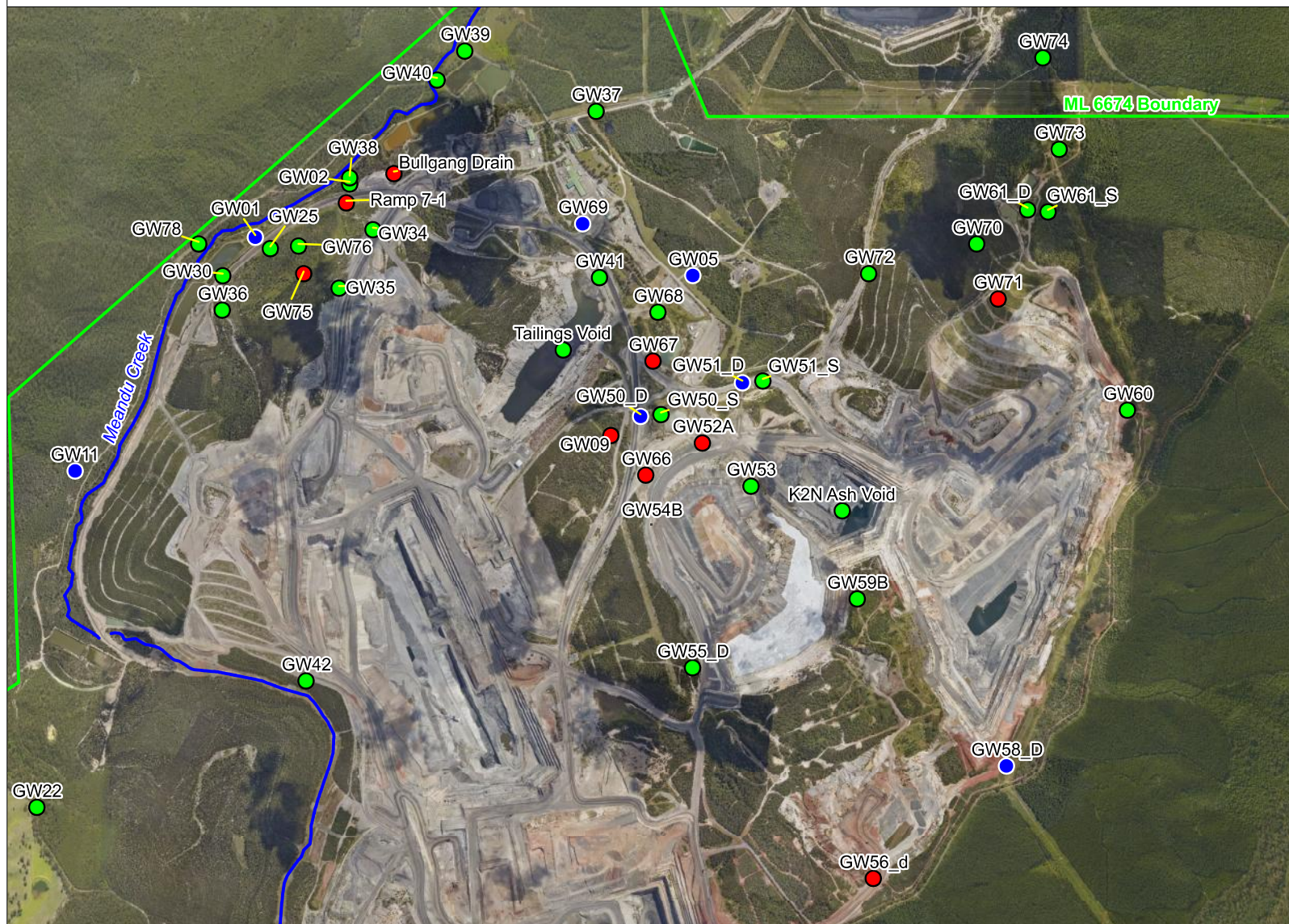
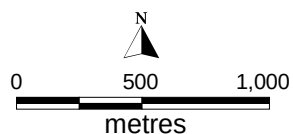
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Groundwater Dissolved Manganese (Mn) Data	
CHECKED	DATE		
SCALE 1:30,000	A4	PROJECT No JBT01-012-059	FIGURE No 39

Dissolved Nickel (Ni) Data

Site	Groundwater Unit	Ni (Dissolved) mg/L	Sample Date
GW01	Regolith	<0.001	Nov-2016
GW02	Regolith	0.001	Dec-2016
GW05	Queen Seam	<0.001	Aug-2016
GW09	Regolith	0.182	Dec-2016
GW11	Regolith	<0.001	Nov-2016
GW22	Regolith	0.002	Dec-2016
GW25	Regolith	0.022	Aug-2016
GW30	Regolith	0.01	Nov-2016
GW34	Regolith	0.01	Aug-2016
GW35	Spoil	0.039	Feb-2017
GW36	Regolith	0.002	Aug-2016
GW37	Regolith	0.002	Aug-2016
GW38	Regolith	0.006	Mar-2017
GW39	Alluvium	0.002	Mar-2017
GW40	Alluvium	0.011	Mar-2017
GW41	Spoil	0.006	Feb-2017
GW42	Spoil	0.035	Nov-2016
GW50_D	Queen Seam	<0.001	Feb-2017
GW50_S	Regolith	0.086	Feb-2017
GW51_D	Queen Seam	<0.001	Feb-2017
GW51_S	Regolith	0.018	Feb-2017
GW52A	Regolith	0.356	Feb-2017
GW53	Regolith	0.015	Feb-2017
GW55_D	Queen Seam	0.048	Feb-2017
GW56_d	Ace Seam	0.109	Mar-2017
GW58_D	King Seam	<0.001	Feb-2017
GW59B	King Seam	0.001	Mar-2017
GW60	Queen Seam	0.004	Feb-2017
GW61_D	Regolith	0.001	Feb-2017
GW61_S	Regolith	0.014	Feb-2017
GW66	Spoil	0.366	Feb-2017
GW67	Regolith	0.095	Feb-2017
GW68	Regolith	0.022	Feb-2017
GW69	Regolith	<0.005	Feb-2017
GW70	Spoil	0.059	Feb-2017
GW71	Spoil	0.102	Mar-2017
GW72	Spoil	0.082	Feb-2017
GW73	Regolith	0.002	Feb-2017
GW74	Regolith	0.048	Feb-2017
GW75	Spoil	0.322	Mar-2017
GW76	Spoil	0.006	Feb-2017
GW78	Regolith	0.015	Mar-2017
K2N Ash	Ash Void	0.048	Oct-2016
Tailings Void	Tailings Void	0.002	Dec-2016
Bullgang Drain	Bullgang Drain	0.471	Feb-2017
Ramp 7-1	Ramp 7-1	0.444	Feb-2017

Dissolved Nickel Range

- <LOR
- LOR to <0.09 mg/L
- >0.09 mg/L



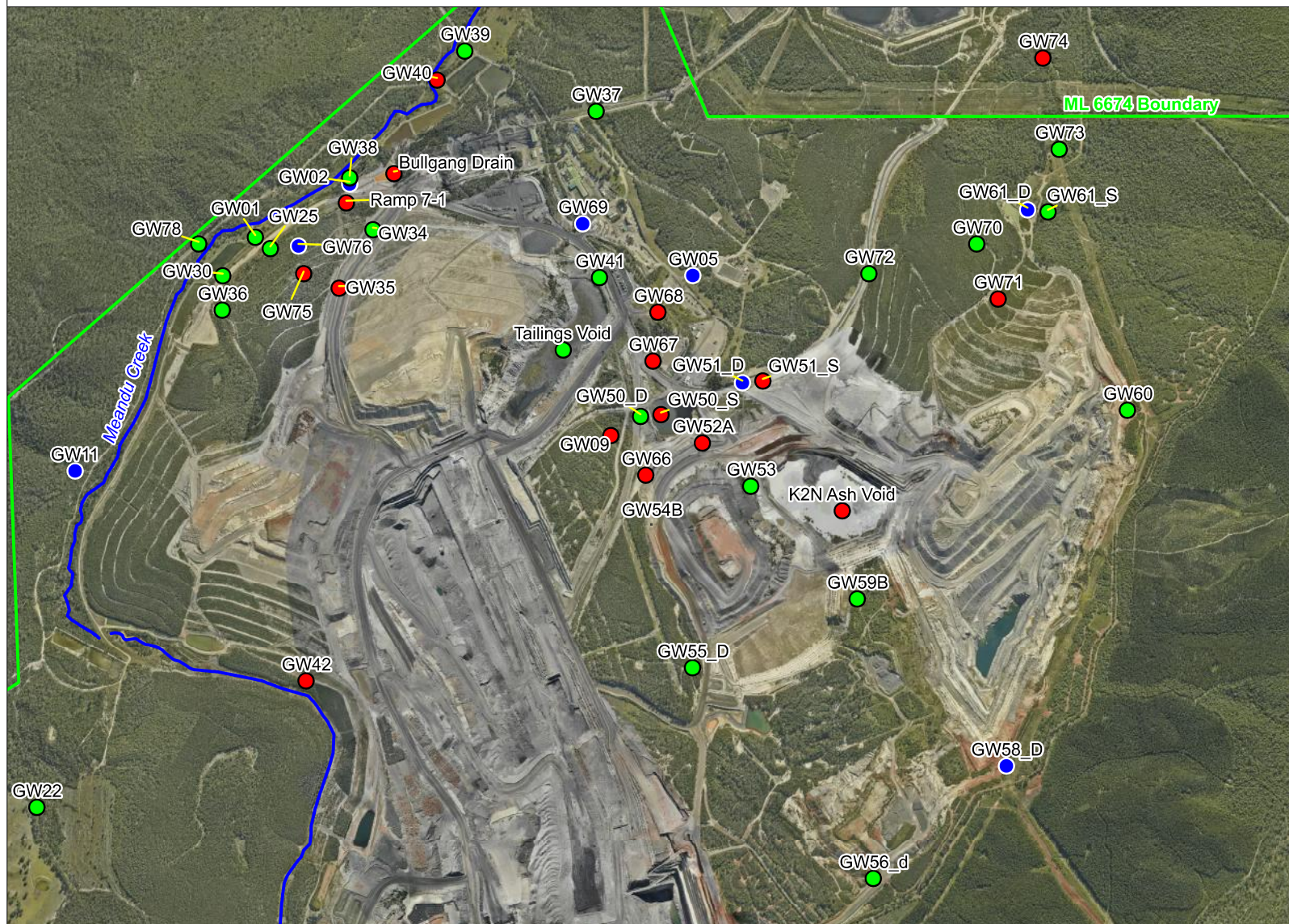
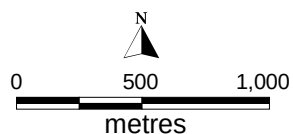
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Groundwater Dissolved Nickel (Ni) Data	
CHECKED	DATE		
SCALE 1:30,000	A4	PROJECT No JBT01-012-059	FIGURE No 40

Dissolved Zinc (Zn) Data

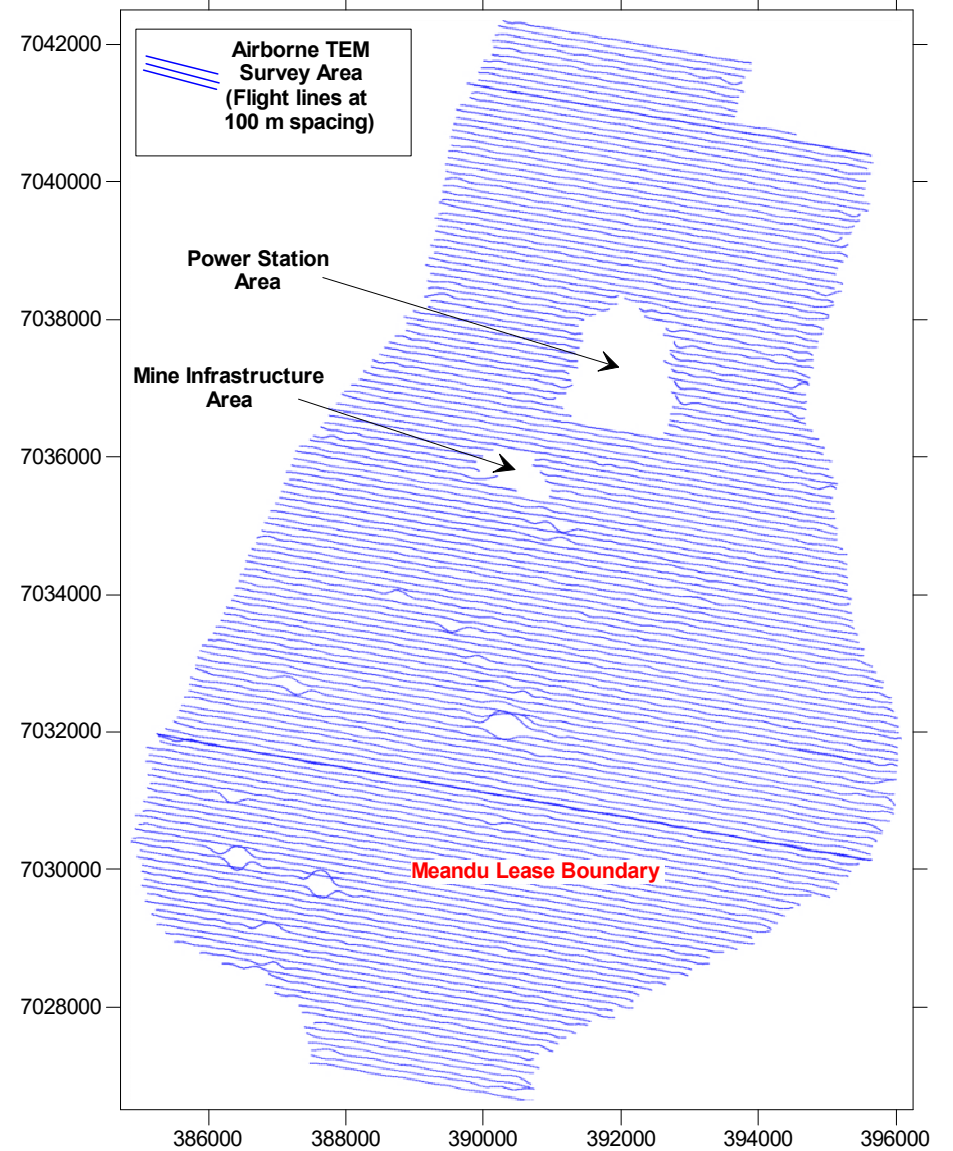
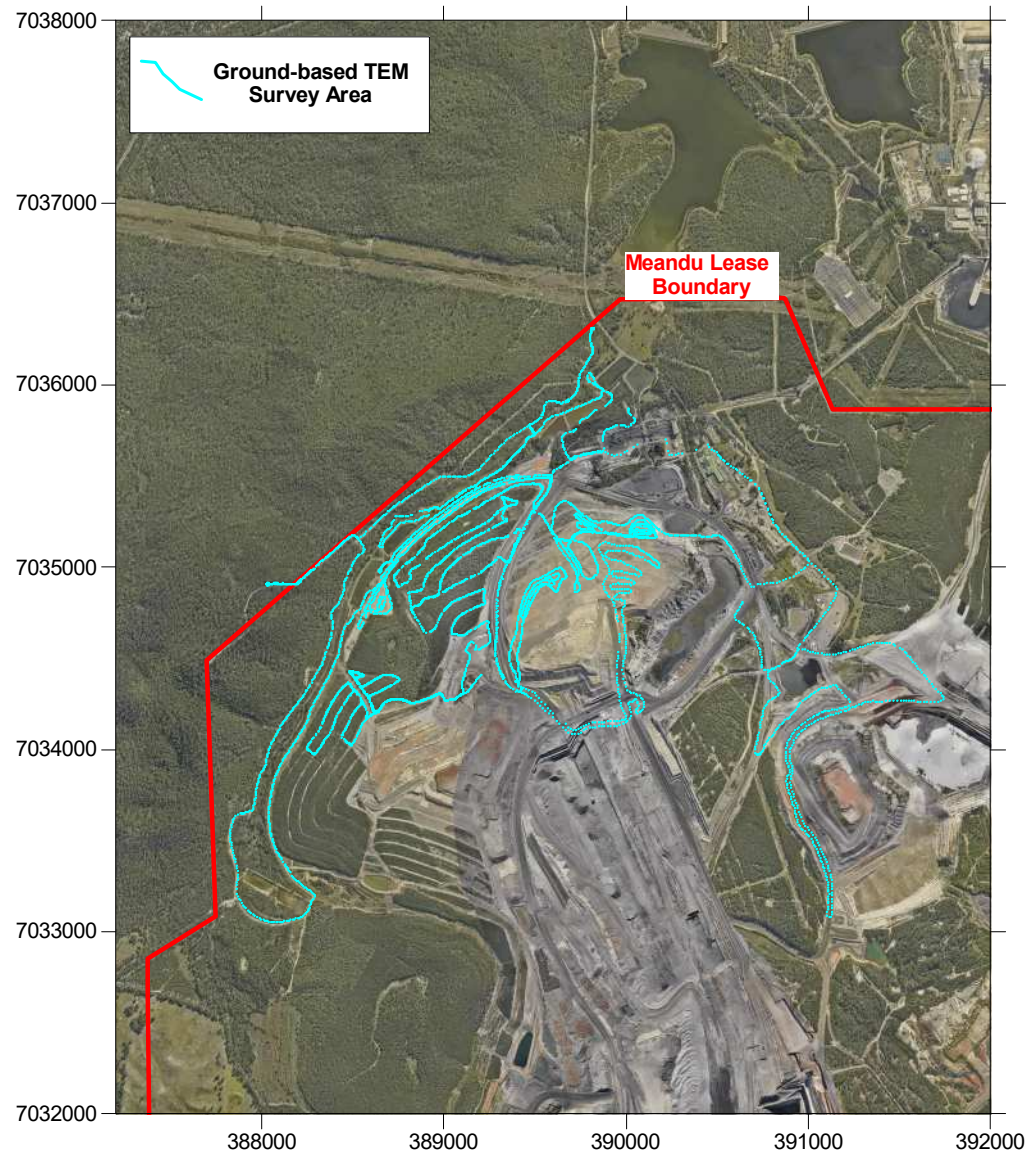
Site	Groundwater Unit	Zn (Dissolved) mg/L	Sample Date
GW01	Regolith	0.034	Nov-2016
GW02	Regolith	<0.005	Dec-2016
GW05	Queen Seam	<0.005	Aug-2016
GW09	Regolith	2.01	Dec-2016
GW11	Regolith	<0.005	Nov-2016
GW22	Regolith	0.018	Dec-2016
GW25	Regolith	0.103	Aug-2016
GW30	Regolith	0.026	Nov-2016
GW34	Regolith	0.099	Aug-2016
GW35	Spoil	0.123	Feb-2016
GW36	Regolith	0.076	Aug-2016
GW37	Regolith	0.043	Aug-2016
GW38	Regolith	0.028	Mar-2017
GW39	Alluvium	0.075	Mar-2017
GW40	Alluvium	0.122	Mar-2017
GW41	Spoil	0.038	Feb-2017
GW42	Spoil	0.144	Nov-2016
GW50_D	Queen Seam	0.006	Feb-2017
GW50_S	Regolith	0.281	Feb-2017
GW51_D	Queen Seam	<0.005	Feb-2017
GW51_S	Regolith	0.132	Feb-2017
GW52A	Regolith	1.52	Feb-2017
GW53	Regolith	0.057	Feb-2017
GW55_D	Queen Seam	0.1	Feb-2017
GW56_d	Ace Seam	0.032	Mar-2017
GW58_D	King Seam	<0.005	Feb-2017
GW59B	King Seam	0.031	Mar-2017
GW60	Queen Seam	0.007	Feb-2017
GW61_D	Regolith	<0.005	Feb-2017
GW61_S	Regolith	0.051	Feb-2017
GW66	Spoil	0.883	Feb-2017
GW67	Regolith	0.263	Feb-2017
GW68	Regolith	0.724	Feb-2017
GW69	Regolith	<0.025	Feb-2017
GW70	Spoil	0.044	Feb-2017
GW71	Spoil	0.299	Mar-2017
GW72	Spoil	0.01	Feb-2017
GW73	Regolith	0.009	Feb-2017
GW74	Regolith	0.293	Feb-2017
GW75	Spoil	1.56	Mar-2017
GW76	Spoil	<0.005	Feb-2017
GW78	Regolith	0.022	Mar-2017
K2N Ash	Ash Void	0.157	Oct-2016
Tailings Void	Tailings Void	0.006	Dec-2016
Bullgang Drain	Bullgang Drain	3.74	Feb-2017
Ramp 7-1	Ramp 7-1	3.42	Feb-2017

Dissolved Zinc Range

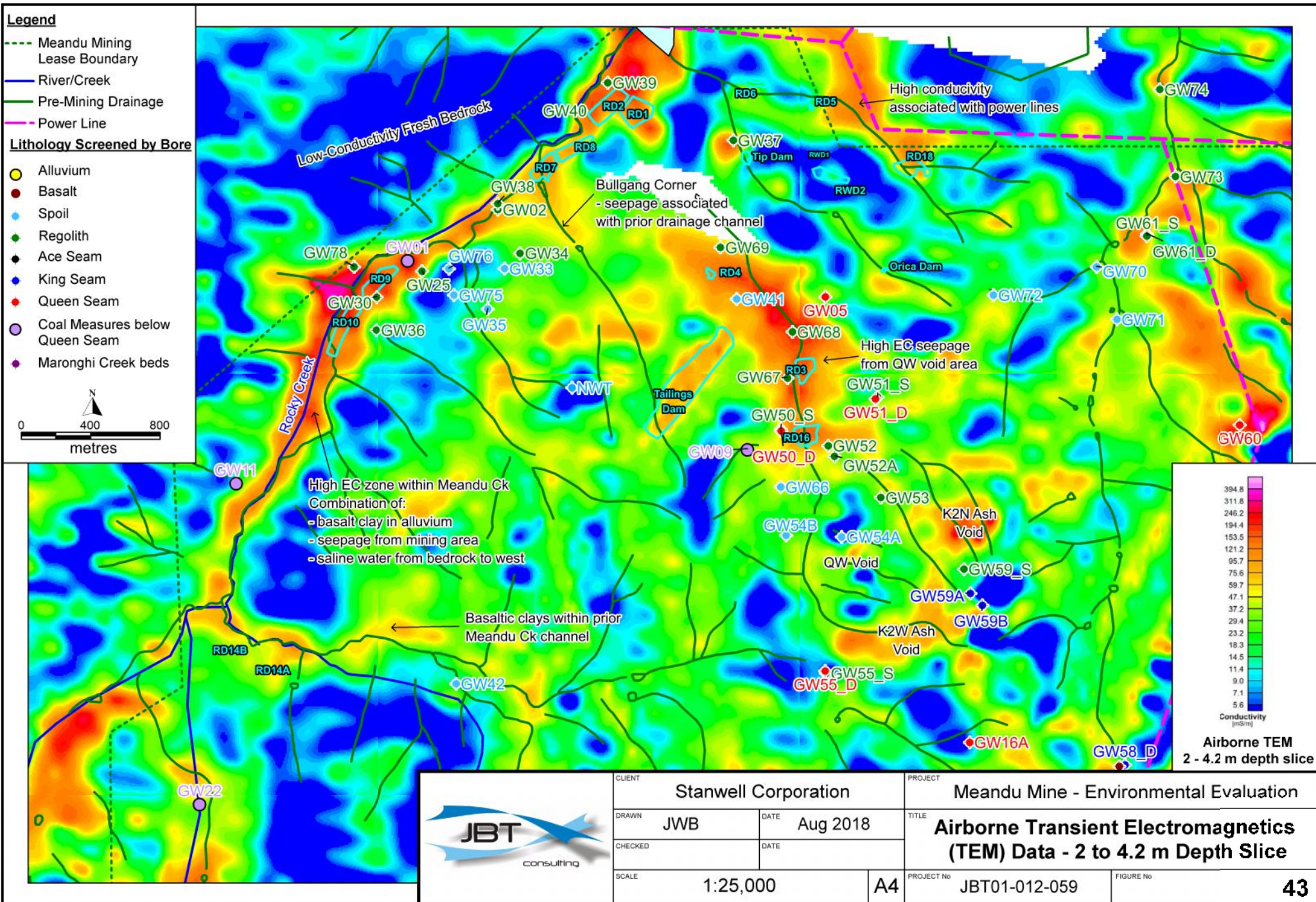
- <LOR
- LOR to <0.1 mg/L
- >0.1 mg/L

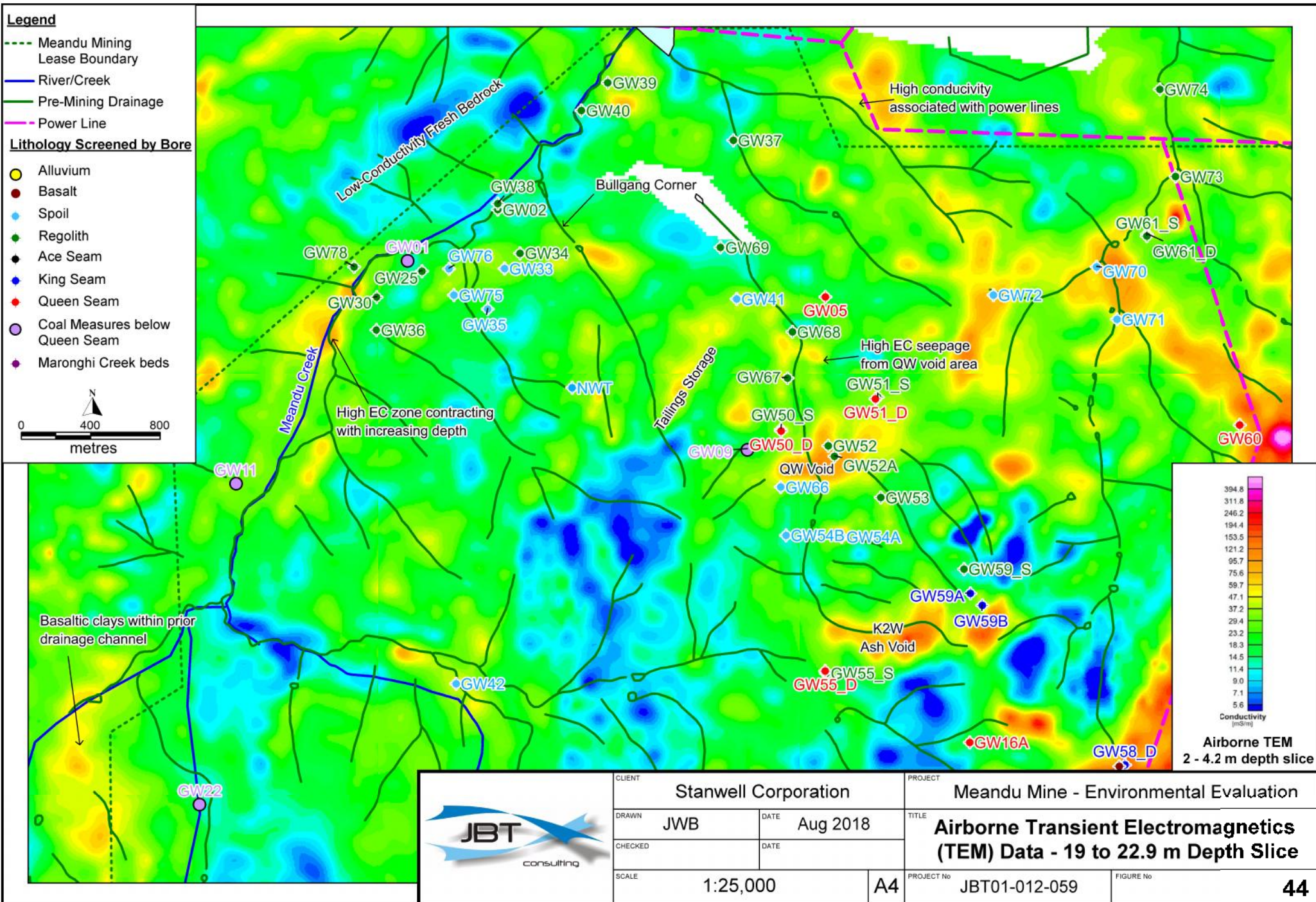


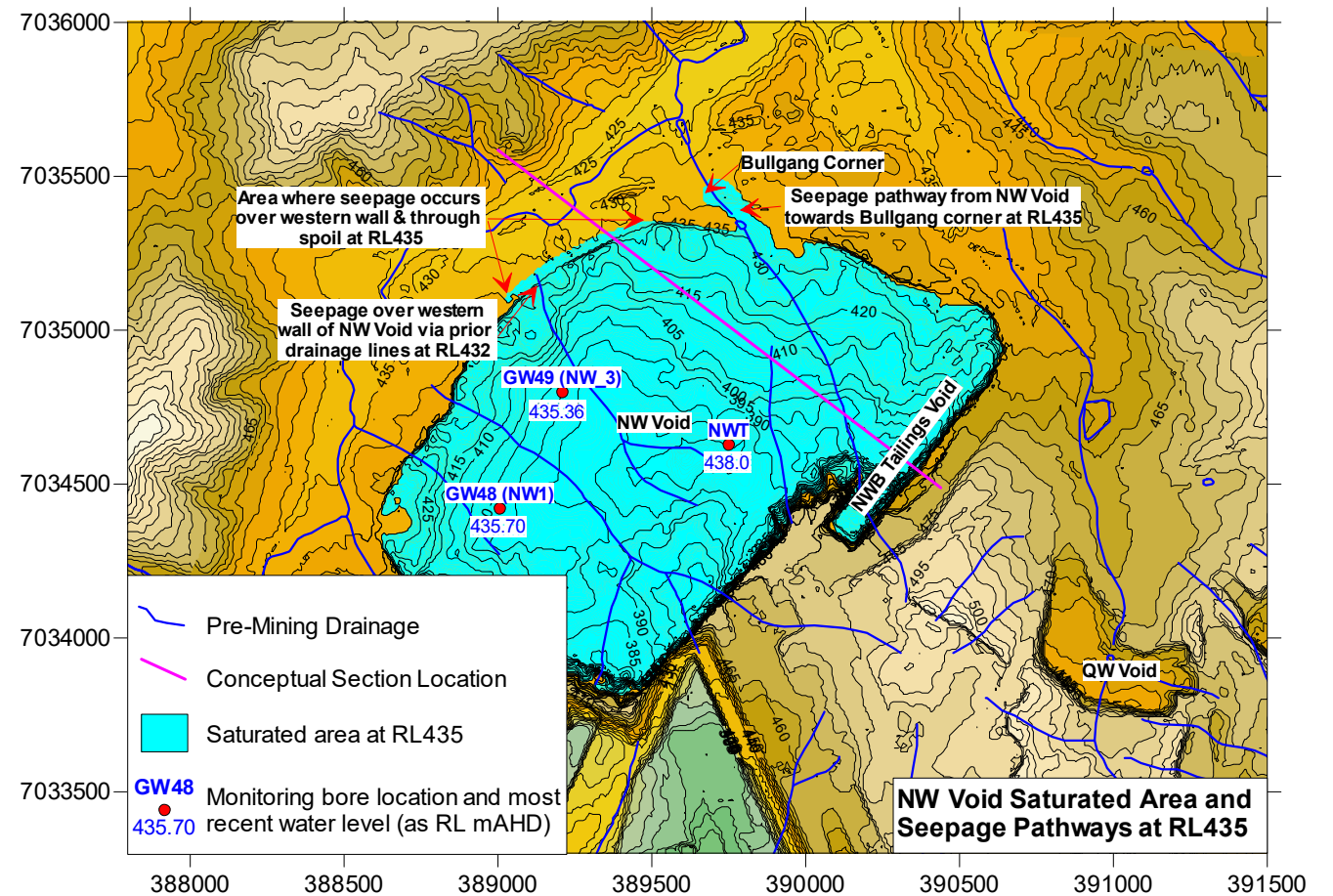
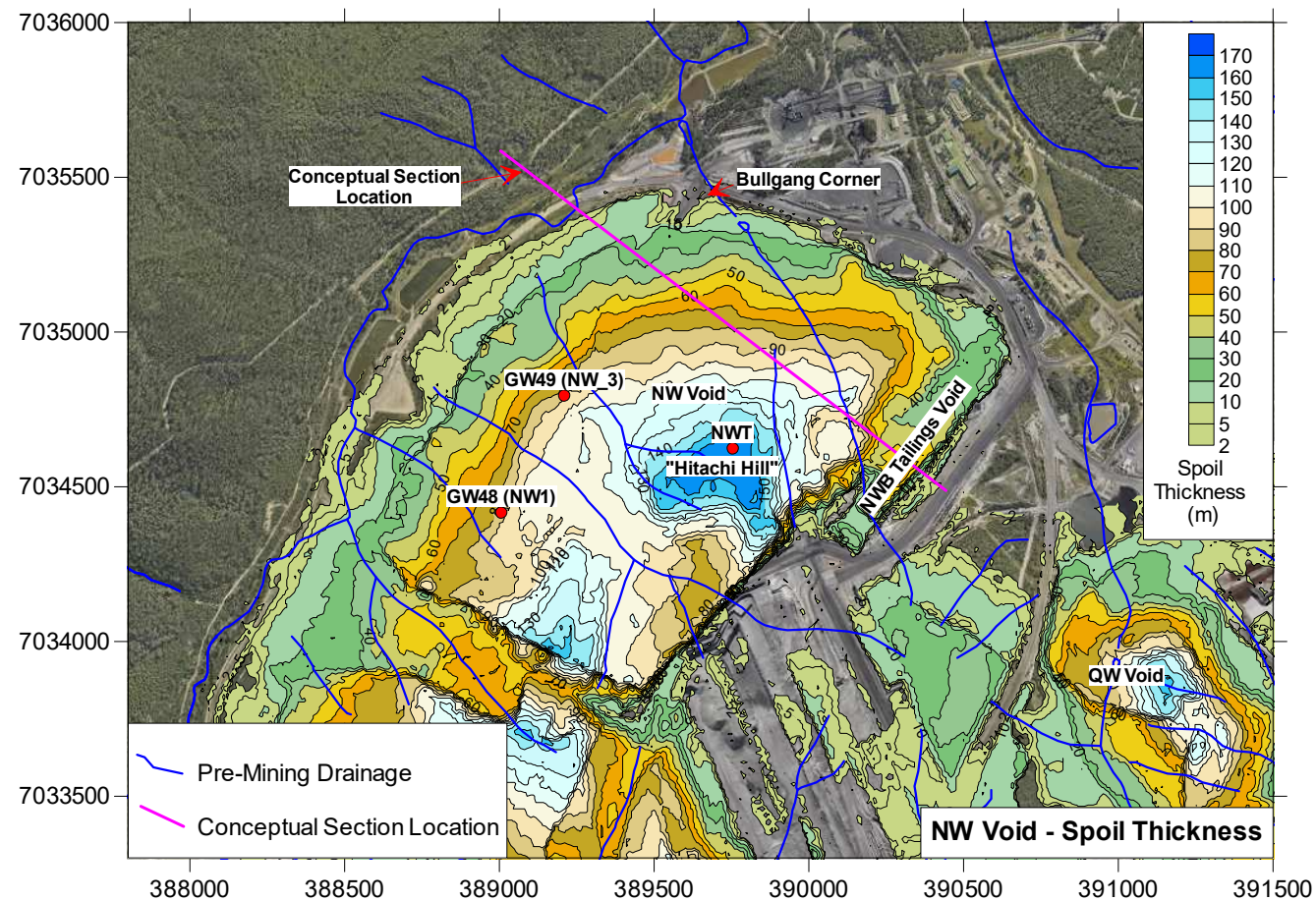
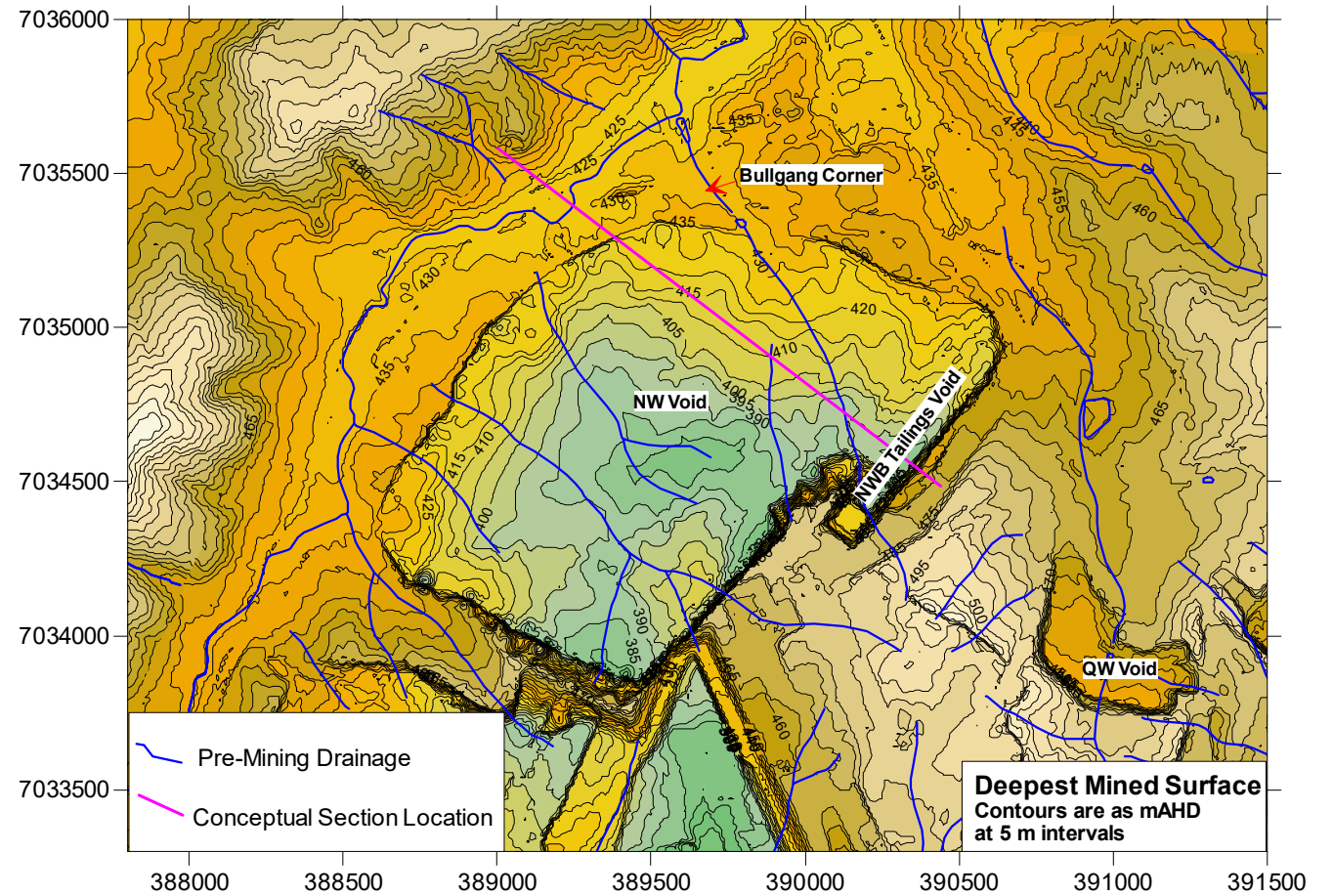
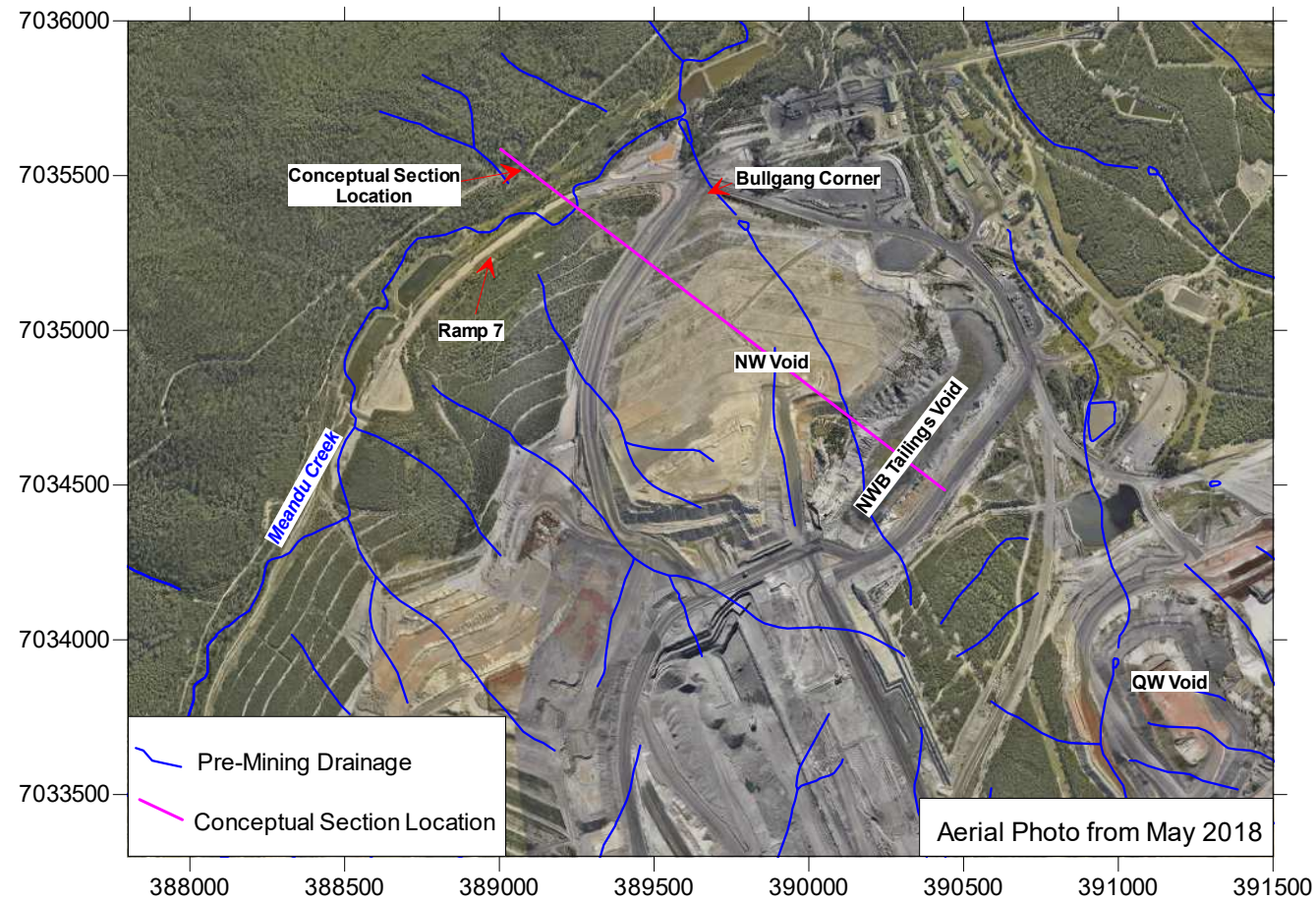
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Groundwater Dissolved Zinc (Zn) Data	
CHECKED	DATE		
SCALE 1:30,000	A4	PROJECT No JBT01-012-059	FIGURE No 41



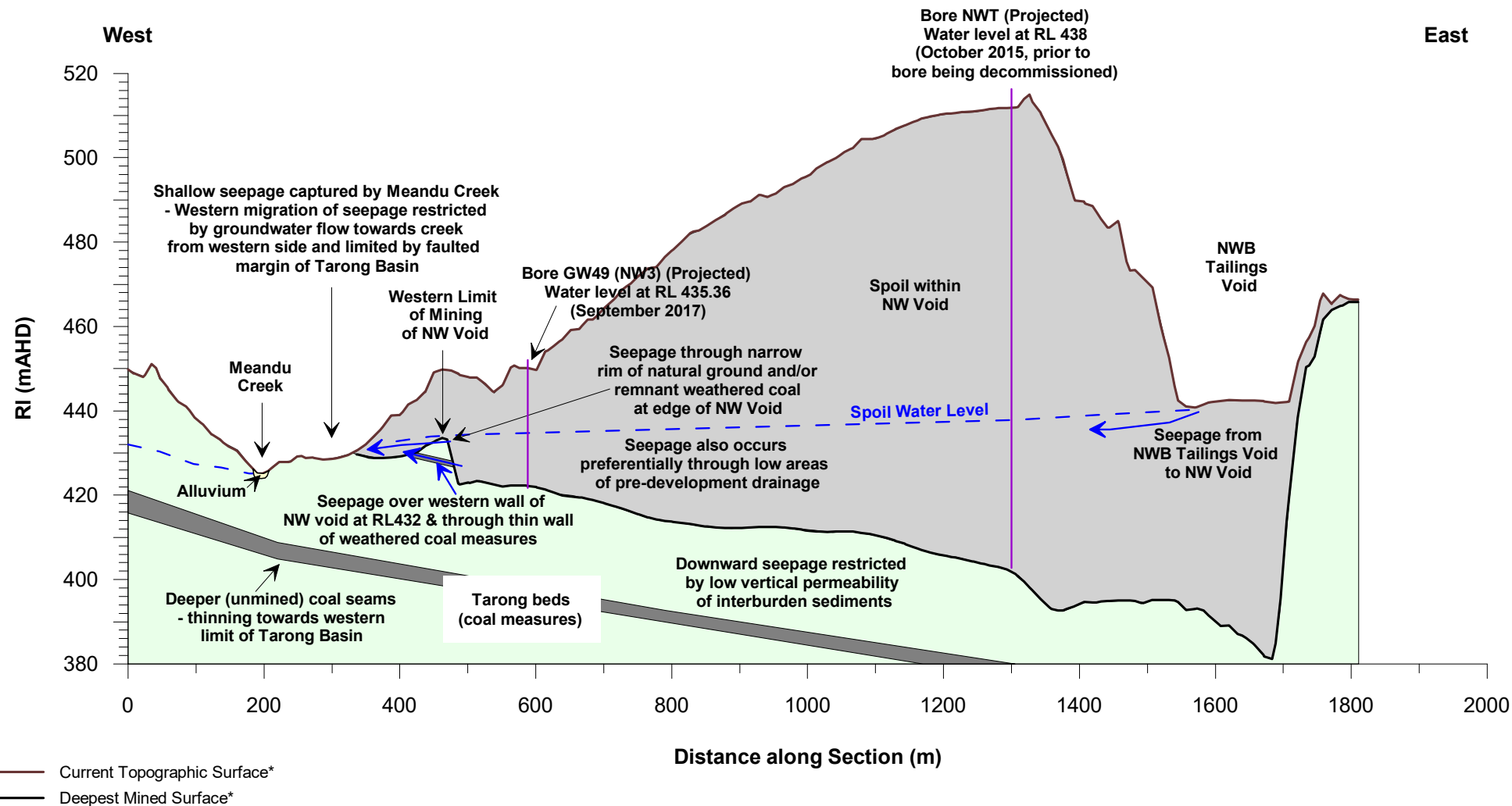
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Location of Geophysics Surveys	
CHECKED	DATE		
SCALE As Shown		PROJECT No. JBT01-012-059	FIGURE No. 42







	CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
	DRAWN JWB	DATE Aug 2018	TITLE Detail of NW Void and Potential Seepage Pathways	
	CHECKED	DATE		
	SCALE As Shown	A3	PROJECT No. JBT01-012-059	FIGURE No. 45

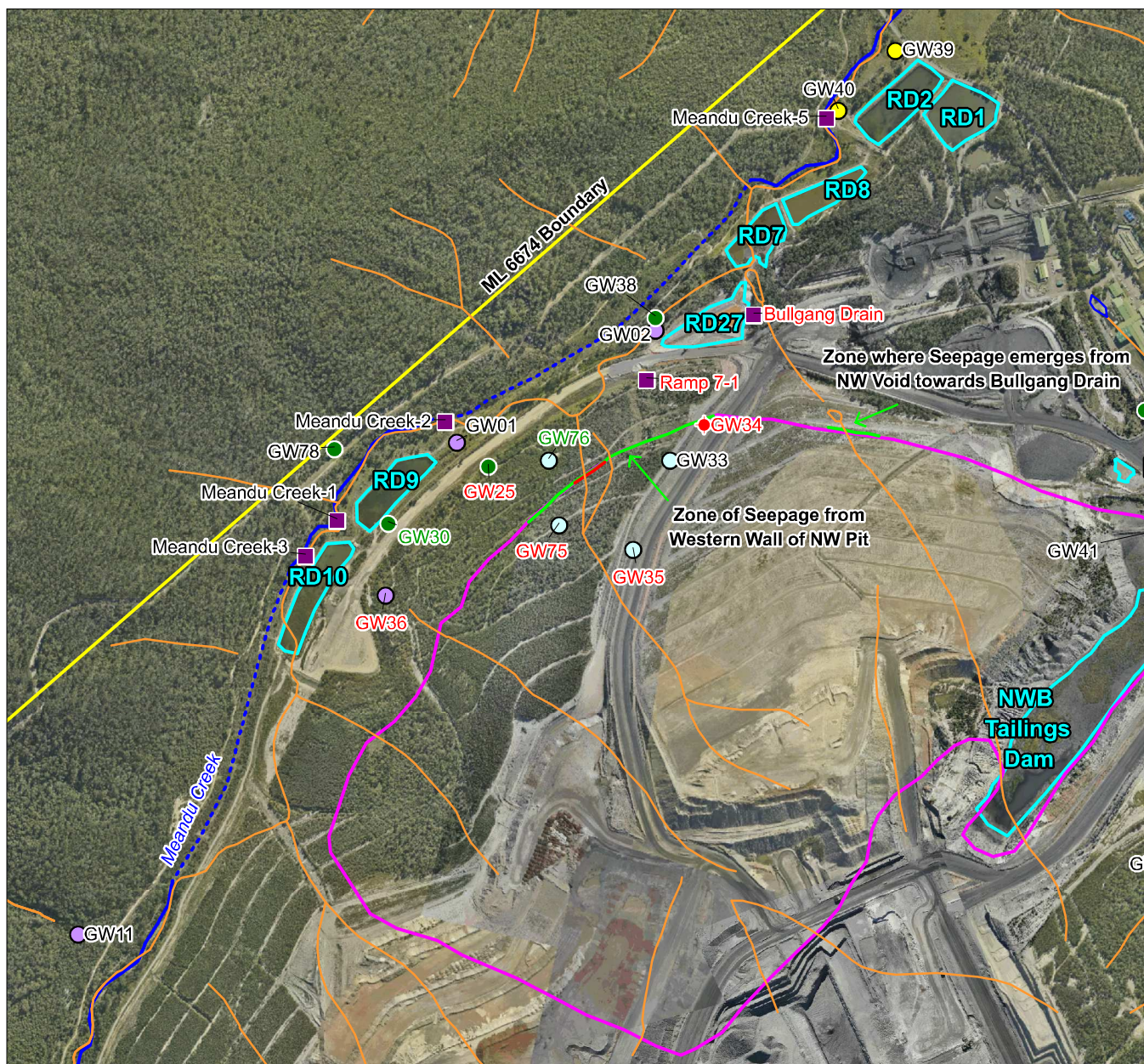


Vertical exaggeration
approximately 6x

* Deepest mined surface and current topography derived from modelled surfaces provided by Stanwell.
The geology of the Tarong beds is based on bore data but is schematic



CLIENT	Stanwell Corporation		PROJECT	Meandu Mine - Environmental Evaluation	
DRAWN	JWB	DATE	Aug 2018	TITLE Conceptual Section through NW Void	
CHECKED		DATE			
SCALE	As Shown		A4	PROJECT No.	FIGURE No.
				JBT01-012-059	46

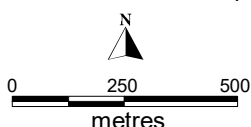


Lithology Screened

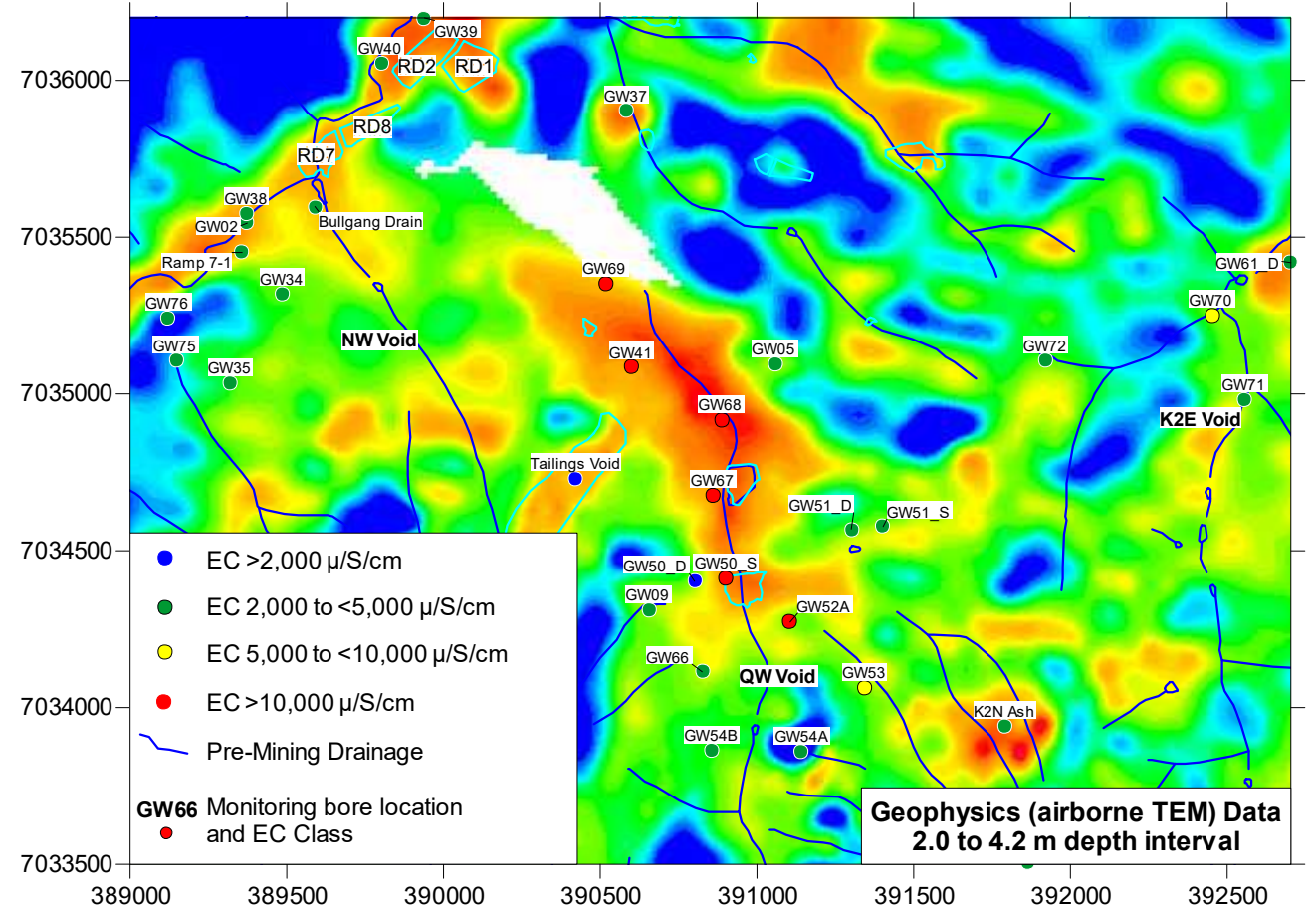
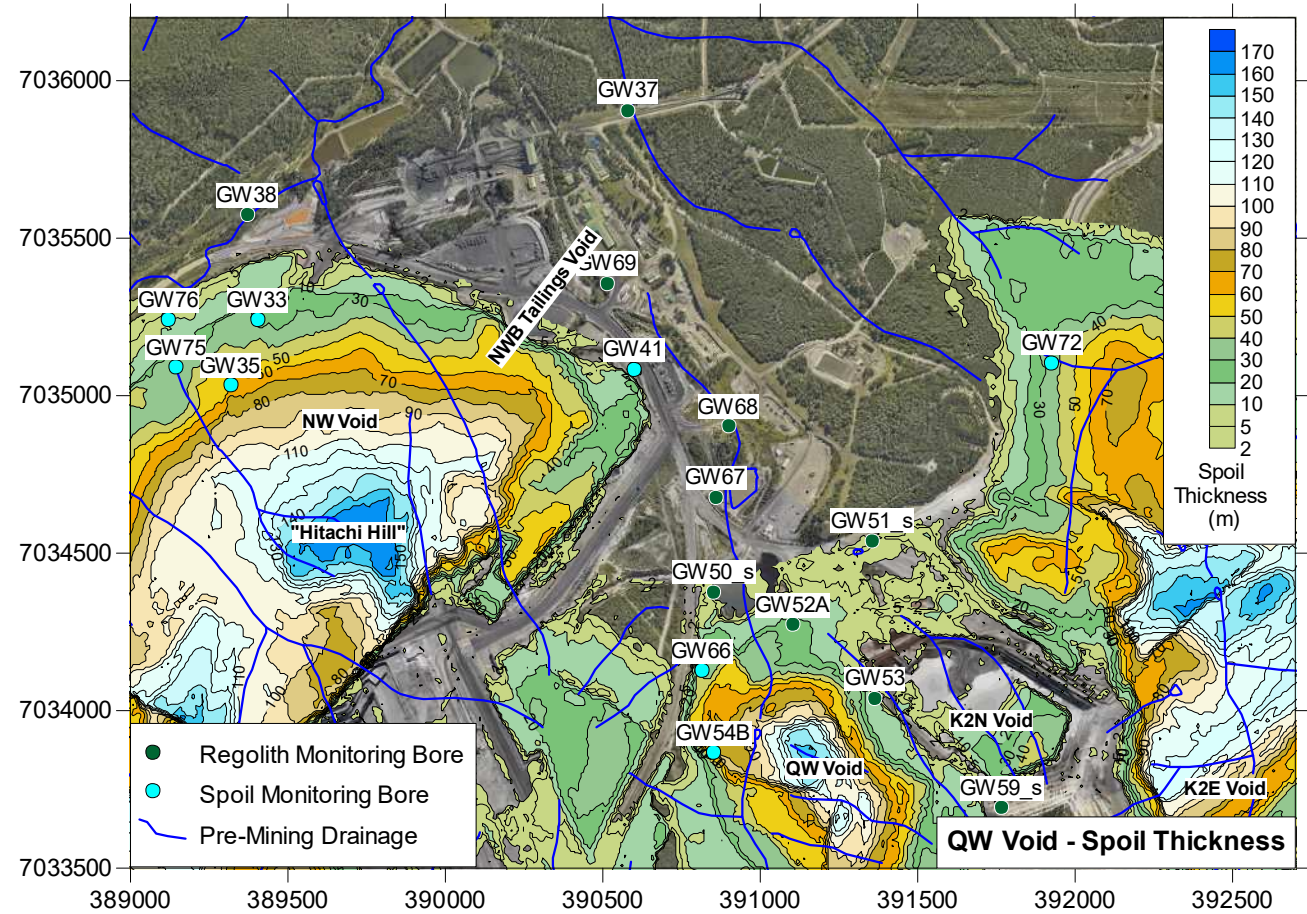
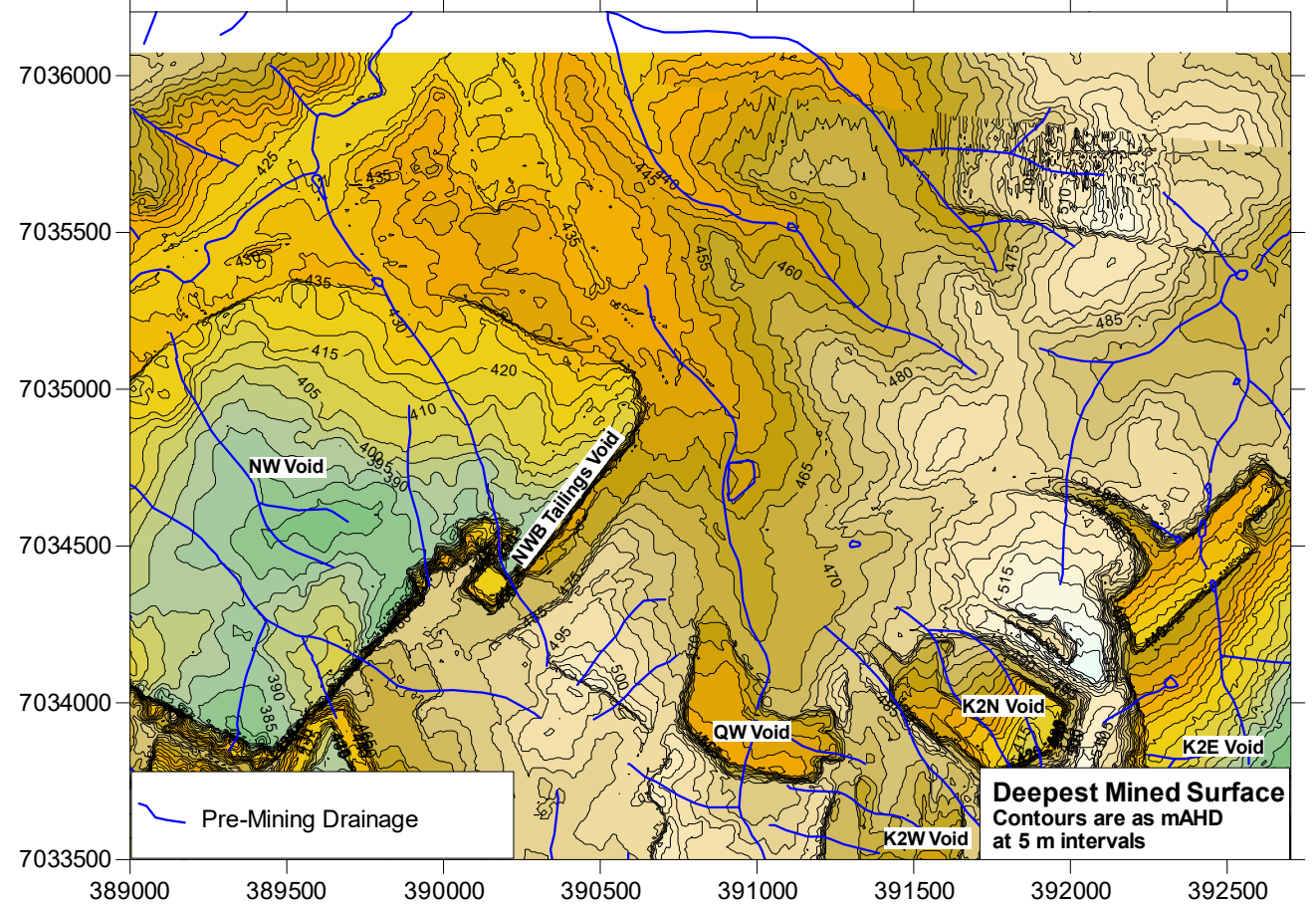
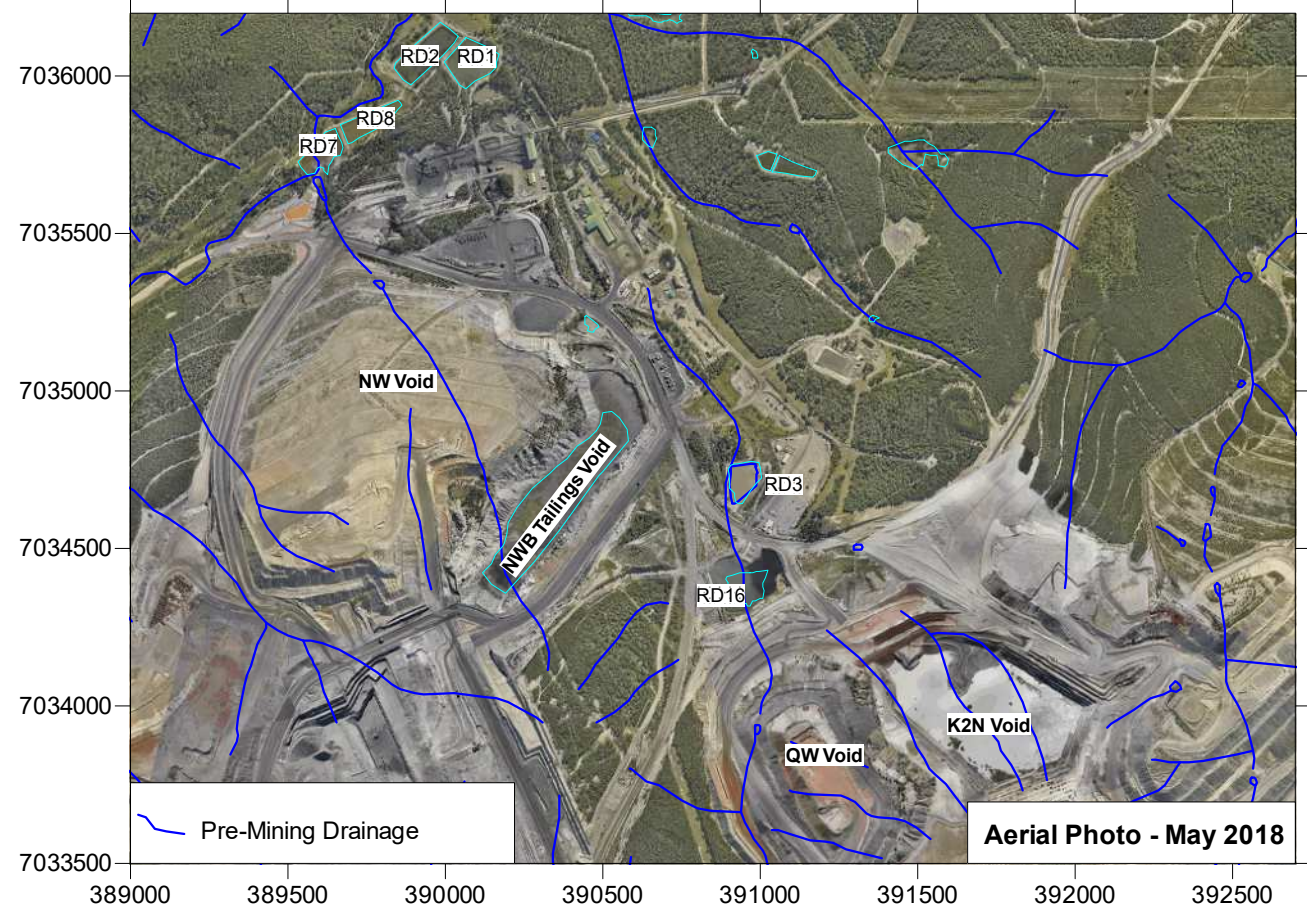
- Alluvium
- Basalt
- Spoil
- Regolith
- Ace Seam
- King Seam
- Queen Seam
- Coal Measures below Queen Seam
- Maronghi Creek beds
- Surface water sampling site

- Retention Dam
- Meandu Creek - Diverted Section
- Meandu Creek - Natural Section
- Pre-Mining Drainage
- Mined Limit of NW Void
- Seepage area from NW Void at RL432
- Seepage area from NW Void at RL435

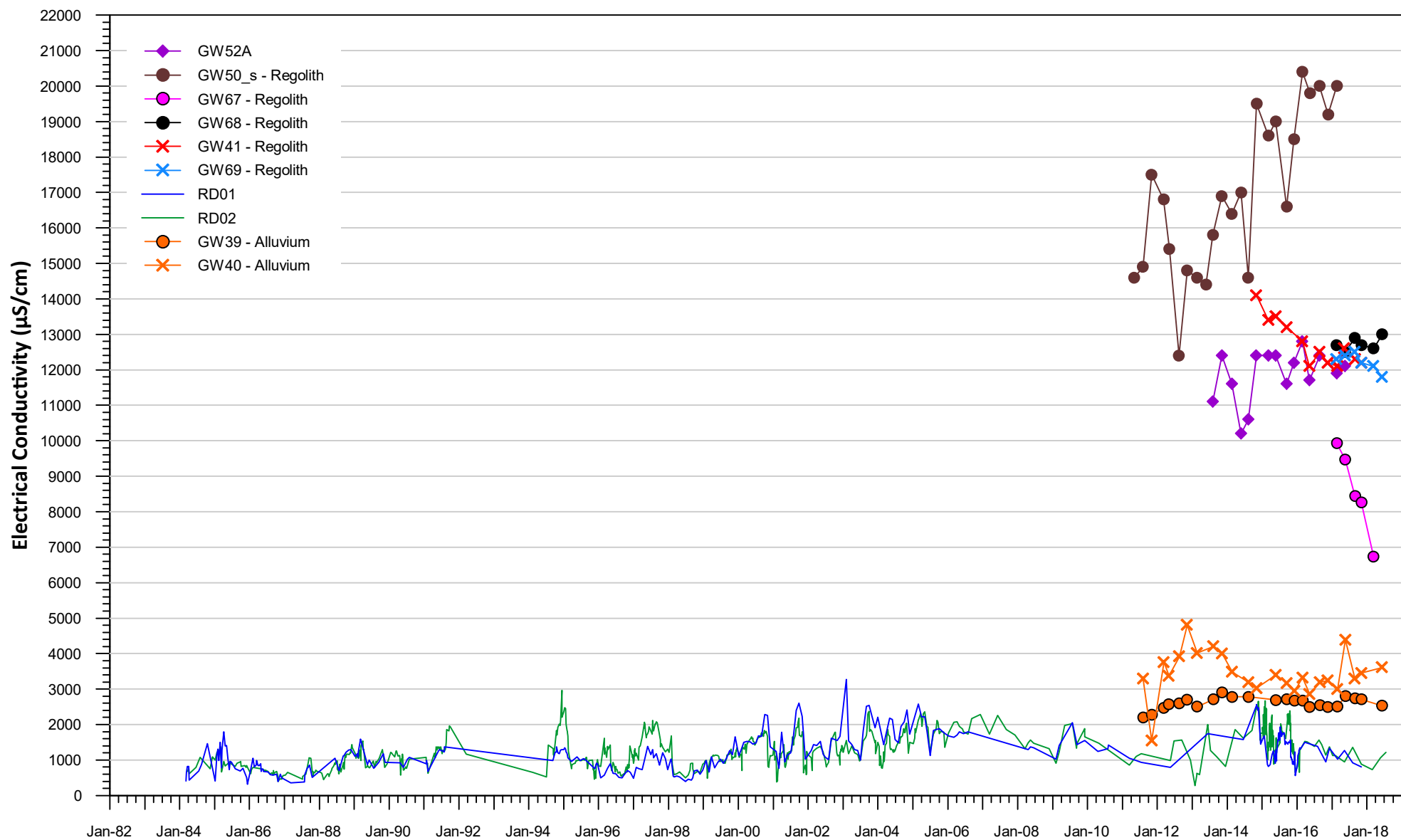
- GW 11 Sampling site - text colour indicates no AMD impact observed/inferred
- GW 25 Sampling site - text colour indicates AMD impact observed/inferred
- GW 30 Sampling site - text colour indicates that impacts from mining observed, but AMD impacts not yet inferred



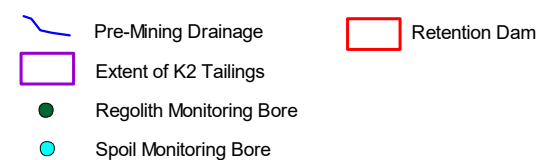
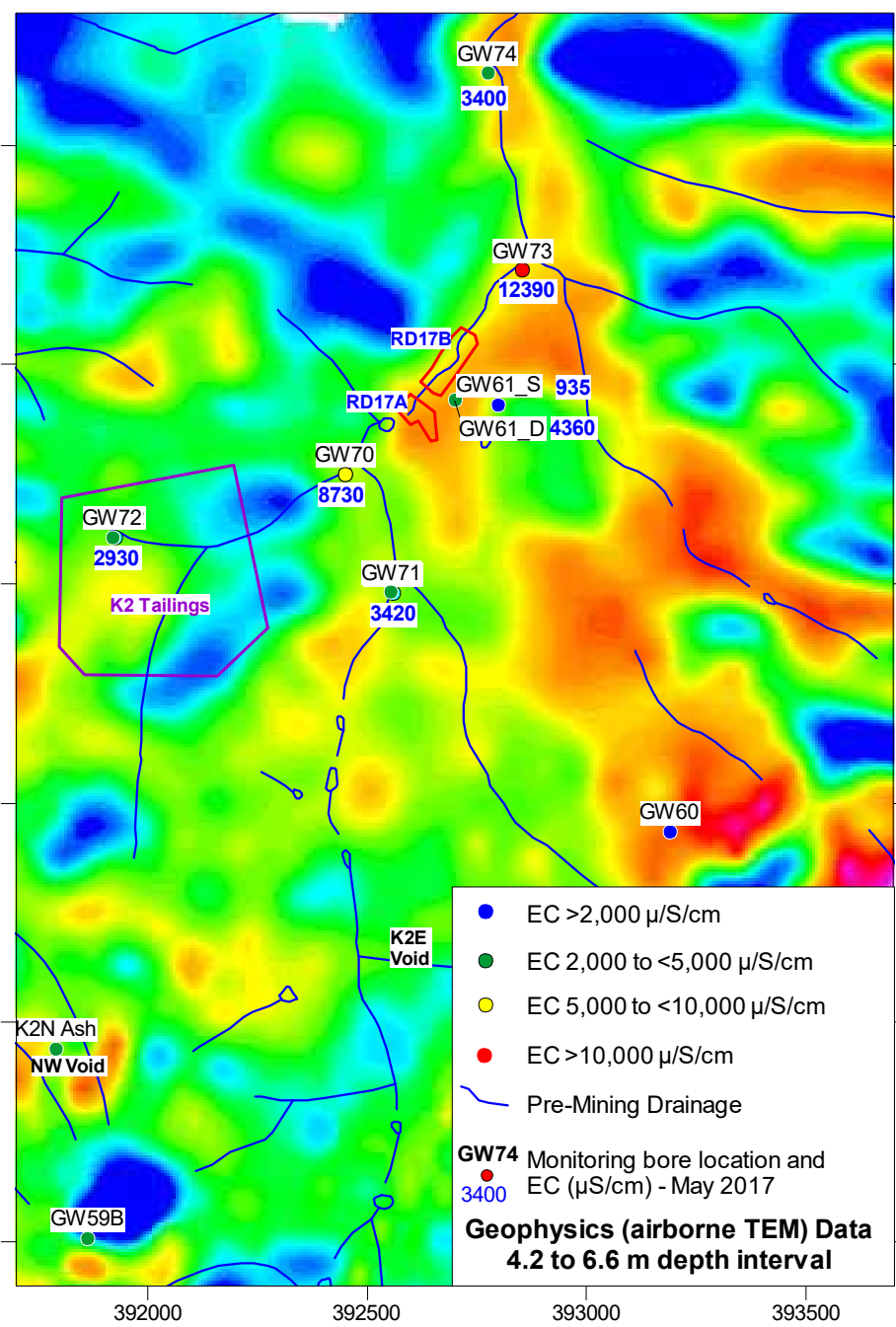
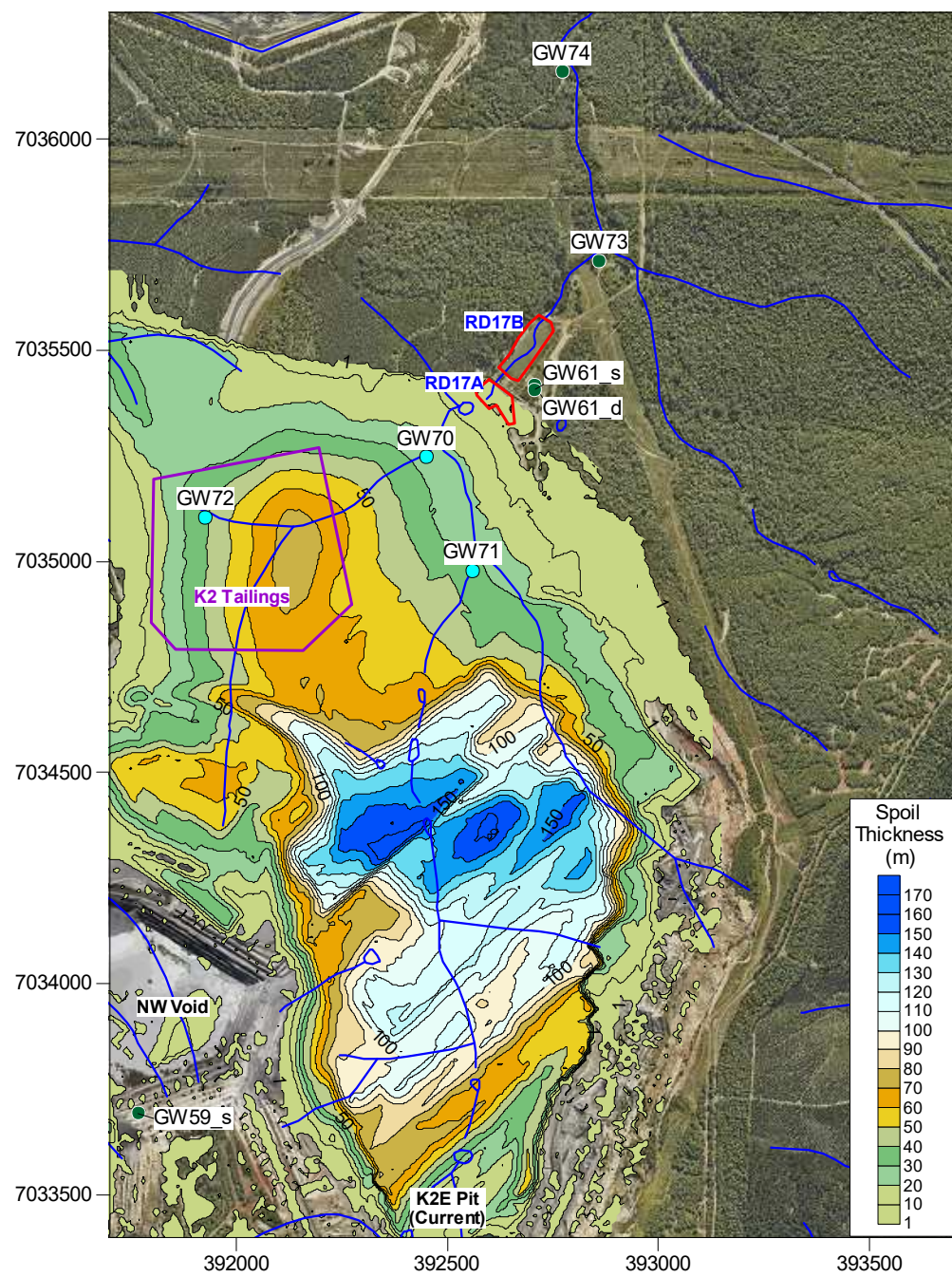
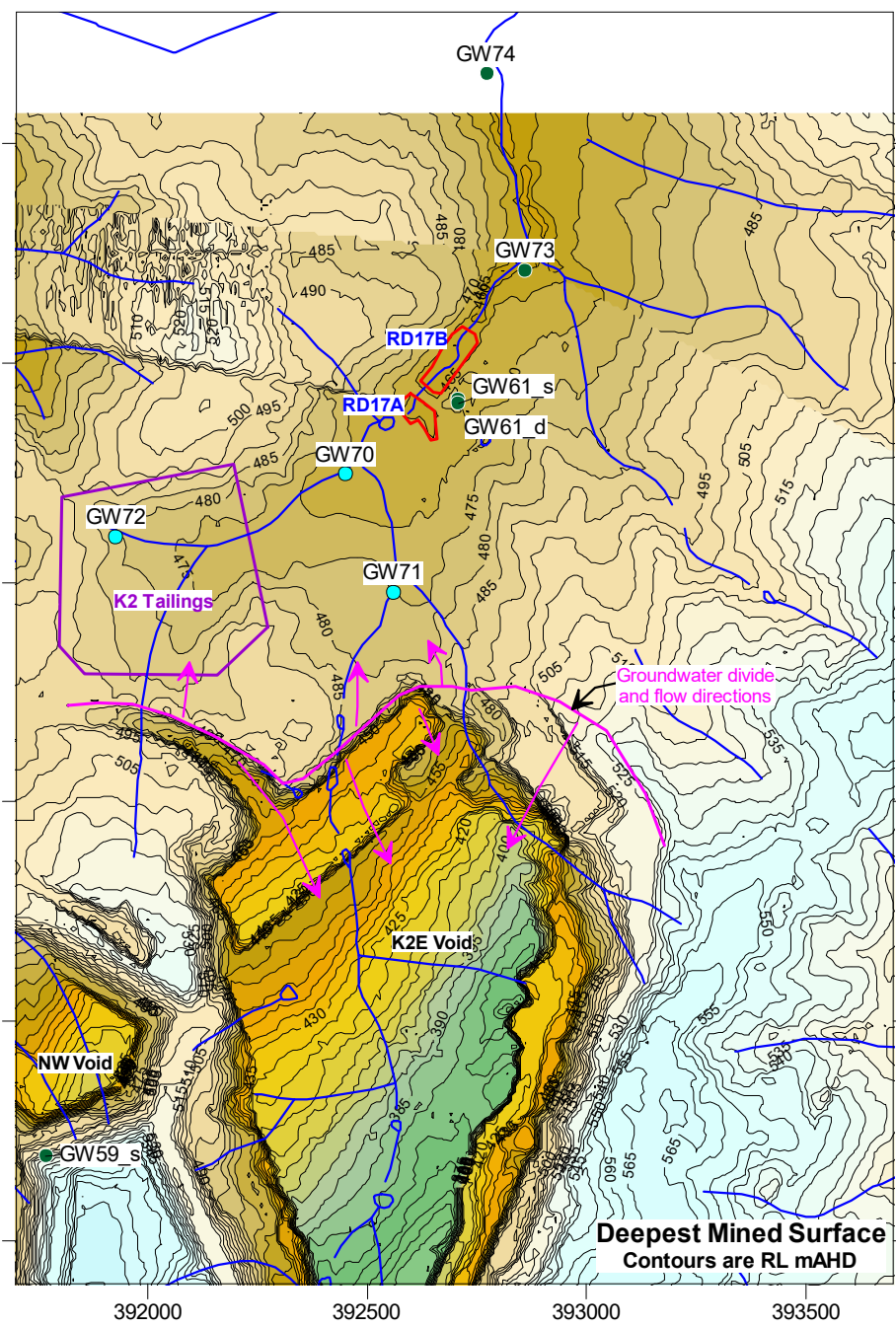
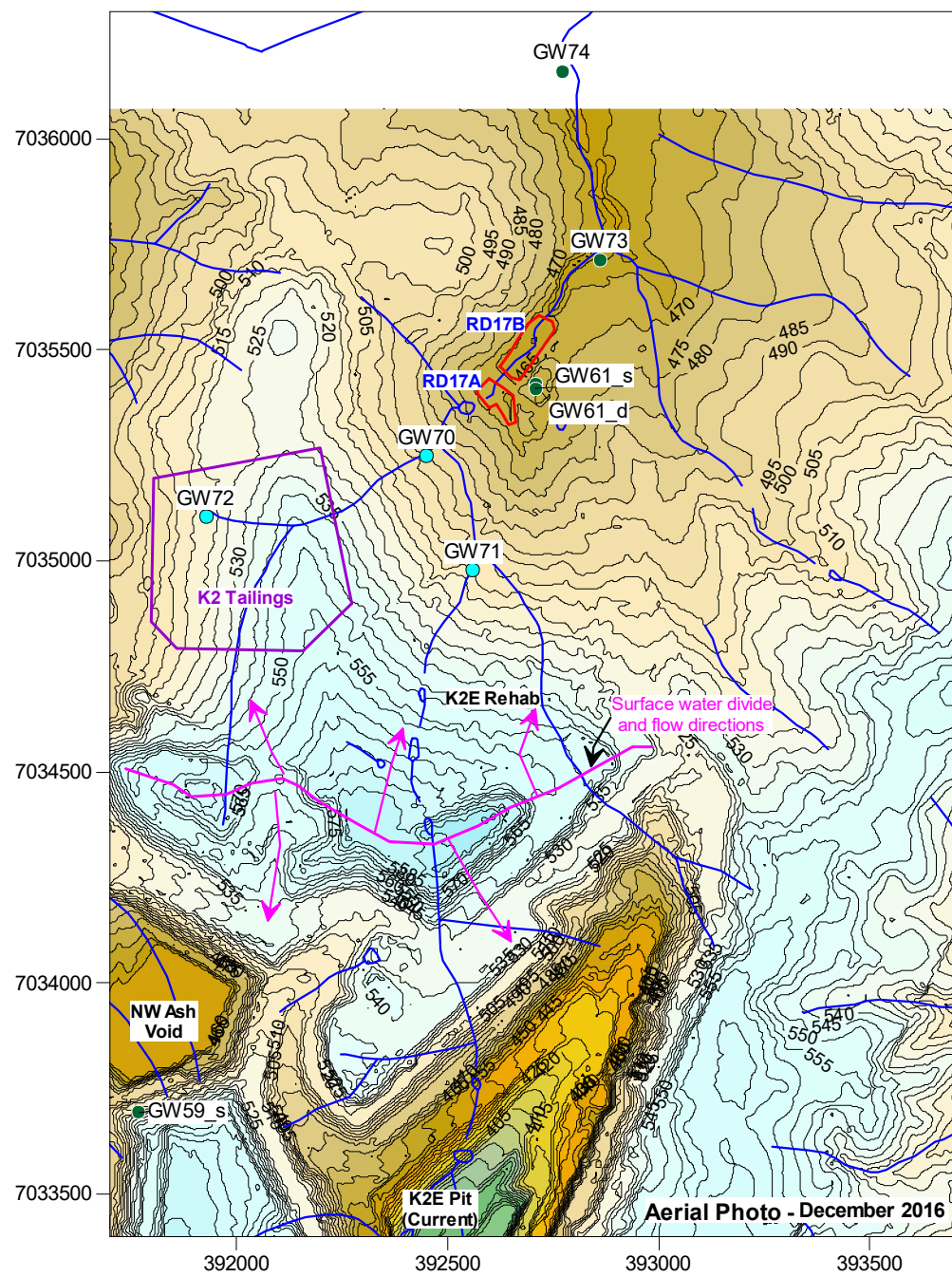
CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE AMD-Impacted Sites and Seepage Areas	
CHECKED	DATE		
SCALE 1:15,000	A4	PROJECT No JBT01-012-059	FIGURE No 47



	CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
	DRAWN JWB	DATE Aug 2018	TITLE Detail of Saline Plume to Northwest of QW Void	
	CHECKED	DATE		
	SCALE As Shown	A3	PROJECT No. JBT01-012-059	FIGURE No. 48



CLIENT Stanwell Corporation		PROJECT Meandu Mine - Environmental Evaluation	
DRAWN JWB	DATE Aug 2018	TITLE Electrical Conductivity (EC) Within/Downstream of High EC Plume	
CHECKED	DATE		
SCALE As Shown	A4	PROJECT No. JBT01-012-059	FIGURE No. 49



CLIENT Stanwell Corporation			PROJECT Meandu Mine - Environmental Evaluation		
DRAWN JWB		DATE Aug 2018		Groundwater Conditions within Black Creek Catchment	
CHECKED		DATE			
SCALE As Shown			A3	PROJECT No. JBT01-012-059	
				FIGURE No. 50	

APPENDIX A

WATER QUALITY RESULTS TABLES

Appendix A-1 – pH, EC, Major Ions and Fluoride

Appendix A-2 – Dissolved and Total Metals/Metalloids

Appendix A-3 – summary statistics for pH, EC, TDS, major ions, fluoride

Appendix A-4 - summary statistics for metals/metalloids

Appendix A1 - pH, EC, Major Ion and Fluoride Data

Site	Groundwater Unit Monitored	Sampled_Date-Time	pH (lab)	pH (field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
Bore	Unit Monitored	Date	pH_Units	pH_Units	uS/cm	uS/cm	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
GW01	Coal Measures below Queen Seam	16/08/1993	5.83	6.3	7960	9610	4450			250	206	1150	23	2590	195				159	
GW01	Coal Measures below Queen Seam	16/01/1997		6.14		8920														
GW01	Coal Measures below Queen Seam	5/03/1997		6.2		7190	4250		50	128	149	1200	21	2230	242				182	
GW01	Coal Measures below Queen Seam	12/05/1998		6.23		6860														
GW01	Coal Measures below Queen Seam	5/01/1999		6.3		6250														
GW01	Coal Measures below Queen Seam	8/06/1999		6.25		5660														
GW01	Coal Measures below Queen Seam	2/09/1999	6.67		6130				117	134	117	900	18	1820	181					
GW01	Coal Measures below Queen Seam	10/01/2000		6.26		5670														
GW01	Coal Measures below Queen Seam	18/07/2000		6.28		5685														
GW01	Coal Measures below Queen Seam	24/01/2001		6.17		5330	2930													
GW01	Coal Measures below Queen Seam	2/02/2001	7.06		6390				19	99	112	918	21	1440	205					
GW01	Coal Measures below Queen Seam	12/06/2001		6.24		5240	2910													
GW01	Coal Measures below Queen Seam	30/01/2002		6.11		5390	2670													
GW01	Coal Measures below Queen Seam	6/06/2002	7.16			3010			82	95	106	924	19	1660	209					0.2
GW01	Coal Measures below Queen Seam	2/08/2002		6.15		5100	2460													
GW01	Coal Measures below Queen Seam	15/10/2002	6.82		4920		3020		91	98	109	872	20	1720	206					0.2
GW01	Coal Measures below Queen Seam	16/01/2003		6.51		5290	2857													
GW01	Coal Measures below Queen Seam	4/07/2003		6.43		5410														
GW01	Coal Measures below Queen Seam	17/02/2004		6.43		5400														
GW01	Coal Measures below Queen Seam	14/07/2004		6.68		5390														
GW01	Coal Measures below Queen Seam	27/01/2005		6.64		5390														
GW01	Coal Measures below Queen Seam	29/06/2005		6.69		5380														
GW01	Coal Measures below Queen Seam	12/01/2006		6.65		5410														
GW01	Coal Measures below Queen Seam	2/01/2007		6.93		4810														
GW01	Coal Measures below Queen Seam	21/04/2008	6.79	6.62	4630	4589				118	108	897	17	1640	208				232	
GW01	Coal Measures below Queen Seam	25/11/2008	7.11		5520					104	108	958	16	1530	199				197	
GW01	Coal Measures below Queen Seam	28/10/2010	7.33		6280		3080			106	104	979	16	1530	203	<1	<1	231	231	0.1
GW01	Coal Measures below Queen Seam	26/10/2011		6.55		5180														
GW01	Coal Measures below Queen Seam	29/11/2016		6.4		5630														
GW01	Coal Measures below Queen Seam	8/03/2017	6.74	6.3		5600	3480		72	142	98	777	16	1460	130	<1	<1	216	216	0.2
GW01	Coal Measures below Queen Seam	16/05/2017	7.04		5060		3110	3290	25	145	92	738	15	1400	115	<1	<1	215	215	0.2
GW02	Regolith	16/08/1993	6.08	6.4	4330	4660	2300			124	89	655	33	1300	138				158	
GW02	Regolith	16/01/1997		7.25		2956														
GW02	Regolith	12/05/1998		6.85		2880														
GW02	Regolith	5/01/1999		7.15		2450														
GW02	Regolith	8/06/1999		6.99		2690														
GW02	Regolith	2/09/1999	7.58		2910				21	124	56	255	35	749	55					
GW02	Regolith	10/01/2000		6.96		2880														
GW02	Regolith	18/07/2000		6.98		2865														
GW02	Regolith	24/01/2001		6.93		2960	1580													
GW02	Regolith	2/02/2001	7.69		3570				8	144	68	362	40	870	65					
GW02	Regolith	12/06/2001		6.88		2910	1550													
GW02	Regolith	30/01/2002		6.73		3210	1570													
GW02	Regolith	6/06/2002	7.52		3250		1880		40	151	71	396	41	933	73					0.1
GW02	Regolith	2/08/2002		6.78		3070	1450													
GW02	Regolith	15/10/2002	7.45		3050		2000		26	148	73	380	42	994	76					<0.1
GW02	Regolith	16/01/2003		6.62		3280	1771													
GW02	Regolith	4/07/2003		6.62		3300														
GW02	Regolith	17/02/2004		6.32		3120														
GW02	Regolith	14/07/2004		6.79		3080														
GW02	Regolith	27/01/2005		6.47		3010														
GW02	Regolith	29/06/2005		6.45		2990														
GW02	Regolith	12/01/2006		6.41		2925														
GW02	Regolith	2/01/2007		6.44		2552														
GW02	Regolith	18/06/2008		6.64		2252														
GW02	Regolith	26/11/2008	7.22		2400					116	55	306	33	622	56				245	
GW02	Regolith	10/08/2010								110	53	305	30	602	61				253	
GW02	Regolith	28/10/2010	7.18		2660		1400			117	52	330	31	662	53	<1	<1	252	252	<0.1
GW02	Regolith	26/10/2011		6.85		2456														
GW02	Regolith	2/12/2016		6.43		3050														
GW02	Regolith	28/02/2017	7.39	6.37		3350	2010		12	182	73	361	36	870	55	<1	<1	198	198	0.1
GW05	Queen Seam	16/08/1993	7.24	7.1	1440	1667	780			49	20	230	14	344	27				206	
GW05	Queen Seam	16/01/1997		7.34		1701														
GW05	Queen Seam	12/05/1998		7.21		1611														
GW05	Queen Seam	5/01/1999		7.35		1620														
GW05	Queen Seam	8/06/1999		7.39		1445														
GW05	Queen Seam	10/01/2000		7.48		1440														
GW05	Queen Seam	18/07/2000		7.41		1435														
GW05	Queen Seam	24/01/2001		7.48		1444	750													
GW05	Queen Seam	12/06/2001		7.35		1512	761													
GW05	Queen Seam	30/01/2002		7.52		1459	688													
GW05	Queen Seam	2/08/2002		7.73		1428	710													
GW05	Queen Seam	16/01/2003		7.72		1469	793													
GW05	Queen Seam	4/07/2003		7.42		1459														
GW05	Queen Seam	17/02/2004		7.3		1490														
GW05	Queen Seam	14/07/2004		7.62		1528														
GW05	Queen Seam	27/01/2005		7.68		1508														
GW05	Queen Seam	29/06/2005		7.65		1532														
GW05	Queen Seam	12/01/2006		7.68		1556														
GW05	Queen Seam	2/01/2007		7.42		1490														
GW05	Queen Seam	21/04/2008	7.59	7.48	1300	1268				57	20	233	14	333	23				220	
GW05	Queen Seam	25/11/2008	7.25		2020					80	33	275	15	455	38				204	
GW05	Queen Seam	5/06/2009	7.56	7.56	2480		1450			86	37	319	14	612	48	61				0.1
GW05	Queen Seam	27/08/2009	7.76	7.76	2390		1370			95	39	352	18	551	56					0.1
GW05	Queen Seam	1/12/2009	7.53	7.53	2660		1270			80	34	293	18	567	46					0.1
GW05	Queen Seam	18/03/2010	7.54	7.54	2140		1230			88	35	299	18	594	44					0.1
GW05	Queen Seam	22/06/2010	7.73	7.73	2180		1210			89	36	319	16	658	46					<0.1
GW05	Queen Seam	8/02/2011	6.65	6.79	644		446			21	12	80	9	88	62					0.1
GW05	Queen Seam	3/05/2011	7.11	6.99	1580		1170			77	32	274	14	480	63	<1	<1	156	156	0.1
GW05	Queen Seam	4/08/2011	7.6	6.98	2770		1620			115	47	356	24	773	63	<1	<1	230	230	<0.1
GW05	Queen Seam	26/10/2011	7.13		2405															
GW05	Queen Seam	31/10/2011	7.71	7.13	2820		1790			114	46	362	18	724	68	<1	<1	242	242	<0.1

Appendix A1 - pH, EC, Major Ion and Fluoride Data

Site	Groundwater Unit Monitored	Sampled_Date-Time	pH (Lab)	pH (Field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
Bore	Unit Monitored	Date	pH_Units	pH_Units	uS/cm	uS/cm	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
GW05	Queen Seam	12/05/2016	7.67	6.9	2950	3097	1700	1920	<1	129	53	386	17	799	76	<1	<1	233	233	<0.1
GW05	Queen Seam	23/08/2016	7.71	6.89	3080	3191	1680	2000	16	130	54	388	18	810	78	<1	<1	246	246	<0.1
GW05	Queen Seam	23/11/2016		6.91		3046														
GW05	Queen Seam	17/02/2017	7.25	6.91		3040	1940		104	128	57	400	19	818	74	<1	<1	233	233	<0.1
GW05	Queen Seam	29/08/2017	7.84		2930		1660	1904.5	12	113	53	384	18	879	73	<1	<1	252	252	<0.1
GW09	Sandstone below Queen Seam	16/08/1993	5.2	5.2	6450	6960	3760			39	228	953	46	1890	480				21	
GW09	Sandstone below Queen Seam	16/01/1997		6.03		1895														
GW09	Sandstone below Queen Seam	12/05/1998		6		1776														
GW09	Sandstone below Queen Seam	5/01/1999		5.95		1705														
GW09	Sandstone below Queen Seam	8/06/1999		5.85		1575														
GW09	Sandstone below Queen Seam	10/01/2000		6.03		1658														
GW09	Sandstone below Queen Seam	18/07/2000		6.06		1640														
GW09	Sandstone below Queen Seam	24/01/2001		6.03		1652	860													
GW09	Sandstone below Queen Seam	12/06/2001		6.06		1687	875													
GW09	Sandstone below Queen Seam	30/01/2002		5.76		1762	837													
GW09	Sandstone below Queen Seam	2/08/2002		5.78		1782	896													
GW09	Sandstone below Queen Seam	16/01/2003		5.92		1740	940													
GW09	Sandstone below Queen Seam	4/07/2003		5.94		1750														
GW09	Sandstone below Queen Seam	17/02/2004		5.72		2020														
GW09	Sandstone below Queen Seam	14/07/2004		5.73		3150														
GW09	Sandstone below Queen Seam	27/01/2005		5.38		4370														
GW09	Sandstone below Queen Seam	29/06/2005		5.75		4280														
GW09	Sandstone below Queen Seam	12/01/2006		5.78		4270														
GW09	Sandstone below Queen Seam	2/01/2007		5.51		4440														
GW09	Sandstone below Queen Seam	21/04/2008	5.55	5.62	4480	4392				34	200	726	45	1560	353				6	
GW09	Sandstone below Queen Seam	26/11/2008	5.31		5060					30	213	754	43	1490	364				20	
GW09	Sandstone below Queen Seam	19/10/2009	5.16		5350		3580			34	269	890	61	1880	448	<1	<1	<1	<1	0.5
GW09	Sandstone below Queen Seam	3/11/2010	5.43		5330		2920			29	194	802	46	1460	371	<1	<1	25	25	

Appendix A1 - pH, EC, Major Ion and Fluoride Data

Site	Groundwater Unit Monitored	Sampled_Date-Time	pH (lab)	pH (field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
Bore	Unit Monitored	Date	pH_Units	pH_Units	uS/cm	uS/cm	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
GW25	Regolith	24/01/2001					624													
GW25	Regolith	12/06/2001					685													
GW25	Regolith	23/07/2001	5.47		926		568		64	4	16	138	8	202	79					
GW25	Regolith	30/01/2002					327													
GW25	Regolith	2/08/2002					457													
GW25	Regolith	16/01/2003					562													
GW25	Regolith	7/07/2003	5.9		1080		620		16	4	19	177	6	221	118					
GW25	Regolith	27/07/2004	5.76		851		472		40	2	13	140	6	186	72					
GW25	Regolith	29/06/2005	6.11		1040		558		65	2	16	155	7	278	82					
GW25	Regolith	12/01/2006		6.13		1070														
GW25	Regolith	2/01/2007		6.05		1102														
GW25	Regolith	26/11/2008	5.27		1300					3	21	219	3	315	94				14	
GW25	Regolith	10/08/2010																		
GW25	Regolith	3/11/2010	5.48		1690		1030			12	51	281	6	309	358	<1	<1	18	18	<0.1
GW25	Regolith	26/10/2011		4.78		1388														
GW25	Regolith	12/03/2015	5.68		1760		1220	1140		32	84	197	16	241	550	<1	<1	8	8	<0.1
GW25	Regolith	24/05/2015	5.38		1620		1040	1050		30	65	177	16	220	526	<1	<1	8	8	<0.1
GW25	Regolith	15/09/2015	5.42		2350		1530	1530		46	105	226	12	460	572	<1	<1	4	4	0.1
GW25	Regolith	3/12/2015	5.84		1550		963	1010		25	58	165	11	280	369	<1	<1	6	6	<0.1
GW25	Regolith	28/02/2016	6.57		1940		1270	1260		30	73	209	13	350	411	<1	<1	9	9	<0.1
GW25	Regolith	12/05/2016	5.6		2180		1460	1420	12	36	92	259	14	452	463	<1	<1	26	26	<0.1
GW25	Regolith	27/08/2016	5.54	5.1	2270	2314	1500	1480	32	34	90	262	12	457	452	<1	<1	22	22	<0.1
GW25	Regolith	22/11/2016	5.48	5.17	1990	2000	1290		8	45	80	239	11	422	399		<1	16	16	<0.1
GW25	Regolith	7/03/2017	6.98	5.3	5820	1720	3780		152	78	137	896	31	1550	376	<1	<1	101	101	<0.1
GW25	Regolith	16/05/2017	5.91		1770		1210	1150	48	20	63	229	12	363	302	<1	<1	35	35	<0.1
GW25	Regolith	4/09/2017	6.68		1490		857	968.5	18	16	50	197	9	309	197	<1	<1	66	66	<0.1
GW30	Regolith	29/06/2005	6.16		1740		1040		18	3	16	278	6	501	74					
GW30	Regolith	12/01/2006		6.23		1785														
GW30	Regolith	2/01/2007		5.71		8400														
GW30	Regolith	12/05/2009		7.28		8900	5080			60	218	1590	36	2960	210				11	<0.1
GW30	Regolith	28/10/2010	5.53		7520		4330			45	157	1360	24	2580	150	<1	<1	28	28	<0.1
GW30	Regolith	26/10/2011		4.65		9650														
GW30	Regolith	29/11/2016		5.31		7875														
GW30	Regolith	7/03/2017	6.59	5.33	7310	7400	4750		222	55	156	1160	28	2250	177	<1	<1	66	66	<0.1
GW34	Regolith - Coal/interburden	5/08/2011								153	96	572	45	985	653	<1	<1	132	132	
GW34	Regolith - Coal/interburden	4/11/2011								120	94	772	37	1050	764	<1	<1	99	99	
GW34	Regolith - Coal/interburden	10/03/2012								108	91	680	36	954	716	<1	<1	99	99	
GW34	Regolith - Coal/interburden	3/05/2012								178	80	425	43	713	619	<1	<1	205	205	
GW34	Regolith - Coal/interburden	18/08/2012					2690			120	86	560	41	864	612	<1	<1	104	104	
GW34	Regolith - Coal/interburden	9/11/2012					1430			105	80	588	35	850	579	<1	<1	72	72	
GW34	Regolith - Coal/interburden	21/02/2013					2280			99	77	576	31	778	666	<1	<1	66	66	
GW34	Regolith - Coal/interburden	27/05/2013					2080			108	78	491	36	741	482	<1	<1	128	128	
GW34	Regolith - Coal/interburden	8/08/2013	6.98		3120		1910			123	80	461	44	790	357	<1	<1	116	116	0.2
GW34	Regolith - Coal/interburden	9/11/2013	6.7		3290		2040			122	77	467	45	786	457	<1	<1	126	126	0.2
GW34	Regolith - Coal/interburden	23/02/2014					2120			117	74	437	45	783	419	<1	<1	109	109	
GW34	Regolith - Coal/interburden	3/11/2014	6.59		3340		2660	2170		118	73	429	38	684	516	<1	<1	85	85	0.2
GW34	Regolith - Coal/interburden	27/05/2015	6.4		3220		1920	2090		115	66	427	34	715	515	<1	<1	121	121	0.3
GW34	Regolith - Coal/interburden	16/09/2015	6.87		2950		1800	1920		125	63	341	32	759	338	<1	<1	131	131	0.2
GW34	Regolith - Coal/interburden	8/12/2015	6.87		2920		1890	1900		125	71	367	38	683	358	<1	<1	154	154	0.2
GW34	Regolith - Coal/interburden	29/02/2016	7.79		3000		1790	1950		132	67	325	37	686	344	<1	<1	141	141	0.1
GW34	Regolith - Coal/interburden	14/05/2016	6.92		2620		1550	1700	<1	146	62	256	38	668	214	<1	<1	190	190	<0.1
GW34	Regolith - Coal/interburden	28/08/2016	6.65	6.08	3070	3138	1860	2000	14	114	67	378	36	677	428	<1	<1	146	146	0.2
GW34	Regolith - Coal/interburden	16/11/2016	6.8		2750		1790		7	123	68	315	38	711	256		<1	186	186	0.1
GW34	Regolith - Coal/interburden	3/03/2017	6.88	5.91	3110	3370	2020		148	113	73	424	37	688	462	<1	<1	107	107	0.2
GW34	Regolith - Coal/interburden	23/05/2017	7.49		3240		1860	2110	74	117	76	421	38	669	444	<1	<1	104	104	0.2
GW34	Regolith - Coal/interburden	4/09/2017	7.59		2780		1580	1807	18	149	71	282	43	674	210	<1	<1	184	184	<0.1
GW35	Spoil	5/08/2011								75	156	187	46	429	547	<1	<1	225	225	
GW35	Spoil	4/11/2011								45	131	176	39	299	525	<1	<1	219	219	
GW35	Spoil	10/03/2012								52	141	154	40	281	524	<1	<1	244	244	
GW35	Spoil	3/05/2012								51	165	137	42	265	623	<1	<1	218	218	
GW35	Spoil	17/08/2012					1630			50	162	143	48	262	626	<1	<1	237	237	
GW35	Spoil	9/11/2012					1510			50	151	144	42	255	544	<1	<1	241	241	
GW35	Spoil	21/02/2013					1530			52	156	142	40	250	606	<1	<1	258	258	
GW35	Spoil	26/05/2013					1640			53	168	138	46	270	590	<1	<1	276	276	
GW35	Spoil	8/08/2013					1510			52	172	138	48	293	609	<1	<1	231	231	
GW35	Spoil	9/11/2013					1630			55	194	126	51	265	678	<1	<1	267	267	
GW35	Spoil	22/02/2014					1710			58	169	129	51	244	624	<1	<1	282	282	
GW35	Spoil	11/08/2014					1470			51	175	129	50	257	605	<1	<1	252	252	
GW35	Spoil	3/11/2014					1250			52	171	118	52	234	510	<1	<1	237	237	
GW35	Spoil	27/05/2015	6.52		2170		1500	1410		53	192	116	51	225	700	<1	<1	304	304	0.3
GW35	Spoil	16/09/2015	6.81		2170		1530	1410		52	175	96	47	244	647	<1	<1	298	298	0.3
GW35	Spoil	8/12/2015	6.8		2150		1740	1400		55	200	104	58	223	665	<1	<1	317	317	0.3
GW35	Spoil	29/02/2016	7.93		2340		1660	1520		56	193	100	57	230	680	<1	<1	308	308	0.2
GW36	Regolith - Coal/interburden	5/08/2011								54	60	260	32	652	48	<1	<1	105	105	
GW36	Regolith - Coal/interburden	4/11/2011								51	65	315	30	734	55	<1	<1	106	106	
GW36	Regolith - Coal/interburden	10/03/2012								58	79	347	32	817	71	<1	<1	105	105	
GW36	Regolith - Coal/interburden	2/05/2012								51	69	275	31	713	53	<1	<1	87	87	
GW36	Regolith - Coal/interburden	18/08/2012					1800			52	65	272	32	686	48	<1	<1	93	93	
GW36	Regolith - Coal/interburden	9/11/2012					1510			54	61	272	29	696	43	<1	<1	54	54	
GW36	Regolith - Coal/interburden	27/05/2013					1080</													

Appendix A1 - pH, EC, Major Ion and Fluoride Data

Site	Groundwater Unit Monitored	Sampled_Date-Time	pH (lab)	pH (field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
Bore	Unit Monitored	Date	pH_Units	pH_Units	uS/cm	uS/cm	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
GW37	Regolith - Sandstone	9/12/2015	6.65		4150		2630	2700		114	124	522	25	1300	35	<1	<1	103	103	0.2
GW37	Regolith - Sandstone	29/02/2016	6.81		4600		2660	2990		117	121	506	25	1480	36	<1	<1	46	46	0.1
GW37	Regolith - Sandstone	15/05/2016	6.47		4390		2520	2850	13	113	116	502	24	1410	35	<1	<1	107	107	0.2
GW37	Regolith - Sandstone	28/08/2016	6.51	5.93	4440	4538	2520	2890	78	111	118	513	24	1310	36	<1	<1	106	106	0.2
GW37	Regolith - Sandstone	17/11/2016	6.26		4410		2870		43	105	119	504	24	1410	36		<1	93	93	0.2
GW37	Regolith - Sandstone	3/03/2017	6.35	5.88	4360	4790	2830		131	114	126	544	25	1330	33	<1	<1	38	38	0.2
GW37	Regolith - Sandstone	23/05/2017	6.51		4580		2780	2980	108	117	131	545	25	1180	32	<1	<1	43	43	0.2
GW37	Regolith - Sandstone	29/08/2017	6.66		4410		2560	2866.5	68	102	122	524	26	1510	35	<1	<1	78	78	0.2
GW38	Regolith - Sandstone	5/08/2011								111	68	413	36	898	85	<1	<1	204	204	
GW38	Regolith - Sandstone	3/11/2011								110	63	407	30	826	85	<1	<1	205	205	
GW38	Regolith - Sandstone	10/03/2012								126	122	738	33	1370	156	<1	<1	180	180	
GW38	Regolith - Sandstone	2/05/2012								128	93	506	35	1040	131	<1	<1	180	180	
GW38	Regolith - Sandstone	17/08/2012					3590			102	128	750	31	1320	240	<1	<1	154	154	
GW38	Regolith - Sandstone	8/11/2012					2260			123	85	502	32	1000	94	<1	<1	189	189	
GW38	Regolith - Sandstone	20/02/2013					3630			125	134	894	33	1620	220	<1	<1	150	150	
GW38	Regolith - Sandstone	27/05/2013					2060			121	85	487	31	983	109	<1	<1	204	204	
GW38	Regolith - Sandstone	8/08/2013	7.4		3260		1880			117	82	474	36	993	87	<1	<1	197	197	0.1
GW38	Regolith - Sandstone	9/11/2013	7.08		3020		1760			87	61	460	31	847	94	<1	<1	210	210	0.2
GW38	Regolith - Sandstone	22/02/2014	8.47		2560		1660			77	50	387	26	678	70	<1	20	185	204	0.2
GW38	Regolith - Sandstone	4/11/2014	7.18		2560		1310	1660		76	48	366	26	613	58	<1	<1	204	204	0.4
GW38	Regolith - Sandstone	27/05/2015	6.36		6630		3970	4310		137	162	1020	32	1710	326	<1	<1	132	132	0.2
GW38	Regolith - Sandstone	16/09/2015	6.6		6370		3790	4140		127	147	814	29	1930	288	<1	<1	143	143	0.2
GW38	Regolith - Sandstone	8/12/2015	6.7		1		4070	<1		120	149	960	31	<1	<1	<1	<1	152	154	<0.1
GW38	Regolith - Sandstone	29/02/2016	7.77		5200		2980	3380		138	116	663	33	1510	179	<1	<1	174	174	0.2
GW38	Regolith - Sandstone	14/05/2016	6.7		4800		2720	3120	2	122	103	672	30	1370	218	<1	<1	190	190	0.2
GW38	Regolith - Sandstone	28/08/2016	6.63	6.1	5490	5364	3080	3570	24	136	120	731	34	1520	199	<1	<1	167	178	0.2
GW38	Regolith - Sandstone	16/11/2016	6.71		4110		2670		4	94	81	583	27	1190	161		<1	203	203	0.2
GW38	Regolith - Sandstone	1/03/2017	7.13	6.37	2770	2980	1800		<1	70	52	434	24	770	81	<1	<1	213	213	0.2
GW38	Regolith - Sandstone	23/05/2017	7.71		4810		2640	3130	44	122	103	640	31	1120	156	<1	<1	199	199	0.2
GW39	Meandu Creek Alluviumy	5/08/2011								37	34	425	9	686	183	<1	<1	127	127	
GW39	Meandu Creek Alluviumy	3/11/2011								35	36	471	8	635	176	<1	<1	126	126	
GW39	Meandu Creek Alluviumy	10/03/2012								32	36	420	8	604	147	<1	<1	120	120	
GW39	Meandu Creek Alluviumy	1/05/2012								33	39	391	8	636	180	<1	<1	104	104	
GW39	Meandu Creek Alluviumy	17/08/2012					1710			40	42	433	9	671	175	<1	<1	113	113	
GW39	Meandu Creek Alluviumy	8/11/2012					1480			42	42	471	8	670	134	<1	<1	120	120	
GW39	Meandu Creek Alluviumy	20/02/2013					1460			28	34	408	7	582	146	<1	<1	108	108	
GW39	Meandu Creek Alluviumy	27/05/2013					1430			33	40	416	7	675	170	<1	<1	115	115	
GW39	Meandu Creek Alluviumy	8/08/2013					1420			36	43	482	8	765	167	<1	<1	108	108	
GW39	Meandu Creek Alluviumy	9/11/2013					1530			36	44	484	10	766	185	<1	<1	109	109	
GW39	Meandu Creek Alluviumy	22/02/2014					1630			32	43	453	11	746	175	<1	<1	95	95	
GW39	Meandu Creek Alluviumy	12/08/2014					1440			32	46	534	9	712	186	<1	<1	108	108	
GW39	Meandu Creek Alluviumy	4/11/2014					1510			34	46	443	9	667	178	<1	<1	99	99	
GW39	Meandu Creek Alluviumy	27/05/2015	6.59		2690		1490	1750		33	41	472	8	722	197	<1	<1	115	115	0.3
GW39	Meandu Creek Alluviumy	16/09/2015	6.93		2720		1490	1760		32	<1	414	<1	<1	198	<1	<1	5	120	0.3
GW39	Meandu Creek Alluviumy	7/12/2015	7.08		2670		1520	1740		30	41	434	8	667	191	<1	<1	124	124	0.3
GW39	Meandu Creek Alluviumy	29/02/2016	7.81		2680		1500	1740		30	41	422	8	683	194	<1	<1	115	115	0.2
GW39	Meandu Creek Alluviumy	14/05/2016	6.69		2500		1420	1620	1	27	38	408	8	677	204	<1	<1	115	115	0.2
GW39	Meandu Creek Alluviumy	28/08/2016	6.7	6.09	2550	2691	1420	1660	13	29	38	415	8	640	190	<1	<1	118	118	0.2
GW39	Meandu Creek Alluviumy	17/11/2016	6.58		2500		1620		7	29	38	413	8	677	204		<1	119	119	0.2
GW39	Meandu Creek Alluviumy	1/03/2017	6.81	5.99	2510	2700	1630		<1	28	40	448	8	668	196	<1	<1	106	106	0.2
GW39	Meandu Creek Alluviumy	22/05/2017	7.43		2800		1490	1820	21	30	46	463	9	652	198	<1	<1	118	118	0.2
GW39	Meandu Creek Alluviumy	29/08/2017	7.24		2740		1540	1781	12	37	39	454	10	775	193	<1	<1	126	126	0.2
GW40	Meandu Creek Alluvium	5/08/2011								36	98	548	4	1150	174	<1	<1	46	46	
GW40	Meandu Creek Alluvium	3/11/2011								30	86	537	2	911	184	<1	<1	52	52	
GW40	Meandu Creek Alluvium	10/03/2012								29	101	557	2	994	137	<1	<1	38	38	
GW40	Meandu Creek Alluvium	1/05/2012								30	91	442	2	842	191	<1	<1	53	53	
GW40	Meandu Creek Alluvium	17/08/2012					2450			29	115	577	3	1070	147	<1	<1	25	25	
GW40	Meandu Creek Alluvium	8/11/2012					2760			35	139	763	3	1410	123	<1	<1	21	21	
GW40	Meandu Creek Alluvium	20/02/2013					2640			30	116	682	3	1190	140	<1	<1	28	28	
GW40	Meandu Creek Alluvium	27/05/2013					2280			27	115	618	2	1120	127	<1	<1	24	24	
GW40	Meandu Creek Alluvium	8/08/2013					2170			31	118	646	2	1230	138	<1	<1	26	26	
GW40	Meandu Creek Alluvium	9/11/2013					2180			32	107	595	3	1080	163	<1	<1	42	42	
GW40	Meandu Creek Alluvium	22/02/2014					2310			25	95	513	3	1020	160	<1	<1	30	30	
GW40	Meandu Creek Alluvium	12/08/2014					1660			33	90	510	3	839	181	<1	<1	62	62	
GW40	Meandu Creek Alluvium	4/11/2014					1540			36	79	411	4	705	199	<1	<1	69	69	
GW40	Meandu Creek Alluvium	27/05/2015	5.97		3400		1940	2210		32	88	526	3	946	168	<1	<1	46	46	0.1
GW40	Meandu Creek Alluvium	16/09/2015	6.44		3170		1830	2060		35	81	442	2	932	164	<1	<1	66	66	0.1
GW40	Meandu Creek Alluvium	8/12/2015	6.63		2950		1760	1920		30	79	423	2	765	208	<1	<1	82	82	0.2
GW40	Meandu Creek Alluvium	29/02/2016	7.35		3320		1910	2160		31	86	447	2	918	171	<1	<1	52	52	0.1
GW40	Meandu Creek Alluvium	14/05/2016	6.33		2850		1660	1850	3	36	78	408	3	805	235	<1	<1	78	78	0.2
GW40	Meandu Creek Alluvium	28/08/2016	6.06	5.43	3190	3266	1880	2070	24	27	84	461	2	890	173	<1	<1	44	44	0.1
GW40	Meandu Creek Alluvium	17/11/2016	5.93		3240		2110		8	23	87	470	2	980	180		<1	41	41	0.1
GW40	Meandu Creek Alluvium	1/03/2017	6.44	5.52	3000	3260	1950		2	26	87	477	2	873	497	<1	<1	46	46	0.1
GW40	Meandu Creek Alluvium	22/05/2017	6.47		4390		2520	2850	73	31	124	636	3	1100	158	<1	<1	27	27	0.2
GW40	Meandu Creek Alluvium	29/08/2017																		

Appendix A1 - pH, EC, Major Ion and Fluoride Data

Site	Groundwater Unit Monitored	Sampled_Date-Time	pH (lab)	pH (field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
Bore	Unit Monitored	Date	pH_Units	pH_Units	uS/cm	uS/cm	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
GW43_D	Queen Seam	20/05/2016	7.39		754		438	490	74	9	17	111	8	175	38	<1	<1	81	81	<0.1
GW43_D	Queen Seam	21/08/2016	6.56	5.83	778	759	443	506	18	8	16	106	7	184	38	<1	<1	74	74	<0.1
GW43_D	Queen Seam	21/02/2017	6.45	5.72	746	768	485		23	9	18	118	8	185	37	<1	<1	74	74	<0.1
GW43_D	Queen Seam	12/05/2017	6.84		761		398	495	1	8	16	102	7	176	35	<1	<1	76	76	<0.1
GW43_S	Basalt	3/03/2015	7.51		2280		1250	1480		62	132	237	8	495	36	<1	<1	563	563	<0.1
GW43_S	Basalt	20/05/2015	7.45		2320		1410	1510		63	129	233	8	471	88	<1	<1	626	626	0.2
GW43_S	Basalt	2/09/2015	7.42		2360		1300	1530		67	123	207	7	423	57	<1	<1	625	625	<0.1
GW43_S	Basalt	26/11/2015					1220													
GW43_S	Basalt	23/02/2016	7.5		2310		1240	1500		61	132	228	8	370	67	<1	<1	697	697	<0.1
GW43_S	Basalt	20/05/2016	8.09		2260		1300	1470	65	64	135	242	9	375	63	<1	<1	645	645	<0.1
GW43_S	Basalt	21/08/2016	7.49	6.89	2300	2310	1280	1500	4	61	130	234	8	374	65	<1	<1	688	688	<0.1
GW43_S	Basalt	21/02/2017	7.43	6.74	2210	2300	1440		23	62	143	254	8	390	69	<1	<1	683	683	<0.1
GW44_D	Queen Seam	24/02/2014	7.78		9990		6490			762	372	871	59	3490	392	<1	<1	129	129	<0.1
GW44_D	Queen Seam	7/08/2014	7.54		10400		6470	6760		760	401	944	67	3590	356	<1	<1	226	226	<0.1
GW44_D	Queen Seam	17/11/2014	7.61		10400		7580	6760		745	416	938	65	3550	404	<1	<1	240	240	<0.1
GW44_D	Queen Seam	4/03/2015	7.5		10600		7560	6890		738	389	889	55	3720	389	<1	<1	268	268	<0.1
GW44_D	Queen Seam	21/05/2015	7.44		10400		7020	6760		701	382	869	53	3760	584	<1	<1	256	256	<0.1
GW44_D	Queen Seam	4/09/2015	7.46		10800		7090	7020		742	361	788	49	3730	436	<1	<1	250	250	<0.1
GW44_D	Queen Seam	28/11/2015					7170													
GW44_D	Queen Seam	24/02/2016	7.43		10900		8130	7080		729	425	942	56	3880	424	<1	<1	262	262	<0.1
GW44_D	Queen Seam	18/05/2016	7.83		11300		6740	7340	43	691	392	919	54	3950	445	<1	<1	267	268	<0.1
GW44_D	Queen Seam	19/08/2016	7.44	7.08	11400	11190	7400	7410	21	724	428	969	54	3910	478	<1	<1	267	267	<0.1
GW44_D	Queen Seam	9/11/2016	7.35		11000		7150		12	758	435	992	55	3880	473		<1	261	261	<0.1
GW44_D	Queen Seam	8/02/2017	7.57	7	11200	11460	7280		23	759	448	952	58	3820	477	<1	<1	268	268	0.1
GW44_S	Queen Seam	24/02/2014	8.12		3880		2520			198	118	449	32	1110	144	<1	<1	194	194	0.2
GW44_S	Queen Seam	7/08/2014	7.44		6620		3820	4300		294	251	708	38	1740	265	<1	<1	321	321	<0.1
GW44_S	Queen Seam	17/11/2014	7.43		9000		5900	5850		396	404	1060	47	2810	434	<1	<1	404	419	<0.1
GW44_S	Queen Seam	4/03/2015	7.2		9890		6560	6430		356	412	1180	37	3300	425	<1	<1	474	474	<0.1
GW44_S	Queen Seam	21/05/2015	7.18		9710		6210	6310		370	403	1060	35	3260	626	<1	<1	462	462	<0.1
GW44_S	Queen Seam	4/09/2015	7.21		10500		6580	6820		401	410	1020	33	3420	537	<1	<1	460	460	<0.1
GW44_S	Queen Seam	28/11/2015					6460													
GW44_S	Queen Seam	23/02/2016	7.19		10800		7790	7020		397	478	1210	37	3510	535	<1	<1	498	498	<0.1
GW44_S	Queen Seam	18/05/2016	7.68		11400		6720	7410	86	386	448	1220	36	3830	557	<1	<1	504	504	<0.1
GW44_S	Queen Seam	19/08/2016	7.21	6.54	11600	11350	7270	7540	22	408	497	1290	37	3750	616	<1	<1	521	521	<0.1
GW44_S	Queen Seam	9/11/2016	7.16		11600		7540		<1	458	540	1400	39	3940	633		<1	542	542	<0.1
GW44_S	Queen Seam	8/02/2017	7.42	6.53	11700	12040	7600		40	437	536	1280	40	3860	620	<1	<1	530	530	<0.1
GW45_D	Queen Seam	25/02/2014	8.33		1230		800			53	20	177	16	293	17	<1	6	164	170	<0.1
GW45_D	Queen Seam	8/08/2014	7.94		1250		603	812		51	19	195	17	270	15	<1	<1	204	204	<0.1
GW45_D	Queen Seam	17/11/2014	8.11		1140		570	741		49	18	178	15	259	14	<1	<1	211	211	<0.1
GW45_D	Queen Seam	5/03/2015	7.93		1130		622	734		45	15	173	13	253	11	<1	<1	228	228	<0.1
GW45_D	Queen Seam	21/05/2015	7.88		1150		590	748		47	17	153	14	265	17	<1	<1	214	219	<0.1
GW45_D	Queen Seam	4/09/2015	7.88		1240		698	806		54	16	146	14	280	15	<1	<1	208	208	<0.1
GW45_D	Queen Seam	27/11/2015					693													
GW45_D	Queen Seam	24/02/2016	7.87		1250		679	812		48	18	157	14	290	13	<1	<1	217	217	<0.1
GW45_D	Queen Seam	19/05/2016	8.22		1320		687	858	5	54	19	163	15	323	16	<1	<1	227	227	<0.1
GW45_D	Queen Seam	20/08/2016	7.85	7.54	1340	1316	755	871	<1	54	21	170	16	305	18	<1	<1	218	218	<0.1
GW45_D	Queen Seam	10/11/2016	7.69		1320		858		4	58	22	179	17	314	19		<1	217	217	<0.1
GW45_D	Queen Seam	9/02/2017		7.48	1310	1350	852		3	59	23	174	17	302	17	<1	<1	212	212	<0.1
GW45_S	King Seam	25/02/2014	8.07		4920		3200			275	196	479	42	1380	214	<1	<1	182	182	0.1
GW45_S	King Seam	8/08/2014	7.41		5730		3170	3720		316	225	527	47	1600	200	<1	<1	247	247	<0.1
GW45_S	King Seam	17/11/2014	7.37		5890		3460	3830		321	263	529	46	1630	248	<1	<1	248	248	0.2
GW45_S	King Seam	4/03/2015	7.29		6220		4080	4040		281	251	550	42	1640	255	<1	<1	282	282	<0.1
GW45_S	King Seam	20/05/2015	7.23		6210		3510	4040		296	252	557	42	1850	376	<1	<1	267	267	0.2
GW45_S	King Seam	3/09/2015	7.19		6460		3900	4200		305	241	510	38	1590	273	<1	<1	250	250	0.1
GW45_S	King Seam	27/11/2015					3960													
GW45_S	King Seam	24/02/2016	7.25		6260		3940	4070		290	258	571	42	1950	254	<1	<1	259	259	0.1
GW45_S	King Seam	19/05/2016	7.73		6260		3570	4070	44	273	228	547	40	1620	251	<1	<1	262	262	0.1
GW45_S	King Seam	20/08/2016	7.86	6.82	6100	5750	741	871	14	54	237	556	39	304	244	<1	<1	218	252	0.1
GW45_S	King Seam	10/11/2016	7.11		5610		3650		25	270	230	545	40	1730	231		<1	246	246	0.1
GW45_S	King Seam	9/02/2017		6.71	5190	5350	3370		20	243	217	503	40	1490	207	<1	<1	226	226	0.2
GW46_D	Queen Seam	24/02/2014	8.41		2060		1340			63	28	345	16	510	77	<1	14	200	215	<0.1
GW46_D	Queen Seam	6/08/2014	7.93		2210		1080	1440		64	29	383	16	512	69	<1	<1	267	267	<0.1
GW46_D	Queen Seam	17/11/2014	7.95		2050		1020	1330		64	29	368	15	495	70	<1	<1	268	268	<0.1
GW46_D	Queen Seam	3/03/2015	7.76		2070		1140	1340		60	22	306	12	460	68	<1	<1	290	290	<0.1
GW46_D	Queen Seam	19/05/2015	7.77		2090		1000	1360		64	28	323	14	540	114	<1	<1	276	276	0.4
GW46_D	Queen Seam	2/09/2015	7.7		2160		1200	1400		67	24	285	13	508	73	<1	<1	261	261	<0.1
GW46_D	Queen Seam	28/11/2015					1130													
GW46_D	Queen Seam	22/02/2016	7.78		2150		1170	1400		60	28	325	14	531	76	<1	<1	272	278	<0.1
GW46_D	Queen Seam	17/05/2016	8.13		2140		1130	1390		62	26	324	14	528	71	<1	<1	282	283	<0.1
GW46_D	Queen Seam	22/08/2016	7.84	7.32	2220	2233	1260	1440	<1	62	28	338	14	508	74	<1	<1	285	285	<0.1
GW46_D	Queen Seam	11/11/2016	7.78		2140		1390		<1	61	27	317	14	528	75		<1	287	287	<0.1
GW46_D	Queen Seam	7/02/2017	7.91	7.35	2120	2160	1380		1	68	30	333	16	507	75	<1	<1	280	280	<0.1

Appendix A1 - pH, EC, Major Ion and Fluoride Data

Site	Groundwater Unit Monitored	Sampled_Date-Time	pH (lab)	pH (field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
Bore	Unit Monitored	Date	pH_Units	pH_Units	uS/cm	uS/cm	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
GW50_D	Queen Seam	26/02/2016	8.29	7.21	1490	1471	776	968		52	28	198	15	323	18	<1	<1	266	266	<0.1
GW50_D	Queen Seam	10/05/2016	7.85	7.23	1420	1448	778	923	2	55	26	195	14	338	17	<1	<1	257	257	<0.1
GW50_D	Queen Seam	23/08/2016	7.96	7.21	1420	1515	832	923	12	55	26	194	15	317	17	<1	<1	255	255	<0.1
GW50_D	Queen Seam	23/11/2016	7.64		1440		936		6	77	26	200	14	328	17		<1	263	263	<0.1
GW50_D	Queen Seam	22/02/2017	7.86	7.13	1410	1460	916		<1	57	29	212	16	337	16	<1	<1	256	256	<0.1
GW50_S	Regolith	5/06/2009		6.06		19300	14000			193	674	2950	100	6620	895					<0.1
GW50_S	Regolith	25/08/2009		6.19		19400	11800			195	658	2910	121	5870	943					<0.1
GW50_S	Regolith	1/12/2009		5.74		18900	12900			175	683	3070	140	8530	921					<0.1
GW50_S	Regolith	17/03/2010		5.82		17900	13300			174	700	3080	130	7020	936					<0.1
GW50_S	Regolith	5/05/2011	4.87	5.67	14600		12500			164	571	2830	112	6490	912	<1	<1	69	69	<0.1
GW50_S	Regolith	3/08/2011	6.14	6.07	14900		12200			148	554	2940	128	6160	887	<1	<1	118	118	<0.1
GW50_S	Regolith	1/11/2011	6.26	6.26	17500		12000			139	543	2880	131	6030	852	<1	<1	109	109	<0.1
GW50_S	Regolith	7/03/2012	6.47	6.47	16800		13900			139	515	2680	107	5620	801	<1	<1	106	106	<0.1
GW50_S	Regolith	5/05/2012	6.35	6.27	15400		12200			123	502	2780	119	5530	834	<1	<1	104	104	<0.1
GW50_S	Regolith	14/08/2012	6.39	5.56	12400	16580	11900			117	502	2730	131	5750	806	<1	<1	99	99	<0.1
GW50_S	Regolith	7/11/2012	6.6	5.48	14800	16650	8960			98	476	2500	82	5160	724	<1	<1	90	90	<0.1
GW50_S	Regolith	18/02/2013	6.37	5.6	14600	15720	11400			116	451	2470	87	4910	772	<1	<1	83	83	<0.1
GW50_S	Regolith	25/05/2013	6.47	5.6	14400		9810			130	511	2720	118	5470	726	<1	<1	114	114	<0.1
GW50_S	Regolith	4/08/2013	6.69	5.65	15800	16500	9830			127	528	2820	120	5500	726	<1	<1	98	98	<0.1
GW50_S	Regolith	6/11/2013	6.23	5.73	16900	18150	11400			124	513	2680	109	5850	767	<1	<1	46	46	<0.1
GW50_S	Regolith	19/02/2014	7.54	5.6	16400	17320	9490			128	542	2760	110	5900	789	<1	<1	29	32	<0.1
GW50_S	Regolith	28/05/2014	6.53	5.76	17000	16840	11400	9420		134	593	2980	115	6570	934	<1	<1	90	90	<0.1
GW50_S	Regolith	9/08/2014	6.29	5.66	14600	18220	10900	9490		147	592	2970	122	6130	912	<1	<1	93	93	<0.1
GW50_S	Regolith	5/11/2014	5.99		19500		12100	12700		131	571	2960	112	6180	772	<1	<1	76	76	<0.1
GW50_S	Regolith	8/03/2015	6.21		18600		12800			136	558	3270	99	6790	867	<1	<1	110	118	<0.1
GW50_S	Regolith	24/05/2015	6.37		19000		12300	12400		141	570	3060	102	6840	963	<1	<1	95	95	0.1
GW50_S	Regolith	15/09/2015	6.38	5.54	16600	19540	13000	11400		134	629	2610	90	6920	964	<1	<1	61	118	0.1
GW50_S	Regolith	1/12/2015	6.26	5.82	18500	19830	13600	12000		166	623	3100	96	6710	913	<1	<1	104	104	0.1
GW50_S	Regolith	28/02/2016	6.61	5.68	20400	19990	13700	13300		141	616	3200	106	6750	949	<1	<1	58	58	0.1
GW50_S	Regolith	15/05/2016	6.39	5.61	19800	21030	13500	12900	8	140	562	3030	105	6570	974	<1	<1	109	109	0.1
GW50_S	Regolith	23/08/2016	6.25	5.65	20000	21240	12500	13000	225	145	626	3310	112	6800	925	<1	<1	119	119	0.2
GW50_S	Regolith	23/11/2016	6.15		19200		12500		149	190	582	3180	104	6690	898		<1	116	116	0.1
GW50_S	Regolith	22/02/2017	6.4	5.62	20000	20620	13000		37	149	663	3600	116	6650	1150	<1	<1	106	106	0.2
GW51_D	Queen Seam	5/06/2009		7.33		1860	870			55.8	33	271	20	447	33					0.1
GW51_D	Queen Seam	26/08/2009		7.21		1930	947			56	36	296	19	440	38					<0.1
GW51_D	Queen Seam	3/12/2009		7.77		1750	964			49	30	254	17	397	31					<0.1
GW51_D	Queen Seam	17/03/2010		7.3		1500	812			47	26	211	17	363	20					<0.1
GW51_D	Queen Seam	22/06/2010	7.66	7.66	1710	1660	882			51	31	251	17	481	27					<0.1
GW51_D	Queen Seam	4/05/2011	7.46	6.96	1340		812			46	25	244	16	368	19	<1	<1	226	226	<0.1
GW51_D	Queen Seam	1/08/2011	7.4	7.4	1360		796			44	24	210	14	378	19	<1	<1	202	202	<0.1
GW51_D	Queen Seam	31/10/2011	7.48	7.47	1680		896			50	28	230	16	399	25	<1	<1	223	223	<0.1
GW51_D	Queen Seam	7/03/2012	7.69	7.69	1570		962			51	27	239	16	379	22	<1	<1	246	246	<0.1
GW51_D	Queen Seam	5/05/2012	7.45	7.45	1620		871			50	28	209	17	380	25	<1	<1	219	219	<0.1
GW51_D	Queen Seam	16/08/2012	7.76	6.96	1530	1824	1040			59	34	237	18	464	31	<1	<1	217	217	<0.1
GW51_D	Queen Seam	7/11/2012	7.96	6.88	1810	1976	1020			61	35	260	17	467	28	<1	<1	219	219	<0.1
GW51_D	Queen Seam	21/02/2013	7.66	6.89	1890	1990	1100			68	39	291	18	478	34	<1	<1	203	203	<0.1
GW51_D	Queen Seam	25/05/2013	7.79	6.99	1960	2174	1040			69	39	275	19	505	33	<1	<1	223	223	<0.1
GW51_D	Queen Seam	3/08/2013	7.81	6.94	2090	2213	1080			79	46	308	22	569	32	<1	<1	227	227	<0.1
GW51_D	Queen Seam	8/11/2013	7.5	7.11	2210	2202	1300			75	44	296	22	604	32	<1	<1	219	219	0.1
GW51_D	Queen Seam	20/02/2014	8.5	6.98	2130	2435	1380			81	46	299	26	572	38	<1	19	164	183	0.1
GW51_D	Queen Seam	9/08/2014	7.62	6.99	2130	2552	1250	1380		96	54	332	22	639	42	<1	<1	208	208	0.1
GW51_D	Queen Seam	2/11/2014	7.7	7.2	2480		1400	1610		110	64	342	22	660	47	<1	<1	220	220	0.1
GW51_D	Queen Seam	8/03/2015	7.55	6.99	2690		1680			119	65	313	20	774	47	<1	<1	229	229	<0.1
GW51_D	Queen Seam	23/05/2015	7.55	6.99	2760		1470	1790		119	66	321	22	808	80	<1	<1	219	219	0.1
GW51_D	Queen Seam	14/09/2015	8.3	7.01	2900	2893	1660	1880		113	62	276	21	785	55	<1	1	223	224	0.1
GW51_D	Queen Seam	3/12/2015	7.88	7.01	2800	2933	1680	1820		125	66	290	21	800	54	<1	<1	238	238	0.1
GW51_D	Queen Seam	25/02/2016	8.05	6.98	3030	3003	1740	1970		133	77	327	22	846	57	<1	<1	227	227	<0.1
GW51_D	Queen Seam	11/05/2016	7.64	7	2940	3045	1770	1910	20	139	73	324	22	820	58	<1	<1	227	227	<0.1
GW51_D	Queen Seam	23/08/2016		6.99		3233														
GW51_D	Queen Seam	26/08/2016	7.56	6.99	3140	3233	1860	2040	3	128	82	348	23	868	57	<1	<1	229	229	0.1
GW51_D	Queen Seam	28/02/2017	7.69	6.9	3240	3530	2110		7	169	93	383	25	950	66	<1	<1	227	227	0.1
GW51_D	Queen Seam	11/05/2017	8.19		3200		1990	2080	<1	139	86	342	25	872	61	<1	<1	231	231	0.1
GW51_D	Queen Seam	29/08/2017	7.95		3230		1830	2099.5	11	148	89	364	26	1110	62	<1	<1	242	242	<0.1
GW51_S	Regolith	4/06/2009		6.06		7850	5260			10	166	1420	26	2130	680					0.1
GW51_S	Regolith	26/08/2009		5.59		8190	4740			2	178	1490	35	1600	819					<0.1
GW51_S	Regolith	3/12/2009		5.49		7780	5430			4	193	1530	41	2720	792					0.2
GW51_S	Regolith	17/03/2010		5.5		7510	5740			2	184	1390	41	2080	779					0.2
GW51_S	Regolith	22/06/2010	5.83	5.83	7060	7060	4840			2	155	1340	35	2230	674					0.1
GW51_S	Regolith	4/05/2011	6.2	5.52	3080	3320	4340			2	47	803	16	929	345	<1	<1	136	136	0.2
GW51_S	Regolith	1/08/2011	6.11	6.11	3540	3540	2020			1	43	710	14	993	300	<1	<1	125	125	0.3
GW51_S	Regolith	31/10/2011	6.19	5.62	3570		2010													

Appendix A1 - pH, EC, Major Ion and Fluoride Data

Site	Groundwater Unit Monitored	Sampled_Date-Time	pH (lab)	pH (field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
Bore	Unit Monitored	Date	pH_Units	pH_Units	uS/cm	uS/cm	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
GW52A	Regolith	8/03/2015	5.55		12400		8110			14	349	2290	17	4400	494	<1	<1	44	44	0.2
GW52A	Regolith	24/05/2015	5.56		12400		7550	8060		14	338	2080	18	4480	649	<1	<1	51	51	0.3
GW52A	Regolith	15/09/2015	5.9	5.01	11600	12640	7200	7540		14	390	1940	16	4570	557	<1	<1	54	54	0.3
GW52A	Regolith	1/12/2015	5.79	5.07	12200	12410	8500	7930		15	328	1910	17	4300	528	<1	<1	55	55	0.3
GW52A	Regolith	26/02/2016	6.81	5.09	12800	12590	7510	8320		14	349	2100	18	4300	536	<1	<1	62	62	0.4
GW52A	Regolith	11/05/2016	5.87	5.02	11700	12390	7500	7600	63	14	341	2120	18	4220	541	<1	<1	49	49	0.3
GW52A	Regolith	26/08/2016	5.56	5.01	12400	12570	7160	8060	57	12	345	2140	18	4130	528	<1	<1	46	46	0.3
GW52A	Regolith	22/02/2017	5.86	5.01	11900	12400	7740		14	15	352	2180	18	4070	527	<1	<1	59	59	0.3
GW52A	Regolith	17/05/2017	5.69		12100		7860	7860	153	13	332	2140	17	3990	549	<1	<1	60	60	0.3
GW53	Regolith	2/11/2014	5.24	4.7	8740	8951	4550	5680		14	316	1520	3	2720	521	<1	<1	9	9	0.2
GW53	Regolith	7/03/2015	4.98	4.58	8270	8160	5210			11	258	1440	2	2620	643	<1	<1	7	7	<0.1
GW53	Regolith	24/05/2015	5.02	4.54	7470	7400	4300	4860		9	227	1240	2	2340	989	<1	<1	7	7	0.2
GW53	Regolith	15/09/2015	5.42	4.55	5210	5525	3150	3390		6	151	814	1	1190	1060	<1	<1	23	23	0.1
GW53	Regolith	3/12/2015	5.49	4.61	4760	4914	3270	3090		5	118	792	1	962	990	<1	<1	26	26	0.1
GW53	Regolith	26/02/2016	6.07	4.67	4640	4192	3120	3020		4	127	839	2	822	1110	<1	<1	28	28	0.1
GW53	Regolith	11/05/2016	5.42	4.73	3780	3891	2370	2460	136	3	91	704	1	609	1070	<1	<1	28	28	<0.1
GW53	Regolith	26/08/2016	5.25	4.69	4100	3945	2610	2660	89	2	115	725	2	750	980	<1	<1	26	26	0.1
GW53	Regolith	27/02/2017	5.38	4.47	5430	5710	3530		66	3	182	1000	4	1260	974	<1	<1	14	14	0.1
GW53	Regolith	11/05/2017	5.02		4630		2440	3010	6	2	127	780	3	905	905	<1	<1	10	10	0.1
GW53	Regolith	30/08/2017	5.47		5380		3430	3497	37	5	158	925	5	1310	849	<1	<1	25	25	0.1
GW54A	Regolith below Spoil	6/05/2012	6.51	6.51	2810		1720			24	106	379	28	683	316	<1	<1	187	187	0.2
GW54A	Regolith below Spoil	16/08/2012	6.4	5.74	2370	2823	1840			16	101	381	28	671	328	<1	<1	165	165	0.2
GW54A	Regolith below Spoil	5/11/2012	6.69	5.62	2190	2900	1340			14	84	348	21	508	284	<1	<1	128	128	0.2
GW54A	Regolith below Spoil	21/02/2013	6.64	5.68	2720	2737	1740			31	105	441	30	549	463	<1	<1	173	173	0.2
GW54A	Regolith below Spoil	4/08/2013	6.87	5.71	2750	2872	1730			14	123	421	28	571	518	<1	<1	134	134	0.1
GW54B	Spoil/ Regolith	28/05/2014	6.02	6	2760	3262	1980	1790		35	82	501	37	976	296	<1	<1	32	32	<0.1
GW54B	Spoil/ Regolith	10/08/2014	5.96	5.22	2970	3396	1800	1930		34	76	543	44	856	304	<1	<1	44	45	0.2
GW54B	Spoil/ Regolith	1/11/2014	5.9	5.21	3230	3499	1750	2100		30	71	497	46	804	315	<1	<1	41	41	0.2
GW54B	Spoil/ Regolith	7/03/2015	5.89	5.36	3300	3388	1950			34	70	489	36	817	336	<1	<1	58	58	0.2
GW54B	Spoil/ Regolith	26/05/2015	5.91	5.18	3280	3359	1940	2130		34	70	460	34	866	397	<1	<1	57	57	0.2
GW54B	Spoil/ Regolith	14/09/2015	6.15	5.34	3420	3412	1900	2220		31	65	391	34	880	358	<1	<1	37	37	0.2
GW55_D	Queen Seam	3/06/2009		6.42		1630	1000			7	52	223	4	437	44					1.6
GW55_D	Queen Seam	25/08/2009		6.45		4630	2150			34	161	522	25	910	226					0.2
GW55_D	Queen Seam	2/12/2009		6.23		3690	2250			33	151	475	26	1100	198					<0.1
GW55_D	Queen Seam	17/03/2010		6.46		3330	2110			50	137	436	23	957	185					<0.1
GW55_D	Queen Seam	21/06/2010	6.26	6.26	3090	3090	1710			22	125	424	20	1030	161					<0.1
GW55_D	Queen Seam	9/02/2011	6.77	5.93	2710		1420			25	108	352	17	765	156					<0.1
GW55_D	Queen Seam	4/05/2011	5.23	5.91	5520		3910			37	254	730	21	1530	363	<1	<1	78	78	0.4
GW55_D	Queen Seam	3/08/2011	6.26	5.97	6830		4720			45	383	1000	32	2410	537	<1	<1	81	81	0.2
GW55_D	Queen Seam	31/10/2011	6.34	6	8580		6140			50	408	1080	34	2640	594	<1	<1	81	81	0.1
GW55_D	Queen Seam	8/03/2012	6.27	6.33	5280		3830			37	236	728	26	1450	364	<1	<1	65	65	<0.1
GW55_D	Queen Seam	6/05/2012	6.54	5.22	8040		6100			61	433	1140	33	2760	708	<1	<1	109	109	<0.1
GW55_D	Queen Seam	16/08/2012	6.32	5.94	4980		4330			37	296	768	35	1880	463	<1	<1	59	59	<0.1
GW55_D	Queen Seam	5/11/2012	6.44	5.82	5030		4500			42	326	915	31	2090	419	<1	<1	32	32	0.1
GW55_D	Queen Seam	22/02/2013	6.54	5.9	5470		4560			36	274	788	28	1540	443	<1	<1	81	81	<0.1
GW55_D	Queen Seam	26/05/2013	6.55	5.83	8940		6910			41	532	1530	31	3650	666	<1	<1	102	102	0.2
GW55_D	Queen Seam	4/08/2013	7.03	5.81	9770	10670	6290			46	512	1610	34	3570	844	<1	<1	110	110	<0.1
GW55_D	Queen Seam	8/11/2013	6.14	5.93	9980	10720	6730			38	466	1480	36	3290	737	<1	<1	71	71	0.1
GW55_D	Queen Seam	20/02/2014	7.93	5.83	8580	9972	5580			41	431	1390	38	3010	687	<1	<1	58	58	<0.1
GW55_D	Queen Seam	10/08/2014	6.58	5.92	7510	9693	5680	4880		43	434	1480	30	3040	711	<1	<1	104	104	<0.1
GW55_D	Queen Seam	1/11/2014	6.38	5.84	8850	9740	5670	5750		43	416	1380	32	2780	585	<1	<1	88	88	<0.1
GW55_D	Queen Seam	7/03/2015	6.39	6.05	9050	9208	6010			29	373	1460	20	2950	878	<1	<1	106	106	<0.1
GW55_D	Queen Seam	26/05/2015	6.28	5.67	7980	8360	5110	5190		27	333	1230	19	2640	697	<1	<1	89	89	0.1
GW55_D	Queen Seam	14/09/2015	7.57	5.78	7780	7930	4880	5060		22	262	989	19	2470	600	<1	<1	79	79	<0.1
GW55_D	Queen Seam	1/12/2015	6.76	5.82	7270	7379	5120	4720		26	305	1130	22	2090	566	<1	<1	87	87	<0.1
GW55_D	Queen Seam	26/02/2016	7.25	5.73	7360	7182	4480	4780		20	273	1060	19	2110	527	<1	<1	76	76	0.1
GW55_D	Queen Seam	14/05/2016	6.66	5.7	6590	6966	4260	4280	3	18	230	966	18	1950	509	<1	<1	92	92	<0.1
GW55_D	Queen Seam	26/08/2016	6.41	5.72	6350	6247	3700	4130	19	16	224	965	18	1830	463	<1	<1	85	85	0.2
GW55_D	Queen Seam	24/02/2017	6.1	5.59	5820	6100	3780		30	17	218	940	18	1450	408	<1	<1	77	77	0.1
GW55_D	Queen Seam	29/08/2017	6.67		5450		3240	3542.5	123	15	177	822	19	1640	414	<1	<1	72	72	<0.1
GW56_D	Ace Seam	2/06/2009		6.23		1170	580			4	19	174	7	250	59					1.6
GW56_D	Ace Seam	23/06/2010	6.35	6.35	1060	1060	548			4	20	188	9	275	58					<0.1
GW56_D	Ace Seam	5/05/2011	4.81	5.89	1040		575			4	18	188	8	252	59	<1	<1	100	100	<0.1
GW56_D	Ace Seam	2/08/2011	6.49	5.81	1010		529			4	18	177	9	237	56	<1	<1	98	98	0.2
GW56_D	Ace Seam	2/11/2011	6.68	5.93	1040		573			4	17	183	8	242	57	<1	<1	102	102	<0.1
GW56_D	Ace Seam	8/03/2012	6.86	6.1	1010		628			4	18	187	8	237	65	<1	<1	104	104	<0.1
GW56_D	Ace Seam	5/05/2012	6.68	5.1	1020		563			4	18	160	8	236	61	<1	<1	94	94	<0.1
GW56_D	Ace Seam	15/08/2012	6.65	5.82	925	1079	651			4	19	179	9	255	62	<1	<1	113	113	<0.1
GW56_D	Ace Seam	5/11/2012	6.92	5.76	955	1080	546			4	17	168	8	233	43	<1	<1	91	91	<0.1
GW56_D	Ace Seam	7/08/2013	7.18	5.82	935	987	541			3	16	184	8	250	44	<1	<1	100	100	<0

Appendix A1 - pH, EC, Major Ion and Fluoride Data

Site	Groundwater Unit Monitored	Sampled_Date-Time	pH (lab)	pH (field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
Bore	Unit Monitored	Date	pH_Units	pH_Units	uS/cm	uS/cm	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
GW59_D	King Seam	3/06/2009		6.95		1360	710			20	31	205	7	259	37					1.6
GW59_D	King Seam	26/08/2009		6.74		1320	588			19	30	219	8	243	40					<0.1
GW59_D	King Seam	22/06/2010	6.72	6.72	1200	1200	655			9	27	198	7	294	35					0.1
GW59_D	King Seam	5/05/2011	4.78	6.32	1190		668			8	29	232	7	263	39	<1	<1	204	204	0.2
GW59_D	King Seam	3/08/2011	6.74	6.38	1200		630			7	27	194	10	263	33	<1	<1	199	199	0.2
GW59B	King Seam	28/05/2014	7.24	6.73	2110	2266	1670	1370		24	160	366	8	417	754	<1	<1	157	157	0.2
GW59B	King Seam	11/08/2014	6.94	6.17	2180	2609	1620	1420		24	140	373	8	433	542	<1	<1	151	151	0.4
GW59B	King Seam	1/11/2014	6.99		2710	2864	1720	1760		23	153	357	8	418	571	<1	<1	161	161	0.4
GW59B	King Seam	7/03/2015	6.75	6.15	2880	2964	1950			29	172	358	8	477	677	<1	<1	170	170	0.1
GW59B	King Seam	26/05/2015	6.71	6.06	2780	2863	1940	1810		31	172	354	9	458	819	<1	<1	158	160	0.5
GW59B	King Seam	14/09/2015	8.06	6.12	2800	2826	1840	1820		30	139	282	10	434	755	<1	<1	149	149	0.2
GW59B	King Seam	30/11/2015	7.05	6.13	2680	2729	1960	1740		39	142	254	11	436	734	<1	<1	144	144	0.2
GW59B	King Seam	25/02/2016	7.55	6.1	2800	2760	1850	1820		41	160	322	12	412	719	<1	<1	138	138	0.2
GW59B	King Seam	15/05/2016	6.97	6.11	2840	3089	1680	1850	2	47	163	323	13	455	783	<1	<1	154	154	0.2
GW59B	King Seam	27/08/2016	6.72	6.18	3030	3163	1970	1970	11	35	153	331	13	493	810	<1	<1	142	142	0.2
GW59B	King Seam	23/11/2016	6.68		2590		1680		51	76	185	346	13	466	573		<1	172	172	0.2
GW59B	King Seam	2/03/2017	7.16	6.11	3340	3640	2170		<1	65	204	421	14	538	880	<1	<1	168	168	0.2
GW59B	King Seam	15/05/2017	6.8		3240		2140	2110	33	32	110	294	14	539	813	<1	<1	159	159	0.2
GW60	Queen Seam	3/06/2009		6.38		1380	730			4	32	184	13	328	49					1.6
GW60	Queen Seam	27/08/2009		6.41		1290	685			5	33	199	16	299	55					0.1
GW60	Queen Seam	2/12/2009		6.11		1330	685			7	32	184	16	373	48					<0.1
GW60	Queen Seam	16/03/2010		6.19		1300	735			9	33	181	16	331	54					0.1
GW60	Queen Seam	21/06/2010	6.33	6.33	1170	1170	609			8	31	172	13	331	46					<0.1
GW60	Queen Seam	3/05/2011	6.46	5.89	1140		706			9	34	205	15	330	54	<1	<1	108	108	<0.1
GW60	Queen Seam	2/08/2011	6.31	5.88	1320		713			9	35	217	14	369	57	<1	<1	118	118	<0.1
GW60	Queen Seam	1/11/2011	6.47	5.9	1340		795			6	35	204	14	349	57	<1	<1	108	108	0.1
GW60	Queen Seam	8/03/2012	6.55	5.98	1230		830			7	33	188	13	314	60	<1	<1	105	105	<0.1
GW60	Queen Seam	4/05/2012	6.5	6.97	1430		779			14	37	190	15	353	64	<1	<1	116	116	<0.1
GW60	Queen Seam	15/08/2012	6.61	5.88	1110	1324	868			6	35	187	15	349	51	<1	<1	98	98	<0.1
GW60	Queen Seam	6/11/2012	6.75	5.73	530	1406	288			2	13	72	5	119	21	<1	<1	40	40	<0.1
GW60	Queen Seam	22/02/2013	6.6	5.82	1250	1339	736			6	36	206	15	323	52	<1	<1	100	100	<0.1
GW60	Queen Seam	25/05/2013	6.61	5.81	1060	1402	555			5	27	153	11	252	42	<1	<1	80	80	<0.1
GW60	Queen Seam	3/08/2013	6.77	5.82	1250	1361	699			7	37	193	16	358	50	<1	<1	88	88	<0.1
GW60	Queen Seam	6/11/2013	6.43	5.97	1420		778			6	38	215	17	389	56	<1	<1	107	107	<0.1
GW60	Queen Seam	20/02/2014	8.28	5.72	1220		793			5	34	187	18	336	50	<1	<1	86	86	<0.1
GW60	Queen Seam	9/08/2014	6.56	5.84	1180	1326	646	767		5	36	208	16	342	51	<1	<1	103	103	<0.1
GW60	Queen Seam	2/11/2014	6.62	5.88	1250	1345	640	812		5	36	205	14	331	49	<1	<1	105	105	<0.1
GW60	Queen Seam	6/03/2015	6.52	5.9	1270	1327	708			5	34	204	13	342	50	<1	<1	125	125	<0.1
GW60	Queen Seam	23/05/2015	6.45	5.85	1370	1321	733	890		5	36	191	15	355	78	<1	<1	108	108	<0.1
GW60	Queen Seam	13/09/2015	6.95	5.62	1410	1389	776	916		5	32	168	14	358	59	<1	<1	104	104	<0.1
GW60	Queen Seam	30/11/2015	6.71	5.88	1320	1309	766	858		5	34	174	14	351	52	<1	<1	118	118	<0.1
GW60	Queen Seam	25/02/2016	6.99	5.9	1330	1352	697	864		5	36	191	15	335	55	<1	<1	99	99	<0.1
GW60	Queen Seam	13/05/2016	6.71	5.86	1340	1364	742	871	<1	5	33	184	15	346	57	<1	<1	129	129	<0.1
GW60	Queen Seam	25/08/2016	6.52	5.89	1270	1324	707	826	17	4	31	179	14	321	46	<1	<1	122	122	<0.1
GW60	Queen Seam	21/02/2017	6.72	5.79	1230	1270	800		12	5	35	199	16	323	54	<1	<1	112	112	<0.1
GW60	Queen Seam	11/05/2017	7.31		1250		644	812	1	4	33	180	16	321	46	<1	<1	98	98	<0.1
GW60	Queen Seam	30/08/2017	7.73		1260		597	819	6	11	33	176	15	339	48	<1	<1	114	114	<0.1
GW61_D	OB	4/06/2009		6.9		3590	2070			84.9	68	560	35	900	90					1.6
GW61_D	OB	26/08/2009		6.81		3630	1710			81	68	568	30	791	94					0.1
GW61_D	OB	2/12/2009		6.96		3600	1910			82	69	544	31	1010	87					0.1
GW61_D	OB	16/03/2010		6.94		3290	1920			82	66	529	28	890	83					0.1
GW61_D	OB	21/06/2010	7.2	7.2	3240	3240	1790			81	66	529	28	1020	83					0.1
GW61_D	OB	9/02/2011	7.54	6.39	3550		2000			84	68	535	27	985	87					0.1
GW61_D	OB	3/05/2011	4.69	6.29	3510		2170			88	71	584	22	989	92	<1	<1	261	261	0.1
GW61_D	OB	1/08/2011	7.19	6.27	4440		2610			97	87	674	27	1290	114	<1	<1	247	247	<0.1
GW61_D	OB	1/11/2011	7.06	6.45	4310		2720			97	88	669	32	1170	117	<1	<1	257	257	0.1
GW61_D	OB	8/03/2012	7.31	6.48	3780		2400			91	74	631	28	997	108	<1	<1	270	270	0.1
GW61_D	OB	3/05/2012	7.42	7.14	3730		2390			94	81	574	31	1020	116	<1	<1	246	246	0.1
GW61_D	OB	14/08/2012	7.32	5.22	3710	1154	2800			102	97	674	36	1300	129	<1	<1	244	244	0.1
GW61_D	OB	6/11/2012	7.72	6.2	4480	5094	2720			104	97	718	31	1270	128	<1	<1	250	250	0.1
GW61_D	OB	19/02/2013	7.12	8.22	4390	4797	2620			120	113	881	37	1480	154	<1	<1	230	230	0.1
GW61_D	OB	24/05/2013	7.12	6.2	3740	6158	2100			76	80	580	27	1050	100	<1	<1	162	162	<0.1
GW61_D	OB	3/08/2013	7.55	6.22	5800	5982	3170			125	138	853	43	1550	153	<1	<1	234	234	0.1
GW61_D	OB	6/11/2013	6.92	6.37	5920		3460			123	133	906	45	1620	159	<1	<1	238	238	0.1
GW61_D	OB	19/02/2014	8.58	6.27	5490		3570			120	131	844	44	1490	169	<1	32	191	223	<0.1
GW61_D	OB	28/05/2014	7.27	6.24	5140		3120	3340		112	118	849	38	1580	151	<1	<1	238	238	0.1
GW61_D	OB	9/08/2014	7.14	6.33	4650	5435	2750	3020		119	121	803	39	1390	153	<1	<1	233	233	0.1
GW61_D	OB	5/11/2014	7.05	4.91	4980	4969	2440	3240		103	99	753	35	1380	114	<1	<1	240	240	0.1
GW61_D	OB	6/03/2015	7.01	6.43	4370	4462	2570			99	89	660	28	1230	115	<1	<1	286	286	<0.1
GW61_D	OB	23/05/2015	7.43	6.43	4430	4352	2510	2880		100	86	645	29	1330	161	<1	<1	280	280	0.1
GW61_D	OB	15/09/2015	7.22	6.36	4100	4294	2400	2660		93	77	536	26	1200	108	<1	<1	284	284	0.1
GW61_D	OB	30/11/2015	7.38	6.46	4180	4280	2360	2720		94	79	572	27	1140	110					

Appendix A1 - pH, EC, Major Ion and Fluoride Data

Site	Groundwater Unit Monitored	Sampled_Date-Time	pH (Lab)	pH (Field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
Bore	Unit Monitored	Date	pH_Units	pH_Units	uS/cm	uS/cm	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
GW61_S	Regolith	19/02/2014	7.31		891		579			2	28	129	14	247	60	<1	<1	11	11	<0.1
GW61_S	Regolith	20/02/2014	7.29	5.81	978		636			2	26	150	16	287	49	<1	<1	11	11	<0.1
GW61_S	Regolith	28/05/2014	6.16	5.38	879		597	571		2	29	154	13	305	70	<1	<1	9	9	<0.1
GW61_S	Regolith	9/08/2014	6.3		1000		514	650		3	29	164	14	312	42	<1	<1	11	11	<0.1
GW61_S	Regolith	10/08/2014	5.74	5.44	1030	1106	528	670		2	24	187	14	314	53	<1	<1	10	10	<0.1
GW61_S	Regolith	5/11/2014	5.86	5.16	1130	1151	595	734		2	24	167	13	311	62	<1	<1	10	10	<0.1
GW61_S	Regolith	6/03/2015	5.77		640		398			2	15	92	9	133	78	<1	<1	9	9	<0.1
GW61_S	Regolith	7/03/2015	5.51	5.27	1040	1112	569			2	26	146	12	285	41	<1	<1	7	7	<0.1
GW61_S	Regolith	23/05/2015	6.06		704		407	458		1	15	104	10	162	94	<1	<1	8	8	<0.1
GW61_S	Regolith	24/05/2015	5.71	5.28	1030	986	567	670		1	23	150	12	328	59	<1	<1	7	7	<0.1
GW61_S	Regolith	15/09/2015	6.26	4.76	2920	1053	560	682		1	51	482	12	763	62	<1	<1	5	5	0.2
GW61_S	Regolith	30/11/2015	6.39	5.98	822	834	505	534		1	15	126	10	214	60	<1	<1	8	8	<0.1
GW61_S	Regolith	25/02/2016	5.52	5.62	905	899	554	588		<1	16	99	11	230	75	<1	<1	4	4	<0.1
GW61_S	Regolith	15/05/2016	5.64	4.93	1010	1043	561	656	4	<1	18	164	13	273	72	<1	<1	9	9	<0.1
GW61_S	Regolith	25/08/2016	5.71	5.19	780	790	459	507	9	<1	14	119	10	178	82	<1	<1	9	9	<0.1
GW61_S	Regolith	23/02/2017	5.74	5.08	842	935	547		5	<1	17	136	12	232	68	<1	<1	8	8	<0.1
GW61_S	Regolith	18/05/2017	6.41		914		515	594	41	<1	16	133	13	197	61	<1	<1	56	56	<0.1
GW61_S	Regolith	30/08/2017	6.98		968		533	629.2	13	1	17	136	41	246	61	<1	<1	48	48	<0.1
GW63_D	Queen Seam	5/09/2015	7.79		1030		578	670		29	10	144	5	223	<1	<1	<1	193	193	0.1
GW63_D	Queen Seam	26/11/2015					550													
GW63_D	Queen Seam	22/02/2016	7.73		1030		536	670		26	10	166	5	224	<1	<1	<1	197	197	0.1
GW63_D	Queen Seam	18/05/2016	8.13		1040		557	676	4	26	9	164	6	236	<1	<1	<1	212	212	0.1
GW63_D	Queen Seam	20/08/2016	7.84	7.45	1040	1039	598	676	<1	25	9	168	6	223	1	<1	<1	205	205	0.1
GW63_D	Queen Seam	10/11/2016	7.74		1010		656		5	26	9	172	6	219	<1		<1		208	0.1
GW63_D	Queen Seam	8/02/2017	8	7.43	1020	1030	663		<1	27	10	174	7	216	<1	<1	<1	203	203	0.2
GW64_D	Maronghi Creek beds	21/08/2016	7.88	7.41	2610	2525	1450	1700	<1	77	32	399	12	621	70	<1	<1	310	310	0.1
GW64_D	Maronghi Creek beds	11/11/2016	7.73		2520				<1	76	31	379	11	641	76			305	305	<0.1
GW64_D	Maronghi Creek beds	7/02/2017	7.82	7.49	2460	2490	1600		4	85	33	396	13	612	64	<1	<1		305	0.1
GW64_S	Maronghi Creek beds	21/08/2016		6.76		5246														
GW65	Maronghi Creek beds	28/11/2015					1750													
GW65	Maronghi Creek beds	23/02/2016	7.38		3800		2210	2470		119	79	490	23	1020	130	<1	<1	342	342	0.1
GW65	Maronghi Creek beds	19/05/2016	7.89		3770		1840	2450	31	121	77	494	23	942	125	<1	<1	346	346	<0.1
GW65	Maronghi Creek beds	19/08/2016	7.53	7.21	3050	3301	1680	1980	6	79	50	434	18	744	104	<1	<1	281	281	0.1
GW65	Maronghi Creek beds	11/11/2016	7.46		3220		2090		<1	102	63	453	19	837	100		<1	323	323	0.1
GW65	Maronghi Creek beds	7/02/2017	7.76	7.17	3420	3400	2220		8	119	72	490	22	893	107	<1	<1	347	347	0.1
GW66	Spoil	25/11/2016		5.42		3522														
GW66	Spoil	27/02/2017	6.04	5.36	3630	3830	2360		203	38	117	436	38	886	384	<1	<1	69	69	<0.1
GW66	Spoil	15/05/2017	5.93		3800		2260	2470	288	32	112	474	36	912	505	<1	<1	78	78	0.1
GW67	Regolith	29/11/2016		5.85		10250														
GW67	Regolith	22/02/2017	6.56	5.57	9930	10340	6450		8	25	236	1870	55	3180	811	<1	<1	140	140	0.3
GW67	Regolith	19/05/2017	6.13		9470		5780	6160	56	18	199	1680	50	2860	724	<1	<1	138	138	0.3
GW67	Regolith	29/08/2017	6.87		8440		4930	5486	18	16	167	1520	47	2580	633	<1	<1	145	145	0.2
GW68	Regolith	25/11/2016		5.66		13210														
GW68	Regolith	17/02/2017	6	5.64	12700	12760	8260		120	96	342	2170	52	4250	665	<1	<1	136	136	0.2
GW68	Regolith	17/05/2017	6.31		12500		8520	8120	175	90	326	2200	50	4010	695	<1	<1	141	141	0.2
GW68	Regolith	29/08/2017	6.88		12900		7400	8385	31	93	297	2040	50	4530	613	<1	<1	151	151	0.2
GW69	Regolith	25/11/2016		6.28		13020														
GW69	Regolith	17/02/2017	6.64	6.26	12300	12520	8000		79	167	318	2080	41	4040	603	<1	<1	236	236	0.1
GW69	Regolith	19/05/2017	7.09		12400		7140	8060	14	169	318	2030	40	4030	590	<1	<1	230	230	0.1
GW69	Regolith	29/08/2017	7.49		12500		7410	8125	24	204	301	2020	43	4370	617	<1	<1	274	274	0.1
GW70	Interface between spoil/ regolith	24/11/2016		6.02		8788														
GW70	Interface between spoil/ regolith	24/02/2017	7.01	6.13	11700	8730	4600		205	80	231	1310	18	2870	137	<1	<1	323	323	0.2
GW70	Interface between spoil/ regolith	18/05/2017	6.37		8210		4940	5340	400	72	211	1260	16	2710	114	<1	<1	214	214	0.3
GW70	Interface between spoil/ regolith	29/08/2017	6.35		8370		4640	5440.5	340	66	210	1200	17	2880	92	<1	<1	238	238	0.4
GW71	Interface between spoil/ regolith	25/11/2016		5.1		2709														
GW71	Interface between spoil/ regolith	2/03/2017	4.8	4.5	3140	3420	2040		317	18	57	439	16	933	190	<1	<1	2	2	0.8
GW71	Interface between spoil/ regolith	18/05/2017	4.82		3290		2190	2140	404	17	57	452	16	911	183	<1	<1	1	1	0.3
GW71	Interface between spoil/ regolith	29/08/2017	4.74		3500		2190	2275	353	16	61	457	24	1060	185	<1	<1	<1	<1	0.7
GW72	Interface between spoil/ regolith	30/11/2016		5.61		2752														
GW72	Interface between spoil/ regolith	28/02/2017	5.97	5.5	2620	2930	1700		498	91	100	236	31	510	568	<1	<1	130	130	<0.1
GW72	Interface between spoil/ regolith	17/05/2017	6.05		2800		1780	1820	557	78	95	241	29	500	589	<1	<1	273	273	<0.1
GW72	Interface between spoil/ regolith	29/08/2017	6.03		2740		1640	1781	204	79	100	244	32	573	557	<1	<1	165	165	<0.1
GW73	Regolith	24/11/2016		6.09		12350														
GW73	Regolith	23/02/2017	6.1	5.98	8110	12390	5270		6	115	307	2190	35	3870	869	<1	<1	129	129	0.3
GW73	Regolith	18/05/2017	6.79		11800		7600	7670	87	102	290	2160	33	3520	873	<1	<1	329	329	0.3
GW73	Regolith	29/08/2017	7.28		12000		6900	7800	31	101	290	2070	34	3920	835	<1	<1	344	344	0.2
GW74	Regolith	25/11/2016		3.88		4223														
GW74	Regolith	23/02/2017	4.21	3.9	3230	3400	2100		182	32	84	467	63	760	603	<1	<1	<1	<1	0.2
GW74	Regolith	18/05/2017	4.19		3060		1960	1990	285	24	77	405	59	658	555	<1	<1	<1	<1	<0.1
GW74	Regolith	6/09/2017	4.13		2750		1640	1787.5	251	20	82	296	66	605	460	<1	<1	<1	<1	0.2
GW75	Spoil	29/11/2016		5.43		3629														
GW75	Spoil	2/03/2017	5.93	5.36	3300	3600	2140		20	62	188	371	40	537	1000	<1	<1	91	91	0.1
GW75	Spoil	17/05/2017	5.99		3470		2490	2260	262	56	179	368	38	538	1020	<1	<1	91	91	<0.1
GW76	Spoil	29/11/2016		5.94		2502														
GW76	Spoil	28/02/2017	6.38	5.99	2400	2740	1560		36											

Appendix A-2 - Total Dissolved Metals/Metalloids

[illegible]

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)	
GW05	Queen Seam	16/01/2003																													
GW05	Queen Seam	4/07/2003																													
GW05	Queen Seam	17/02/2004																													
GW05	Queen Seam	14/07/2004																													
GW05	Queen Seam	27/01/2005																													
GW05	Queen Seam	29/06/2005																													
GW05	Queen Seam	12/01/2006																													
GW05	Queen Seam	2/01/2007																													
GW05	Queen Seam	21/04/2008				0.002			<0.001				0.006										0.006						0.065		
GW05	Queen Seam	25/11/2008							<0.0001				0.001										0.018						0.049		
GW05	Queen Seam	5/06/2009					<0.05														<0.000001				<0.01		<0.01				
GW05	Queen Seam	27/08/2009					<0.05																		<0.01		<0.01				
GW05	Queen Seam	1/12/2009					0.09																		<0.01		<0.01				
GW05	Queen Seam	18/03/2010					<0.05																		<0.01		<0.01				
GW05	Queen Seam	22/06/2010			<0.001	<0.001	<0.05	<0.05																	<0.01	<0.01	<0.01	<0.01			
GW05	Queen Seam	8/02/2011			0.004	<0.001	0.24	0.22																	<0.01	<0.01	<0.01	<0.01			
GW05	Queen Seam	3/05/2011			0.001	<0.001	0.14	0.15																	<0.01	<0.01	<0.01	<0.01			
GW05	Queen Seam	4/08/2011			<0.001	<0.001	<0.05	<0.05																	<0.01	<0.01	<0.01	<0.01			
GW05	Queen Seam	26/10/2011																													
GW05	Queen Seam	31/10/2011			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	7/03/2012			0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	5/05/2012			0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	14/08/2012			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	8/11/2012			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	18/02/2013			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	26/05/2013			<0.001	<0.001	0.06	0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	3/08/2013			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	8/11/2013			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	21/02/2014			<0.001	<0.001	<0.05	0.06																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	28/05/2014			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	8/08/2014			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	5/11/2014			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	8/03/2015			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	24/05/2015			<0.001	<0.001	<0.05	<0.05																		<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	15/09/2015	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05									0.89	0.77	0.096	0.098	<0.000001	<0.000001				<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	4/12/2015	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05									0.82	0.82	0.094	0.092	<0.000001	<0.000001				<0.01	<0.01	<0.01	<0.01		
GW05	Queen Seam	28/02/2016	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.03	0.98	0.94	0.113	0.103	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005	
GW05	Queen Seam	12/05/2016	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1	0.97	0.91	0.098	0.099		<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW05	Queen Seam	23/08/2016	<0.01	<0.01	<0.001	<0.001	0.06	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.05	0.95	0.91	0.101	0.096	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005	
GW05	Queen Seam	23/11/2016																													
GW05	Queen Seam	17/02/2017	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	0.9	0.88	0.87	0.102	0.095	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005	
GW05	Queen Seam	29/08/2017	1.75	<0.01	0.002	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	0.008	<0.001	0.65	<0.05	2.25	0.65	0.124	0.112	<0.001	<0.001	0.002	<0.001	<0.01	<0.01	<0.01	<0.01	0.038	0.036	
GW09	Sandstone below Queen Seam	16/08/1993	1.1			<0.01			<0.005				<0.01				51.8		5.5				0.34		<0.01				2.29		
GW09	Sandstone below Queen Seam	16/01/1997																													
GW09	Sandstone below Queen Seam	12/05/1998																													
GW09	Sandstone below Queen Seam	5/01/1999																													
GW09	Sandstone below Queen Seam	8/06/1999																													
GW09	Sandstone below Queen Seam	10/01/2000																													
GW09	Sandstone below Queen Seam	18/07/2000																													
GW09	Sandstone below Queen Seam	24/01/2001																													
GW09	Sandstone below Queen Seam	12/06/2001																													
GW09	Sandstone below Queen Seam	30/01/2002																													
GW09	Sandstone below Queen Seam	2/08/2002																													
GW09	Sandstone below Queen Seam	16/01/2003																													
GW09	Sandstone below Queen Seam	4/07/2003																													
GW09	Sandstone below Queen Seam	17/02/2004																													
GW09	Sandstone below Queen Seam	14/07/2004																													
GW09	Sandstone below Queen Seam	27/01/2005																													
GW09	Sandstone below Queen Seam	29/06/2005																													
GW09	Sandstone below Queen Seam	12/01/2006																													
GW09	Sandstone below Queen Seam	2/01/2007																													
GW09	Sandstone below Queen Seam	21/04/2008							<0.001				0.007										0.236						2.38		
GW09	Sandstone below Queen Seam	26/11/2008								0.0001			0.008										0.219						2.07		
GW09	Sandstone below Queen Seam	19/10/2009				<0.001	0.2			0.0009	0.419		0.002						2.14		<										

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW11	Coal Measures below Queen Seam	5/01/1999																												
GW11	Coal Measures below Queen Seam	8/06/1999																												
GW11	Coal Measures below Queen Seam	10/01/2000																												
GW11	Coal Measures below Queen Seam	18/07/2000																												
GW11	Coal Measures below Queen Seam	24/01/2001																												
GW11	Coal Measures below Queen Seam	12/06/2001																												
GW11	Coal Measures below Queen Seam	30/01/2002																												
GW11	Coal Measures below Queen Seam	6/06/2002	1.51		<0.001				<0.001		<0.001		0.009				<0.01		0.03				0.007		<0.01				0.037	
GW11	Coal Measures below Queen Seam	2/08/2002																												
GW11	Coal Measures below Queen Seam	15/10/2002	0.16		<0.001		0.2		<0.001		<0.001		0.002				1.4		0.105				<0.001		<0.01				0.008	
GW11	Coal Measures below Queen Seam	16/01/2003																												
GW11	Coal Measures below Queen Seam	4/07/2003																												
GW11	Coal Measures below Queen Seam	17/02/2004																												
GW11	Coal Measures below Queen Seam	14/07/2004																												
GW11	Coal Measures below Queen Seam	27/01/2005																												
GW11	Coal Measures below Queen Seam	29/06/2005																												
GW11	Coal Measures below Queen Seam	12/01/2006																												
GW11	Coal Measures below Queen Seam	2/01/2007																												
GW11	Coal Measures below Queen Seam	27/11/2008							<0.0001				0.002										0.004						0.016	
GW11	Coal Measures below Queen Seam	28/10/2010				<0.001	0.09		<0.0001	<0.001		<0.001							0.016		0.000002		<0.001		<0.01		<0.01		<0.005	
GW11	Coal Measures below Queen Seam	29/11/2016																												
GW11	Coal Measures below Queen Seam	8/03/2017	0.03	<0.01	<0.001	<0.001	0.07	0.08	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.25	6.25	6.75	6.5	0.225	0.22	0.002	0.002	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW11	Coal Measures below Queen Seam	8/09/2017	0.44	0.02	0.001	<0.001	0.06	0.06	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.05	3.88	6.51	3.58	0.111	0.102	0.002	0.002	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.006	0.008
GW21	Coal Measures below Queen Seam	16/01/1997																												
GW21	Coal Measures below Queen Seam	5/01/1999																												
GW21	Coal Measures below Queen Seam	8/06/1999																												
GW21	Coal Measures below Queen Seam	10/01/2000																												
GW21	Coal Measures below Queen Seam	18/07/2000																												
GW21	Coal Measures below Queen Seam	24/01/2001																												
GW21	Coal Measures below Queen Seam	12/06/2001																												
GW21	Coal Measures below Queen Seam	30/01/2002																												
GW21	Coal Measures below Queen Seam	2/08/2002																												
GW21	Coal Measures below Queen Seam	16/01/2003																												
GW21	Coal Measures below Queen Seam	4/07/2003																												
GW21	Coal Measures below Queen Seam	17/02/2004																												
GW21	Coal Measures below Queen Seam	14/07/2004																												
GW21	Coal Measures below Queen Seam	27/01/2005																												
GW21	Coal Measures below Queen Seam	29/06/2005																												
GW21	Coal Measures below Queen Seam	12/01/2006																												
GW21	Coal Measures below Queen Seam	2/01/2007																												
GW21	Coal Measures below Queen Seam	12/05/2009				0.005	0.08		0.0002				0.015								0.000001		0.012		<0.01		0.02		0.028	
GW21	Coal Measures below Queen Seam	28/10/2010				0.002	0.09		<0.0001	0.001		<0.001							2.12		<0.000001		0.003		<0.01		<0.01		0.017	
GW21	Coal Measures below Queen Seam	26/10/2011																												
GW21	Coal Measures below Queen Seam	2/03/2017	0.38	<0.01	0.002	<0.001	0.1	0.09	0.0003	0.0003	0.002	0.003	0.002	<0.001	<0.05	19.3	27.4	19.2	1.96	2.06	<0.001	<0.001	0.003	0.003	<0.01	<0.01	<0.01	<0.01	0.026	0.085
GW21	Coal Measures below Queen Seam	16/05/2017	0.32	<0.01	0.002	0.002	0.09	0.08	<0.0001	<0.0001	0.002	0.002	0.002	<0.001	1.6	33.5	36.5	35.1	2.15	1.96	<0.001	<0.001	0.003	0.003	<0.01	<0.01	<0.01	<0.01	<0.005	0.008
GW22	Coal Measures below Queen Seam	16/08/1993	3			<0.01			<0.005				<0.01				20.4		2.4				<0.01		<0.01				<0.01	
GW22	Coal Measures below Queen Seam	16/01/1997																												
GW22	Coal Measures below Queen Seam	5/01/1999																												
GW22	Coal Measures below Queen Seam	8/06/1999																												
GW22	Coal Measures below Queen Seam	10/01/2000																												
GW22	Coal Measures below Queen Seam	18/07/2000																												
GW22	Coal Measures below Queen Seam	24/01/2001																												
GW22	Coal Measures below Queen Seam	12/06/2001																												
GW22	Coal Measures below Queen Seam	30/01/2002																												
GW22	Coal Measures below Queen Seam	2/08/2002																												
GW22	Coal Measures below Queen Seam	16/01/2003																												
GW22	Coal Measures below Queen Seam	4/07/2003																												
GW22	Coal Measures below Queen Seam	17/02/2004																												
GW22	Coal Measures below Queen Seam	14/07/2004																												
GW22	Coal Measures below Queen Seam	27/01/2005																												
GW22	Coal Measures below Queen Seam	29/06/2005																												
GW22	Coal Measures below Queen Seam	12/01/2006																												
GW22	Coal Measures below Queen Seam	2/01/2007																												
GW22	Coal Measures below Queen Seam	21/04/2008							0.0023				0.014										0.006						0.309	
GW22	Coal Measures below Queen Seam	27/11/2008							0.002				0.005										0.004						0.24	
GW22	Coal Measures below Queen Seam	28/10/2010				<0.001	0.22		0.0009	<0.001			0.002						0.008		<0.000001		0.001		<0.01		<0.01		0.133	
GW22	Coal Measures below Queen Seam	26/10/2011																												
GW22	Coal Measures below Queen Seam	1/12/2016																												
GW22	Coal Measures below Queen Seam	6/03/2017	5.03	0.12	0.002	<0.001	0.05	0.35	0.0003	<0.0001	0.152	0.006	0.009	<0.001	0.42	7.08	15.8	7.5	9.04	0.203	<0.001	<0.001	0.026	0.002	<0.01	<0.01	0.02	<0.01	0.116	0.018
GW22	Coal Measures below Queen Seam	8/09/2017	0.19	0.17	<0.001	<0.001	0.38	0.41	0.0001	0.0002	0.009	0.008	<0.001	<0.001	1.7	10	11	11.7	0.258	0.263	<0.001	<0.001	0.005	0.004	<0.01	<0.01	<0.01	<0.01	0.039	0.041
GW2																														

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW25	Regolith	24/01/2001																												
GW25	Regolith	12/06/2001																												
GW25	Regolith	23/07/2001			<0.001				<0.001				<0.01				0.29		0.31				0.01		<0.01				0.033	
GW25	Regolith	30/01/2002																												
GW25	Regolith	2/08/2002																												
GW25	Regolith	16/01/2003																												
GW25	Regolith	7/07/2003	2.22		0.006				<0.0001				0.009				9.8						0.019		<0.001				0.042	
GW25	Regolith	27/07/2004	0.8		0.002				0.0001				<0.01				1.1						0.01		<0.01				0.018	
GW25	Regolith	29/06/2005	0.19		<0.001				0.0001				0.001				0.98						0.015		<0.01				0.036	
GW25	Regolith	12/01/2006																												
GW25	Regolith	2/01/2007																												
GW25	Regolith	26/11/2008								0.0006			0.018										0.019						0.05	
GW25	Regolith	10/08/2010				<0.001	<0.05			<0.0001	0.006		0.002						0.24		<0.000001		0.012		<0.01		<0.01		0.043	
GW25	Regolith	3/11/2010				0.004	0.06			0.0004	0.035		0.004						1.01		<0.000001		0.055		<0.01		<0.01		0.156	
GW25	Regolith	26/10/2011																												
GW25	Regolith	12/03/2015	0.32	0.04	0.004	<0.001	0.05	0.05	0.0003	0.0003	0.091	0.087	0.003	0.003	<0.05	<0.05	0.3	<0.05	10.6	9.03	<0.000001	<0.000001	0.033	0.029	<0.01	<0.01	<0.01	<0.01	0.08	0.083
GW25	Regolith	24/05/2015	0.52	0.14	<0.001	<0.001	0.05	0.06	0.0004	0.0004	0.056	0.057	0.003	0.003	<0.05	<0.05	0.28	<0.05	6.04	5.97	<0.000001	<0.000001	0.035	0.034	<0.01	<0.01	<0.01	<0.01	0.147	0.145
GW25	Regolith	15/09/2015	3.72	0.38	0.002	<0.001	<0.05	0.07	0.0017	0.0016	0.125	0.109	0.007	0.002	<0.05	<0.05	5.54	<0.05	12.5	12.6	<0.000001	<0.000001	0.058	0.051	<0.01	<0.01	0.01	<0.01	0.544	0.498
GW25	Regolith	3/12/2015	1.62	0.08	<0.001	<0.001	0.05	<0.05	0.0006	0.0006	0.083	0.077	0.005	<0.001	<0.05	<0.05	1.95	<0.05	7.23	6.61	<0.000001	<0.000001	0.031	0.029	<0.01	<0.01	<0.01	<0.01	0.206	0.205
GW25	Regolith	28/02/2016	3.49	0.04	0.002	<0.001	0.06	0.06	0.0007	0.0006	0.205	0.195	0.006	0.002	<0.05	0.17	6.21	<0.05	13.4	12.7	<0.000001	<0.000001	0.039	0.035	<0.01	<0.01	0.01	<0.01	0.238	0.227
GW25	Regolith	12/05/2016	16.1	0.02	0.005	<0.001	0.07	0.08	0.0007	0.0006	0.377	0.33	0.024	0.002	<0.05	0.75	35.4	0.73	19.1	17.3	<0.000001	<0.000001	0.05	0.037	<0.01	<0.01	0.07	<0.01	0.288	0.221
GW25	Regolith	27/08/2016	12.8	0.02	0.005	<0.001	0.06	0.07	0.0006	0.0006	0.34	0.309	0.018	0.002	2.19	0.89	37.1	3.08	16.6	16.4	<0.000001	<0.000001	0.048	0.037	<0.01	<0.01	0.05	<0.01	0.249	0.214
GW25	Regolith	22/11/2016	15.8	<0.01	0.006	<0.001	0.06	0.29	0.0004	0.0003	0.263	0.231	0.024	0.001	<0.05	2.52	57	2.08	13	9.52	<0.001	<0.001	0.043	0.031	<0.01	<0.01	0.07	<0.01	0.199	0.423
GW25	Regolith	7/03/2017	8.27	0.01	0.003	<0.001	0.07	0.06	<0.0001	0.0002	0.016	0.146	0.008	0.001	0.21	2.76	10.4	3	0.676	8.4	<0.001	<0.001	0.014	0.022	<0.01	<0.01	0.01	<0.01	0.03	0.103
GW25	Regolith	16/05/2017	17.7	0.01	0.008	<0.001	0.06	0.06	0.0002	0.0002	0.16	0.135	0.024	<0.001	<0.05	3.16	68.5	3.19	9.34	8.25	<0.001	<0.001	0.037	0.021	<0.01	<0.01	0.07	<0.01	0.158	0.096
GW25	Regolith	4/09/2017	0.06	<0.01	0.002	<0.001	0.05	<0.05	0.0004	0.0003	0.102	0.096	0.002	0.001	<0.05	3.92	14.9	3.65	5.94	5.6	<0.001	<0.001	0.02	0.019	<0.01	<0.01	<0.01	<0.01	0.07	0.07
GW30	Regolith	29/06/2005	1.88		<0.001				<0.0001				0.009				2.07					0.007		<0.01					0.038	
GW30	Regolith	12/01/2006																												
GW30	Regolith	2/01/2007																												
GW30	Regolith	12/05/2009				0.006	0.07			0.0002			0.003								<0.000001		0.033		<0.01		<0.01		0.118	
GW30	Regolith	28/10/2010				<0.001	0.06			0.0002	0.022		<0.001						0.344		<0.000001		0.015		<0.01		<0.01		0.075	
GW30	Regolith	26/10/2011																												
GW30	Regolith	29/11/2016																												
GW30	Regolith	7/03/2017	0.15	<0.01	<0.001	0.002	0.35	0.07	<0.0001	<0.0001	0.006	0.016	<0.001	<0.001	0.21	6.33	7.88	6.54	0.209	0.649	<0.001	<0.001	0.002	0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.026
GW34	Regolith - Coal/interburden	5/08/2011																												
GW34	Regolith - Coal/interburden	4/11/2011																												
GW34	Regolith - Coal/interburden	10/03/2012																												
GW34	Regolith - Coal/interburden	3/05/2012																												
GW34	Regolith - Coal/interburden	18/08/2012																												
GW34	Regolith - Coal/interburden	9/11/2012																												
GW34	Regolith - Coal/interburden	21/02/2013																												
GW34	Regolith - Coal/interburden	27/05/2013																												
GW34	Regolith - Coal/interburden	8/08/2013	0.05	<0.01	0.003	0.003	0.12	0.1	<0.0001	0.0001	0.02	0.024	0.005	0.002			24	24.9	1.22	1.31	<0.000001	<0.000001	0.018	0.017	<0.01	<0.01	<0.01	<0.01	0.161	0.148
GW34	Regolith - Coal/interburden	9/11/2013	0.04	<0.01	0.003	0.003	0.06	<0.05	<0.0001	<0.0001	0.018	0.017	0.014	0.006		13.4	19	18.5	1.05	0.992	0.000001	<0.000001	0.023	0.019	<0.01	<0.01	<0.01	<0.01	0.192	0.078
GW34	Regolith - Coal/interburden	23/02/2014																												
GW34	Regolith - Coal/interburden	3/11/2014	0.1	<0.01	0.003	<0.001	<0.05	0.05	<0.0001	<0.0001	0.019	0.017	0.006	<0.001		19	23.4	6.96	1.16	1.09	<0.000001	<0.000001	0.016	0.012	<0.01	<0.01	<0.01	<0.01	0.122	0.086
GW34	Regolith - Coal/interburden	27/05/2015	0.03	<0.01	0.004	0.004	0.08	0.06	<0.0001	<0.0001	0.02	0.018	0.002	0.001	2.7	23	33.7	25.7	1.27	1.17	<0.000001	<0.000001	0.014	0.013	<0.01	<0.01	<0.01	<0.01	0.107	0.093
GW34	Regolith - Coal/interburden	16/09/2015	0.06	<0.01	0.003	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.012	0.012	0.002	<0.001	0.17	<0.05	9.26	0.17	0.777	0.903	<0.000001	<0.000001	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.686	0.575
GW34	Regolith - Coal/interburden	8/12/2015	0.4	<0.01	0.002	0.002	0.1	0.08	<0.0001	<0.0001	0.011	0.009	0.003	<0.001		16.3	17	13.9	0.757	0.693	<0.000001	<0.000001	0.014	0.012	<0.01	<0.01	<0.01	<0.01	0.14	0.076
GW34	Regolith - Coal/interburden	29/02/2016	0.02	<0.01	0.002	0.002	0.06	<0.05	<0.0001	<0.0001	0.009	0.008	0.001	<0.001	0.1	13	14.3	13.1	0.644	0.6	<0.000001	<0.000001	0.009	0.008	<0.01	<0.01	<0.01	<0.01	0.074	0.066
GW34	Regolith - Coal/interburden	14/05/2016	0.05	<0.01	0.001	<0.001	0.07	0.07	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.05	4.24	6.34	4.24	0.108	0.102	<0.000001	<0.000001	0.006	0.006	<0.01	<0.01	<0.01	<0.01	0.043	0.023
GW34	Regolith - Coal/interburden	28/08/2016	0.08	<0.01	0.003	0.003	0.13	0.08	<0.0001	<0.0001	0.013	0.012	0.004	<0.001	<0.05	19.8	20.2	19.8	0.924	0.918	<0.000001	<0.000001	0.012	0.011	<0.01	<0.01	<0.01	<0.01	0.111	0.104
GW34	Regolith - Coal/interburden	16/11/2016	0.02	<0.01	0.002																									

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW36	Regolith - Coal/interburden	5/08/2011																												
GW36	Regolith - Coal/interburden	4/11/2011																												
GW36	Regolith - Coal/interburden	10/03/2012																												
GW36	Regolith - Coal/interburden	2/05/2012																												
GW36	Regolith - Coal/interburden	18/08/2012																												
GW36	Regolith - Coal/interburden	9/11/2012																												
GW36	Regolith - Coal/interburden	27/05/2013																												
GW36	Regolith - Coal/interburden	8/08/2013																												
GW36	Regolith - Coal/interburden	9/11/2013																												
GW36	Regolith - Coal/interburden	22/02/2014																												
GW36	Regolith - Coal/interburden	12/08/2014																												
GW36	Regolith - Coal/interburden	4/11/2014																												
GW36	Regolith - Coal/interburden	27/05/2015	0.09	<0.01	<0.001	<0.001	<0.05	0.08	<0.0001	<0.0001	<0.001	<0.001	0.004	0.001	26.5	65.9	110	92.4	2.58	2.5	<0.000001	<0.000001	0.001	0.001	<0.01	<0.01	<0.01	<0.01	0.027	0.03
GW36	Regolith - Coal/interburden	16/09/2015	0.13	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.001	<0.001	0.01	0.001	6.4	83.4	84.3	89.8	2.44	2.66	<0.000001	<0.000001	0.002	0.003	<0.01	<0.01	<0.01	<0.01	0.034	0.023
GW36	Regolith - Coal/interburden	8/12/2015	0.05	<0.01	<0.001	<0.001	0.09	0.06	<0.0001	<0.0001	<0.001	<0.001	0.004	0.001		85	92	76.8	2.81	2.4	<0.000001	<0.000001	0.005	0.004	<0.01	<0.01	<0.01	<0.01	0.044	0.043
GW36	Regolith - Coal/interburden	29/02/2016	0.07	<0.01	<0.001	<0.001	0.05	<0.05	<0.0001	<0.0001	0.001	<0.001	0.003	0.001	8.7	78.8	89.7	87.5	2.8	2.6	<0.000001	<0.000001	0.005	0.005	<0.01	<0.01	<0.01	<0.01	0.043	0.041
GW36	Regolith - Coal/interburden	14/05/2016	0.04	<0.01	<0.001	<0.001	0.07	0.06	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<1	92.7	93.8	88	2.98	2.78	<0.000001	<0.000001	0.003	0.003	<0.01	<0.01	<0.01	<0.01	0.045	0.042
GW36	Regolith - Coal/interburden	27/08/2016	0.08	<0.01	<0.001	<0.001	0.12	0.07	<0.0001	<0.0001	<0.001	<0.001	0.013	<0.001	9.9	81.8	91	91.7	2.8	2.8	<0.000001	<0.000001	0.007	0.005	<0.01	<0.01	<0.01	<0.01	0.077	0.07
GW36	Regolith - Coal/interburden	17/11/2016	0.05	<0.01	<0.001	<0.001	0.12	0.06	<0.0001	<0.0001	<0.001	<0.001	0.005	<0.001	4.1	73.6	77.5	77.7	2.56	2.49	<0.001	<0.001	0.027	0.028	<0.01	<0.01	<0.01	<0.01	0.049	0.052
GW36	Regolith - Coal/interburden	1/03/2017	0.15	<0.01	0.001	<0.001	0.07	<0.05	<0.0001	<0.0001	<0.001	<0.001	0.011	0.007	<0.05	88.1	109	81.2	2.68	2.51	0.002	<0.001	<0.001	0.002	<0.01	<0.01	<0.01	<0.01	0.098	0.076
GW36	Regolith - Coal/interburden	23/05/2017	0.07	<0.01	<0.001	<0.001	0.07	0.07	<0.0001	<0.0001	<0.001	<0.001	0.006	0.005	4.1	81.6	84.3	85.7	2.59	2.49	<0.001	<0.001	0.002	0.002	<0.01	<0.01	<0.01	<0.01	0.03	0.03
GW37	Regolith - Sandstone	4/08/2011																												
GW37	Regolith - Sandstone	3/11/2011																												
GW37	Regolith - Sandstone	9/03/2012																												
GW37	Regolith - Sandstone	2/05/2012																												
GW37	Regolith - Sandstone	17/08/2012																												
GW37	Regolith - Sandstone	8/11/2012																												
GW37	Regolith - Sandstone	21/02/2013																												
GW37	Regolith - Sandstone	27/05/2013																												
GW37	Regolith - Sandstone	9/08/2013																												
GW37	Regolith - Sandstone	9/11/2013																												
GW37	Regolith - Sandstone	23/02/2014																												
GW37	Regolith - Sandstone	12/08/2014																												
GW37	Regolith - Sandstone	4/11/2014																												
GW37	Regolith - Sandstone	27/05/2015	0.16	<0.01	0.001	<0.001	<0.05	0.06	<0.0001	<0.0001	0.001	<0.001	0.009	<0.001	7.4	52.1	69.8	59.5	5.69	5.68	<0.000001	<0.000001	0.002	0.002	<0.01	<0.01	<0.01	<0.01	0.114	0.075
GW37	Regolith - Sandstone	17/09/2015	0.08	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	0.008	<0.001	2	44.7	48.4	46.7	4.91	4.98	<0.000001	<0.000001	0.002	0.002	<0.01	<0.01	<0.01	<0.01	0.044	0.025
GW37	Regolith - Sandstone	9/12/2015	0.17	<0.01	0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.001	<0.001	0.015	0.003		49.7	54.2	43.4	5.82	5.04	0.000001	<0.000001	0.014	0.011	<0.01	<0.01	<0.01	<0.01	0.154	0.114
GW37	Regolith - Sandstone	29/02/2016	0.11	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.001	<0.001	0.005	<0.001	4.2	48	53.7	52.2	5.82	5.49	<0.000001	<0.000001	0.006	0.004	<0.01	<0.01	<0.01	<0.01	0.074	0.064
GW37	Regolith - Sandstone	15/05/2016	0.18	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.001	<0.001	0.005	<0.001	<1	56.7	54.8	51.3	6.04	5.77	<0.000001	<0.000001	0.004	0.002	<0.01	<0.01	<0.01	<0.01	0.127	0.082
GW37	Regolith - Sandstone	28/08/2016	0.19	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.001	<0.001	0.008	<0.001	3.8	48.4	51.6	52.2	5.73	5.74	<0.000001	<0.000001	0.004	0.003	<0.01	<0.01	<0.01	<0.01	0.07	0.064
GW37	Regolith - Sandstone	17/11/2016	0.05	<0.01	<0.001	<0.001	0.09	<0.05	<0.0001	<0.0001	<0.001	<0.001	0.008	0.006	<0.05	48	50.5	47.7	5.58	5.46	<0.001	<0.001	0.003	0.003	<0.01	<0.01	<0.01	<0.01	0.04	0.067
GW37	Regolith - Sandstone	3/03/2017	0.06	<0.01	0.005	<0.001	0.07	<0.05	0.0008	<0.0001	0.016	<0.001	0.004	0.006	<0.05	52.4	22.4	48.5	1.06	5.82	<0.001	<0.001	0.011	0.002	<0.01	<0.01	<0.01	<0.01	0.119	0.043
GW37	Regolith - Sandstone	23/05/2017	0.05	<0.01	0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.001	0.001	0.014	0.011	<0.05	52.7	57.1	52.4	5.68	5.52	<0.001	<0.001	0.002	0.001	<0.01	<0.01	<0.01	<0.01	0.026	0.026
GW37	Regolith - Sandstone	29/08/2017	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	5.1	47.9	51.9	53	5.76	5.84	<0.001	<0.001	0.002	0.001	<0.01	<0.01	<0.01	<0.01	0.019	0.02
GW38	Regolith - Sandstone	5/08/2011																												
GW38	Regolith - Sandstone	3/11/2011																												
GW38	Regolith - Sandstone	10/03/2012																												
GW38	Regolith - Sandstone	2/05/2012																												
GW38	Regolith - Sandstone	17/08/2012																												
GW38	Regolith - Sandstone	8/11/2012																												
GW38	Regolith - Sandstone	20/02/2013																												
GW38	Regolith - Sandstone	27/05/2013																												
GW38	Regolith - Sandstone	8/08/2013	0.27	<0.01	0.008	0.006	0.1	0.09	<0.0001	0.0001	0.011	0.01	0.004	<0.001			6.26	4.26	1.02	0.872	<0.000001	<0.000001	0.007	0.004	<0.01	<0.01	<0.01	<0.01	0.04	0.024
GW38	Regolith - Sandstone	9/11/2013	0.08	<0.01	0.006	0.004	<0.05	<0.05	<0.0001	<0.0001	0.012	0.011	0.004	0.002		3.24	4.57	3.09	0.65	0.6	<0.000001	<0.000001	0.006	0.005	<0.01	<0.01	<0.01	<0.01	0.021	0.02
GW38	Regolith - Sandstone	22/02/2014	0.08	0.02	0.005	0.003	0.06	0.06	<0.0																					

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW39	Meandu Creek Alluviumy	8/08/2013																												
GW39	Meandu Creek Alluviumy	9/11/2013																												
GW39	Meandu Creek Alluviumy	22/02/2014																												
GW39	Meandu Creek Alluviumy	12/08/2014																												
GW39	Meandu Creek Alluviumy	4/11/2014																												
GW39	Meandu Creek Alluviumy	27/05/2015	0.29	<0.01	<0.001	<0.001	0.05	0.11	<0.0001	<0.0001	0.002	0.002	0.002	<0.001	<0.05	0.25	0.51	0.22	0.273	0.271	<0.000001	<0.000001	0.002	0.002	<0.01	<0.01	<0.01	<0.01	0.023	0.023
GW39	Meandu Creek Alluviumy	16/09/2015	1.38	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.003	<0.001	<0.001	<0.001	<0.05	0.16	1.45	0.13	<0.001	0.29	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	0.013
GW39	Meandu Creek Alluviumy	7/12/2015	2.72	<0.01	<0.001	<0.001	0.23	0.08	<0.0001	<0.0001	0.004	0.002	0.012	0.003		0.24	3.4	0.1	0.303	0.246	<0.000001	<0.000001	0.009	0.006	<0.01	<0.01	<0.01	<0.01	0.063	0.035
GW39	Meandu Creek Alluviumy	29/02/2016	0.72	<0.01	<0.001	<0.001	0.05	<0.05	<0.0001	<0.0001	0.003	0.002	0.002	<0.001	<0.05	0.26	1.11	0.26	0.279	0.256	<0.000001	<0.000001	0.003	0.002	<0.01	<0.01	<0.01	<0.01	0.016	0.012
GW39	Meandu Creek Alluviumy	14/05/2016	2.28	<0.01	<0.001	<0.001	0.07	0.06	<0.0001	<0.0001	0.003	0.002	0.007	0.004	<0.05	0.12	3.23	0.13	0.299	0.265	<0.000001	<0.000001	0.004	0.003	<0.01	<0.01	<0.01	<0.01	0.034	0.034
GW39	Meandu Creek Alluviumy	28/08/2016	1.24	<0.01	<0.001	<0.001	0.09	0.08	<0.0001	<0.0001	0.003	0.002	0.003	<0.001	<0.05	0.09	1.66	0.12	0.282	0.268	<0.000001	<0.000001	0.004	0.003	<0.01	<0.01	<0.01	<0.01	0.022	0.058
GW39	Meandu Creek Alluviumy	17/11/2016	0.82	<0.01	<0.001	<0.001	0.11	0.07	<0.0001	<0.0001	0.003	0.003	0.004	<0.001	0.18	0.38	1.51	0.56	0.266	0.269	<0.001	<0.001	0.004	0.003	<0.01	<0.01	<0.01	<0.01	0.014	0.027
GW39	Meandu Creek Alluviumy	1/03/2017	2.13	<0.01	<0.001	<0.001	0.08	0.05	<0.0001	<0.0001	0.004	0.003	0.003	<0.001	<0.05	0.17	2.64	0.21	0.35	0.32	<0.001	<0.001	<0.001	0.002	<0.01	<0.01	<0.01	<0.01	0.021	0.075
GW39	Meandu Creek Alluviumy	22/05/2017	0.55	<0.01	<0.001	<0.001	0.07	0.07	<0.0001	<0.0001	0.003	0.003	0.002	0	<0.05	0.18	0.8	0.17	0.278	0.266	<0.001	<0.001	0.003	0.003	<0.01	<0.01	<0.01	<0.01	0.016	0.013
GW39	Meandu Creek Alluviumy	29/08/2017	3.16	<0.01	0.001	<0.001	0.05	<0.05	0.0002	<0.0001	0.005	0.002	0.011	0.001	<0.05	0.11	3.45	0.06	0.254	0.23	0.002	0.002	0.014	0.01	<0.01	<0.01	<0.01	<0.01	0.055	0.038
GW40	Meandu Creek Alluvium	5/08/2011																												
GW40	Meandu Creek Alluvium	3/11/2011																												
GW40	Meandu Creek Alluvium	10/03/2012																												
GW40	Meandu Creek Alluvium	1/05/2012																												
GW40	Meandu Creek Alluvium	17/08/2012																												
GW40	Meandu Creek Alluvium	8/11/2012																												
GW40	Meandu Creek Alluvium	20/02/2013																												
GW40	Meandu Creek Alluvium	27/05/2013																												
GW40	Meandu Creek Alluvium	8/08/2013																												
GW40	Meandu Creek Alluvium	9/11/2013																												
GW40	Meandu Creek Alluvium	22/02/2014																												
GW40	Meandu Creek Alluvium	12/08/2014																												
GW40	Meandu Creek Alluvium	4/11/2014																												
GW40	Meandu Creek Alluvium	27/05/2015	0.62	<0.01	<0.001	<0.001	<0.05	0.1	<0.0001	<0.0001	0.026	0.025	0.003	<0.001	<0.05	1.6	2.16	1.46	0.763	0.75	<0.000001	<0.000001	0.019	0.018	<0.01	<0.01	<0.01	<0.01	0.046	0.05
GW40	Meandu Creek Alluvium	16/09/2015	0.46	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.015	0.014	0.004	0.002	<0.05	0.07	0.88	0.06	0.609	0.631	<0.000001	<0.000001	0.013	0.012	<0.01	<0.01	<0.01	<0.01	0.025	0.025
GW40	Meandu Creek Alluvium	8/12/2015	1.97	<0.01	<0.001	<0.001	0.12	0.07	<0.0001	<0.0001	0.016	0.013	0.005	0.003		0.17	3.46	0.17	0.628	0.563	<0.000001	<0.000001	0.013	0.01	<0.01	<0.01	<0.01	<0.01	0.052	0.04
GW40	Meandu Creek Alluvium	29/02/2016	1.39	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.022	0.02	0.002	0.001	<0.05	0.47	3.07	0.43	0.994	0.927	<0.000001	<0.000001	0.013	0.011	<0.01	<0.01	<0.01	<0.01	0.041	0.036
GW40	Meandu Creek Alluvium	14/05/2016	1.27	<0.01	<0.001	<0.001	0.08	0.07	<0.0001	<0.0001	0.013	0.011	0.002	<0.001	0.14	0.16	2.63	0.3	0.66	0.574	<0.000001	<0.000001	0.009	0.008	<0.01	<0.01	<0.01	<0.01	0.035	0.03
GW40	Meandu Creek Alluvium	28/08/2016	2.23	<0.01	<0.001	<0.001	0.09	0.08	<0.0001	<0.0001	0.02	0.018	0.005	0.002	<0.05	0.36	4.49	0.37	0.979	0.963	<0.000001	<0.000001	0.015	0.013	<0.01	<0.01	<0.01	<0.01	0.047	0.121
GW40	Meandu Creek Alluvium	17/11/2016	1.18	<0.01	<0.001	<0.001	0.1	0.06	<0.0001	<0.0001	0.025	0.024	0.004	0.002	<0.05	0.6	3.22	0.55	1.03	0.953	<0.001	<0.001	0.015	0.016	<0.01	<0.01	<0.01	<0.01	0.049	0.083
GW40	Meandu Creek Alluvium	1/03/2017	3.33	<0.01	0.002	<0.001	0.07	0.08	<0.0001	<0.0001	0.022	0.021	0.007	<0.001	<0.05	0.46	6.25	0.48	0.989	0.898	<0.001	<0.001	0.009	0.011	<0.01	<0.01	0.01	<0.01	0.056	0.122
GW40	Meandu Creek Alluvium	22/05/2017	3.48	0.01	0.002	<0.001	0.06	0.06	<0.0001	<0.0001	0.039	0.034	0.008	0.004	<0.05	2.68	9.18	2.31	0.745	0.682	<0.001	<0.001	0.033	0.03	<0.01	<0.01	0.01	<0.01	0.075	0.08
GW40	Meandu Creek Alluvium	29/08/2017	1.43	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	0.011	0.01	0.007	0.004	<0.05	0.22	3.34	0.26	0.49	0.472	<0.001	<0.001	0.025	0.023	<0.01	<0.01	<0.01	<0.01	0.107	0.108
GW41	Interface between spoil/ regolith	2/11/2014	2.92	<0.01	0.004	0.001	0.09	0.1	<0.0001	<0.0001	0.005	0.002	0.015	<0.001		21.2	27	20	0.747	0.674	0.000003	0.000001	0.007	0.002	<0.01	<0.01	0.02	<0.01	0.06	0.027
GW41	Interface between spoil/ regolith	8/03/2015	2.36	<0.01	0.004	<0.001	0.17	0.11	0.0002	<0.0001	0.004	0.001	0.011	<0.001	<0.05	21.6	25.4	16.4	0.636	0.602	0.000004	<0.000001	0.006	0.001	<0.01	<0.01	0.01	<0.01	0.055	<0.005
GW41	Interface between spoil/ regolith	23/05/2015	19.2	<0.01	0.015	<0.001	0.12	0.1	0.0004	<0.0001	0.016	0.002	0.111	<0.001	<0.05	22.3	66.9	20.5	0.911	0.643	0.000009	<0.000001	0.034	0.002	<0.01	<0.01	0.09	<0.01	0.296	0.02
GW41	Interface between spoil/ regolith	15/09/2015	0.45	<0.01	0.002	<0.001	0.1	0.08	<0.0001	<0.0001	0.002	<0.001	0.001	<0.001	<0.05	21.4	20.4	19.8	0.615	0.628	0.000001	<0.000001	0.002	0.001	<0.01	<0.01	<0.01	<0.01	0.014	0.014
GW41	Interface between spoil/ regolith	28/02/2016	0.87	0.02	0.003	0.002	0.41	0.35	0.0001	<0.0001	0.013	0.012	0.004	<0.001	0.08	9.68	11.2	9.76	0.463	0.443	0.000002	0.000002	0.006	0.005	<0.01	<0.01	0.01	<0.01	0.04	0.034
GW41	Interface between spoil/ regolith	12/05/2016	0.92	0.03	0.003	0.002	0.41	0.4	<0.0001	<0.0001	0.012	0.011	0.008	<0.001	<0.05	8.18	9.29	7.85	0.441	0.39	0.000002	0.000001	0.006	0.004	<0.01	<0.01	0.01	<0.01	0.044	0.029
GW41	Interface between spoil/ regolith	26/08/2016	0.04	0.01	0.001	0.001	0.28	0.3	<0.0001	<0.0001	0.009	0.008	<0.001	<0.001	<0.05	11.8	11.7	11.8	0.487	0.483	0.000001	0.000001	0.004	0.004	<0.01	<0.01	<0.01	<0.01	0.023	0.023
GW41	Interface between spoil/ regolith	17/11/2016	0.22	0.05	0.002	0.002	0.54	0.43	<0.0001	<0.0001	0.01	0.011	<0.001	<0.001	<0.05	4.04	3.97	3.91	0.321	0.327	0.001	0.001	0.004	0.004	<0.01	<0.01	<0.01	<0.01	0.034	0.062
GW41	Interface between spoil/ regolith																													

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW43_D	Queen Seam	21/08/2016	<0.01	<0.01	<0.001	<0.001	0.12	0.12	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	5.58	5.25	5.04	0.101	0.091	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW43_D	Queen Seam	21/02/2017	<0.01	<0.01	<0.001	<0.001	0.1	0.11	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.31	5.02	5.32	5.33	0.1	0.1	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW43_D	Queen Seam	12/05/2017	<0.01	<0.01	<0.001	<0.001	0.12	0.14	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	5.98	5.54	5.08	0.094	0.093	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW43_S	Basalt	3/03/2015	0.17	0.01	<0.001	<0.001	0.16	0.1	<0.0001	0.0002	<0.001	<0.001	<0.001	0.001			1.02	1.22	0.052	0.054	<0.000001	<0.000001	<0.001	0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW43_S	Basalt	20/05/2015	0.07	<0.01	<0.001	<0.001	0.13	0.14	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			1.68	1.37	0.059	0.055	<0.000001	<0.000001	0.001	0.008	<0.01	<0.01	<0.01	<0.01	<0.005	0.007
GW43_S	Basalt	2/09/2015	1.12	<0.01	<0.001	<0.001	0.1	0.11	<0.0001	0.0001	<0.001	<0.001	<0.001	<0.001			1.8	1.31	0.059	0.051	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	0.007
GW43_S	Basalt	26/11/2015	0.02	<0.01	<0.001	<0.001	0.13	0.15	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			1.53	1.3	0.047	0.046	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW43_S	Basalt	23/02/2016	0.03	<0.01	<0.001	<0.001	0.12	0.11	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			1.65	1.55	0.052	0.05	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW43_S	Basalt	20/05/2016	0.04	<0.01	<0.001	<0.001	0.16	0.15	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.71	1.71	1.56	0.056	0.055	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW43_S	Basalt	21/08/2016	0.03	<0.01	<0.001	<0.001	0.13	0.14	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.77	1.6	1.5	0.054	0.048	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW43_S	Basalt	21/02/2017	0.02	<0.01	<0.001	<0.001	0.07	0.12	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.05	1.58	1.64	1.57	0.058	0.057	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_D	Queen Seam	24/02/2014	0.02	<0.01	0.003	<0.001	0.09	0.08	0.0002	<0.0001	0.001	<0.001	0.003	0.001			5.12	3.88	0.112	0.093	<0.000001	<0.000001	0.003	<0.001	<0.01	<0.01	<0.01	<0.01	0.009	0.006
GW44_D	Queen Seam	7/08/2014	0.1	<0.01	<0.001	<0.001	0.11	0.06	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001			4.25	2.86	0.13	0.12	0.000001	0.000001	0.015	0.01	<0.01	<0.01	<0.01	<0.01	0.009	0.01
GW44_D	Queen Seam	17/11/2014	<0.01	<0.01	<0.001	<0.001	0.14	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	0.001			4.29	3.69	0.098	0.102	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	0.006
GW44_D	Queen Seam	4/03/2015	<0.01	<0.01	<0.001	<0.001	0.12	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			4.15	3.67	0.102	0.095	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_D	Queen Seam	21/05/2015	<0.01	<0.01	<0.001	<0.001	0.08	0.06	<0.0001	<0.0001	<0.001	<0.001	0.001	<0.001			4.84	4.02	0.107	0.1	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_D	Queen Seam	4/09/2015	<0.01	<0.01	<0.001	<0.001	<0.05	0.07	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			4.69	3.65	0.108	0.099	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.006	<0.005
GW44_D	Queen Seam	28/11/2015	<0.01	<0.01	<0.001	<0.001	0.1	0.09	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			4.27	3.62	0.097	0.091	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_D	Queen Seam	24/02/2016	<0.01	<0.01	<0.001	<0.001	0.08	0.06	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			4.69	4.56	0.111	0.106	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_D	Queen Seam	18/05/2016	<0.01	<0.01	<0.001	<0.001	0.11	0.09	<0.0001	<0.0001	<0.001	<0.001	0.003	<0.001	<0.05	4.68	5.14	4.49	0.106	0.107	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_D	Queen Seam	19/08/2016	<0.01	<0.01	<0.001	<0.001	0.1	0.1	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	4.61	4.7	4.34	0.11	0.094	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_D	Queen Seam	9/11/2016	<0.01	<0.01	<0.001	<0.001	0.11	0.12	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	4.75	4.7	4.65	0.106	0.102	<0.001	<0.001	<0.001	0.002	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_D	Queen Seam	8/02/2017	<0.01	<0.01	0.002	<0.001	0.08	0.07	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	4.8	5.36	4.32	0.119	0.104	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_S	Queen Seam	24/02/2014	0.07	<0.01	0.003	<0.001	0.13	0.08	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001			3.27	2.4	0.118	0.102	0.000004	0.000004	0.004	0.003	<0.01	<0.01	<0.01	<0.01	0.018	0.007
GW44_S	Queen Seam	7/08/2014	0.07	<0.01	<0.001	<0.001	0.13	0.08	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			3.92	3.31	0.22	0.207	0.000002	0.000002	0.012	0.009	<0.01	<0.01	<0.01	<0.01	0.006	0.057
GW44_S	Queen Seam	17/11/2014	0.19	<0.01	<0.001	<0.001	0.12	<0.05	<0.0001	<0.0001	<0.001	<0.001	0.001	0.001			5.08	3.89	0.264	0.273	0.000003	0.000003	0.008	0.005	<0.01	<0.01	<0.01	<0.01	0.008	0.007
GW44_S	Queen Seam	4/03/2015	0.06	<0.01	<0.001	<0.001	0.09	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			4.3	3.96	0.28	0.269	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_S	Queen Seam	21/05/2015	0.16	<0.01	<0.001	<0.001	0.07	0.08	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001			5.37	4.35	0.319	0.282	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_S	Queen Seam	4/09/2015	0.02	<0.01	<0.001	<0.001	0.08	0.07	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			5.64	4.06	0.359	0.299	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_S	Queen Seam	28/11/2015	<0.01	<0.01	<0.001	<0.001	0.09	0.08	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			4.68	3.97	0.292	0.282	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_S	Queen Seam	23/02/2016	<0.01	<0.01	<0.001	<0.001	0.06	0.06	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			5.01	4.95	0.33	0.317	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_S	Queen Seam	18/05/2016	0.02	<0.01	0.001	<0.001	0.1	0.08	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.05	5.06	5.79	4.97	0.336	0.334	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_S	Queen Seam	19/08/2016	<0.01	<0.01	<0.001	<0.001	0.08	0.09	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	5.48	5.23	4.86	0.353	0.309	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_S	Queen Seam	9/11/2016	<0.01	<0.01	<0.001	<0.001	0.1	0.1	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	5.82	5.38	5.53	0.355	0.352	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW44_S	Queen Seam	8/02/2017	<0.01	<0.01	0.001	<0.001	0.07	0.06	<0.0001	<0.0001	<0.001	<0.001	0.001	<0.001	<0.05	5.3	6.01	4.94	0.402	0.343	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW45_D	Queen Seam	25/02/2014	0.12	0.02	0.002	<0.001	0.06	0.05	0.0002	<0.0001	<0.001	<0.001	0.002	<0.001		</														

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW46_S	King Seam	17/11/2014	0.02	<0.01	<0.001	<0.001	0.36	0.24	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			2.32	1.69	0.024	0.021	<0.000001	<0.000001	0.002	<0.001	<0.01	<0.01	<0.01	<0.01	0.009	0.008
GW46_S	King Seam	4/03/2015	0.01	<0.01	0.001	<0.001	0.29	0.27	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			2.1	1.98	0.015	0.015	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW46_S	King Seam	19/05/2015	<0.01	<0.01	0.002	0.001	0.3	0.24	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			2.42	2.21	0.015	0.014	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW46_S	King Seam	2/09/2015	0.02	<0.01	0.001	0.001	0.25	0.27	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			2.77	2.01	0.018	0.013	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW46_S	King Seam	29/11/2015	<0.01	<0.01	<0.001	0.001	0.29	0.28	<0.0001	0.0001	<0.001	<0.001	<0.001	<0.001			2.26	1.9	0.013	0.013	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW46_S	King Seam	22/02/2016	<0.01	<0.01	0.001	0.001	0.25	0.25	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			2.42	2.38	0.014	0.014	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW46_S	King Seam	17/05/2016	<0.01	<0.01	0.001	0.001	0.34	0.28	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	2.53	2.82	2.33	0.014	0.014	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW46_S	King Seam	22/08/2016	<0.01	<0.01	0.001	0.001	0.29	0.34	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.06	2.47	2.41	2.53	0.014	0.013	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	0.132
GW46_S	King Seam	11/11/2016	<0.01	<0.01	0.001	0.001	0.3	0.27	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	2.45	2.42	2.37	0.014	0.014	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW46_S	King Seam	7/02/2017	<0.01	<0.01	0.002	0.001	0.3	0.3	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	2.38	2.72	2.22	0.014	0.013	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW47	#N/A	30/08/2017	0.03	<0.01	<0.001	<0.001	0.18	0.16	<0.0001	<0.0001	0.006	0.004	0.01	<0.001	0.51	2.29	33.2	2.8	1.79	1.6	<0.001	<0.001	0.007	0.003	<0.01	<0.01	<0.01	<0.01	0.066	0.006
GW50_D	Queen Seam	2/06/2009					0.15														<0.000001				<0.01		<0.01			
GW50_D	Queen Seam	5/06/2009					<0.05														0.000002				<0.01		<0.01			
GW50_D	Queen Seam	25/08/2009					0.05														0.000002				<0.01		<0.01			
GW50_D	Queen Seam	1/12/2009					0.06														0.000006				<0.01		<0.01			
GW50_D	Queen Seam	17/03/2010					0.06														0.000004				<0.01		<0.01			
GW50_D	Queen Seam	5/05/2011			<0.001	<0.001	<0.05	0.06													0.000001	0.000002			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	3/08/2011			<0.001	<0.001	0.05	0.06													<0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	1/11/2011			<0.001	0.001	<0.05	<0.05													0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	7/03/2012			<0.001	<0.001	<0.05	<0.05													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	5/05/2012			0.001	<0.001	<0.05	<0.05													0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	14/08/2012			<0.001	<0.001	<0.05	0.05													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	7/11/2012			<0.001	<0.001	<0.05	<0.05													0.000003	0.000002			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	18/02/2013			<0.001	<0.001	<0.05	<0.05													<0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	25/05/2013			<0.001	<0.001	<0.05	<0.05													0.000002	0.000003			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	4/08/2013			<0.001	<0.001	<0.05	0.06													0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	6/11/2013			<0.001	<0.001	0.07	0.05													0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	19/02/2014			<0.001	<0.001	0.07	0.05													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	28/05/2014			<0.001	<0.001	<0.05	<0.05													<0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	9/08/2014			<0.001	<0.001	<0.05	<0.05													0.000003	0.000002			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	5/11/2014			<0.001	<0.001	<0.05	<0.05													0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	8/03/2015			<0.001	<0.001	<0.05	<0.05													<0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	23/05/2015			<0.001	<0.001	<0.05	<0.05													0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	14/09/2015	0.01	<0.01	<0.001	<0.001	<0.05	<0.05									0.18	0.16	0.021	0.02	<0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	1/12/2015	0.02	<0.01	<0.001	<0.001	<0.05	0.05									0.18	0.16	0.02	0.019	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_D	Queen Seam	26/02/2016	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	0.26	0.2	0.17	0.02	0.02	0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW50_D	Queen Seam	10/05/2016	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	0.17	0.18	0.17	0.019	0.018	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	0.005
GW50_D	Queen Seam	23/08/2016	<0.01	<0.01	<0.001	<0.001	0.07	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	0.19	0.17	0.17	0.018	0.018	0.000001	0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW50_D	Queen Seam	23/11/2016	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	0.17	0.2	0.18	0.019	0.02	0.002	0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.026	0.006
GW50_D	Queen Seam	22/02/2017	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	0.16	0.18	0.17	0.019	0.019	0.001	0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	0.006
GW50_S	Regolith	5/06/2009					0.17														<0.000001				0.02		<0.01			
GW50_S	Regolith	25/08/2009					0.17														<0.000001				<0.01		<0.01			
GW50_S	Regolith	1/12/2009					0.17														<0.000001				<0.01		<0.01			
GW50_S	Regolith	17/03/2010					0.14														<0.000001				<0.01		<0.01			
GW50_S	Regolith	5/05/2011			<0.001	<0.001	0.13	0.17													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_S	Regolith	3/08/2011			<0.001	<0.001	0.16	0.16													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_S	Regolith	1/11/2011			<0.001	0.002	0.15	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW50_S	Regolith	7/03/2012			<0.001																									

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW51_D	Queen Seam	4/05/2011			<0.001	<0.001	<0.05	0.05													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	1/08/2011			<0.001	<0.001	0.05	0.05													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	31/10/2011			<0.001	<0.001	<0.05	<0.05													0.000003	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	7/03/2012			<0.001	<0.001	<0.05	<0.05													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	5/05/2012			<0.001	<0.001	<0.05	<0.05													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	16/08/2012			<0.001	<0.001	0.06	<0.05													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	7/11/2012			<0.001	<0.001	0.06	0.06													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	21/02/2013			<0.001	<0.001	<0.05	0.05													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	25/05/2013			<0.001	<0.001	0.07	0.06													0.000003	0.000003			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	3/08/2013			<0.001	<0.001	0.06	0.08													0.000002	0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	8/11/2013			<0.001	<0.001	0.1	<0.05													0.000002	0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	20/02/2014			<0.001	<0.001	0.08	0.08													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	9/08/2014			<0.001	<0.001	0.07	0.06													0.000003	0.000003			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	2/11/2014			<0.001	<0.001	0.11	<0.05													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	8/03/2015			<0.001	<0.001	0.05	<0.05													0.000001	0.000002			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	23/05/2015			<0.001	<0.001	<0.05	<0.05													0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	14/09/2015	<0.01	<0.01	<0.001	<0.001	0.06	<0.05									0.93	0.89	0.031	0.032	0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	3/12/2015	<0.01	<0.01	<0.001	<0.001	0.06	<0.05									0.93	0.94	0.031	0.03	0.000002	0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_D	Queen Seam	25/02/2016	<0.01	<0.01	<0.001	<0.001	0.07	0.06	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.15	1.17	1.09	0.038	0.034	0.000002	0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW51_D	Queen Seam	11/05/2016	<0.01	<0.01	<0.001	<0.001	0.06	0.06	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.05	1.23	1.2	1.1	0.035	0.034		0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW51_D	Queen Seam	23/08/2016																												
GW51_D	Queen Seam	26/08/2016	<0.01	<0.01	<0.001	<0.001	0.07	0.06	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.28	1.22	1.21	0.037	0.036	0.000002	0.000002	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW51_D	Queen Seam	28/02/2017	0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.36	1.33	1.26	0.042	0.038	0.002	0.002	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW51_D	Queen Seam	11/05/2017	<0.01	<0.01	<0.001	<0.001	0.07	0.06	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.44	1.23	1.24	0.037	0.037	0.001	0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW51_D	Queen Seam	29/08/2017	0.03	<0.01	<0.001	<0.001	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.74	1.34	1.21	0.042	0.041	0.002	0.001	0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.008	<0.005
GW51_S	Regolith	4/06/2009					0.5														<0.000001				0.01		<0.01			
GW51_S	Regolith	26/08/2009					0.63														<0.000001				<0.01		<0.01			
GW51_S	Regolith	3/12/2009					0.59														<0.000001				<0.01		<0.01			
GW51_S	Regolith	17/03/2010					0.49														<0.000001				<0.01		<0.01			
GW51_S	Regolith	22/06/2010			0.004	<0.001	0.5	0.5													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	4/05/2011			<0.001	<0.001	0.51	0.52													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	1/08/2011			<0.001	<0.001	0.54	0.6													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	31/10/2011			<0.001	0.001	0.54	0.54													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	7/03/2012			<0.001	<0.001	0.55	0.56													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	5/05/2012			0.003	<0.001	0.49	0.48													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	16/08/2012			<0.001	<0.001	0.6	0.51													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	7/11/2012			<0.001	<0.001	0.57	0.58													0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	19/02/2013			0.002	<0.001	0.57	0.53													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	25/05/2013			0.002	0.001	0.62	0.57													0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	3/08/2013			0.001	<0.001	0.49	0.59													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	8/11/2013			0.001	<0.001	0.54	0.62													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	20/02/2014			0.002	<0.001	0.64	0.57													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	28/05/2014			0.003	<0.001	0.58	0.55													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	9/08/2014			0.002	<0.001	0.64	0.59													0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	2/11/2014			<0.001	<0.001	0.7	0.48													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	8/03/2015			<0.001	<0.001	0.58	0.57													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	23/05/2015			0.001	<0.001	0.48	0.5													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	3/12/2015	0.4	0.01	<0.001	<0.001	0.53	0.51									0.3	<0.05	1.16	1.14	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW51_S	Regolith	26/02/2016	0.31	0.01	<0.001	<0.001	0.58	0.54	0.0002	0.0001	0.035	0.032	0.011	0.004	<0.05	<0.05	0.35	<0.05	1.39	1.36	<0.000001	<0.000001	0.019	0.018	<0.01	<0.01	<0.01	<0.01	0.16	0.139
GW51_S	Regolith	11/05/2016	1.95	0.02	0.002	<0.001	0.59	0.62	0.0002	0.0001	0.034	0.034	0.044	0.003	0.05	<0.05	1.95	0.05	1.46	1.42		<0.000001	0.02	0.019	<0.01	<0.01	<0.01	<0.01	0.173	0.146
GW51_S	Regolith	26/08/2016	0.12	0.01	<0.001	<0.001	0.61	0.59	0.0001	0.0001	0.033	0.033	0.006	0.004	<0.05	<0.05	0.09	<0.05	1.43	1.36	<0.000001	<								

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW52A	Regolith	15/09/2015	0.56	0.2	<0.001	<0.001	0.29	0.31									0.97	0.71	5.88	5.9	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW52A	Regolith	1/12/2015	0.76	0.2	0.001	<0.001	0.34	0.31									1.11	0.82	5.99	5.54	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW52A	Regolith	26/02/2016	0.6	0.18	<0.001	<0.001	0.38	0.35	0.0064	0.006	0.464	0.438	0.006	0.001	<0.05	0.8	1.05	0.67	6.09	5.95	<0.000001	<0.000001	0.395	0.366	<0.01	<0.01	<0.01	<0.01	1.88	1.7
GW52A	Regolith	11/05/2016	0.88	0.19	<0.001	<0.001	0.39	0.43	0.0062	0.0064	0.437	0.467	0.006	0.002	<0.05	0.77	1.02	0.67	6.08	6.23		0.000006	0.377	0.387	<0.01	<0.01	<0.01	<0.01	1.82	1.9
GW52A	Regolith	26/08/2016	0.82	0.18	<0.001	<0.001	0.38	0.36	0.0066	0.006	0.463	0.464	0.008	0.003	<0.05	0.77	1.05	0.73	6.32	6.04	<0.000001	<0.000001	0.39	0.386	<0.01	<0.01	<0.01	<0.01	1.83	1.74
GW52A	Regolith	22/02/2017	0.77	0.18	<0.001	<0.001	0.32	0.33	0.006	0.0045	0.454	0.429	0.006	<0.001	<0.05	0.99	1.2	0.85	5.89	6.05	<0.001	<0.001	0.342	0.356	<0.01	<0.01	<0.01	<0.01	1.6	1.52
GW52A	Regolith	17/05/2017	0.37	0.17	<0.001	<0.001	0.36	0.36	0.0054	0.0051	0.465	0.432	0.004	0.001	<0.05	0.89	0.81	0.71	6.3	5.74	<0.001	<0.001	0.342	0.341	<0.01	<0.01	<0.01	<0.01	1.6	1.58
GW53	Regolith	2/11/2014			0.002	<0.001	0.47	0.29													<0.000001	<0.000001			<0.01	<0.01	0.04	0.02		
GW53	Regolith	7/03/2015			<0.001	<0.001	0.44	0.37													<0.000001	<0.000001			<0.01	<0.01	0.02	0.01		
GW53	Regolith	24/05/2015			<0.001	<0.001	0.3	0.36													<0.000001	<0.000001			0.01	<0.01	0.03	0.02		
GW53	Regolith	15/09/2015	0.55	0.4	<0.001	<0.001	0.34	0.32									0.1	0.06	0.167	0.166	<0.000001	<0.000001			0.01	0.01	0.02	0.02		
GW53	Regolith	3/12/2015	0.46	0.36	<0.001	<0.001	0.41	0.38									0.08	0.06	0.142	0.138	<0.000001	<0.000001			<0.01	<0.01	0.02	0.01		
GW53	Regolith	26/02/2016	0.4	0.34	<0.001	<0.001	0.43	0.4	<0.0001	<0.0001	0.016	0.016	0.001	<0.001	<0.05	<0.05	0.08	<0.05	0.114	0.11	<0.000001	<0.000001	0.005	0.006	0.02	0.02	0.02	0.02	0.019	0.016
GW53	Regolith	11/05/2016	0.81	0.34	<0.001	<0.001	0.45	0.46	<0.0001	<0.0001	0.012	0.012	0.002	<0.001	<0.05	<0.05	0.11	<0.05	0.089	0.087		<0.000001	0.004	0.004	<0.01	0.01	0.02	0.02	0.021	0.011
GW53	Regolith	26/08/2016	0.55	0.31	<0.001	<0.001	0.48	0.46	<0.0001	<0.0001	0.017	0.016	<0.001	<0.001	<0.05	<0.05	0.06	<0.05	0.083	0.082	<0.000001	<0.000001	0.006	0.003	<0.01	<0.01	0.02	0.02	0.018	0.014
GW53	Regolith	27/02/2017	0.54	0.2	<0.001	<0.001	0.57	0.56	0.0004	0.0003	0.033	0.031	<0.001	0.001	<0.05	0.06	<0.05	<0.05	0.056	0.055	<0.001	<0.001	0.014	0.015	0.01	0.01	0.02	0.02	0.058	0.057
GW53	Regolith	11/05/2017	0.5	0.38	<0.001	<0.001	0.74	0.69	0.0002	0.0002	0.022	0.022	<0.001	<0.001	<0.05	<0.05	<0.05	<0.05	0.049	0.052	<0.001	<0.001	0.01	0.01	<0.01	<0.01	0.02	0.02	0.036	0.038
GW53	Regolith	30/08/2017	1.1	0.43	<0.001	<0.001	0.66	0.63	0.0002	0.0002	0.025	0.024	0.049	0.044	<0.05	0.38	0.98	0.39	0.138	0.138	<0.001	<0.001	0.025	0.023	<0.01	<0.01	0.02	0.01	0.241	0.243
GW54A	Regolith below Spoil	6/05/2012			0.007	0.002	0.13	0.17													0.000002	0.000001			<0.01	<0.01	<0.01	<0.01		
GW54A	Regolith below Spoil	16/08/2012			0.006	0.003	0.18	0.16													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW54A	Regolith below Spoil	5/11/2012			0.009	0.002	0.17	0.16													0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW54A	Regolith below Spoil	21/02/2013			0.008	0.003	0.16	0.18													0.000004	0.000002			<0.01	<0.01	<0.01	<0.01		
GW54A	Regolith below Spoil	4/08/2013			0.005	0.005	0.16	0.18													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW54B	Spoil/ Regolith	28/05/2014			0.013	0.007	0.12	0.11													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW54B	Spoil/ Regolith	10/08/2014			0.016	0.015	0.13	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW54B	Spoil/ Regolith	1/11/2014			0.022	0.008	0.13	0.07													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW54B	Spoil/ Regolith	7/03/2015			0.014	0.015	0.14	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW54B	Spoil/ Regolith	26/05/2015			0.018	0.016	0.11	0.11													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW54B	Spoil/ Regolith	14/09/2015	0.05	0.04	0.015	0.015	0.16	0.11									94.2	82.6	4.42	4.71	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	3/06/2009					0.16														<0.000001				<0.01		<0.01			
GW55_D	Queen Seam	25/08/2009					0.16														<0.000001				<0.01		<0.01			
GW55_D	Queen Seam	2/12/2009					0.13														<0.000001				<0.01		<0.01			
GW55_D	Queen Seam	17/03/2010					0.12														<0.000001				<0.01			<0.01		
GW55_D	Queen Seam	21/06/2010			0.003	<0.001	0.15	0.15													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	9/02/2011			<0.001	<0.001	0.15	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	4/05/2011			<0.001	<0.001	0.17	0.16													0.000005	0.000002			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	3/08/2011			0.002	<0.001	0.15	0.15													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	31/10/2011			0.002	<0.001	0.16	0.13													0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	8/03/2012			0.002	<0.001	0.12	0.13													0.000003	0.000006			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	6/05/2012			0.002	<0.001	0.1	0.14													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	16/08/2012			0.001	<0.001	0.14	0.13													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	5/11/2012			<0.001	<0.001	0.15	0.14													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	22/02/2013			0.002	<0.001	0.1	0.11													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	26/05/2013			0.017	<0.001	0.18	0.16													0.000002	0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	4/08/2013			0.002	0.001	0.17	0.21													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	8/11/2013			0.027	<0.001	0.19	0.18													0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	20/02/2014			0.014	<0.001	0.24	0.17													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	10/08/2014			0.001	0.001	0.19	0.21													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	1/11/2014			0.004	<0.001	0.25	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW55_D	Queen Seam	7/03/2015			0.002	0.002	0.21	0.18													<0.000001	<0.000001			<0.01	<0.01	<0.01			

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW56_D	Ace Seam	26/05/2015			<0.001	<0.001	0.24	0.25													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW56_D	Ace Seam	7/03/2017	0.21	<0.01	<0.001	<0.001	0.27	0.24	<0.0001	<0.0001	0.001	0.001	0.005	0.001	<0.05	1.17	1.64	1.17	0.069	0.068	<0.001	<0.001	0.077	0.109	<0.01	<0.01	<0.01	<0.01	0.046	0.032
GW56_D	Ace Seam	23/05/2017	0.65	<0.01	<0.001		0.28	0.23	<0.0001	<0.0001	0.002	<0.001	0.016	<0.001	<0.05	2.28	4.04	2	0.102	0.09	<0.001	<0.001	0.09	0.003	<0.01	<0.01	<0.01	<0.01	0.09	0.006
GW58_D	King Seam	2/06/2009					0.16														<0.000001				<0.01		<0.01			
GW58_D	King Seam	27/08/2009					0.18														<0.000001				<0.01		<0.01			
GW58_D	King Seam	2/12/2009					0.14														<0.000001				<0.01		<0.01			
GW58_D	King Seam	16/03/2010					0.13														0.000002				<0.01		<0.01			
GW58_D	King Seam	21/06/2010			<0.001	0.001	0.13	0.13													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	9/02/2011			<0.001	<0.001	0.15	0.13													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	4/05/2011			<0.001	<0.001	0.11	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	2/08/2011			<0.001	0.001	0.12	0.13													<0.01	<0.01			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	2/11/2011			<0.001	<0.001	0.1	0.09													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	9/03/2012			<0.001	<0.001	0.09	0.1													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	4/05/2012			<0.001	<0.001	0.08	0.09													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	15/08/2012			<0.001	<0.001	0.12	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	6/11/2012			<0.001	<0.001	0.13	0.08													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	22/02/2013			<0.001	<0.001	0.12	0.13													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	26/05/2013			<0.001	<0.001	0.14	0.11													<0.000001	0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	5/08/2013			<0.001	<0.001	0.14	0.16													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	7/11/2013			<0.001	<0.001	0.15	0.25													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	21/02/2014			<0.001	<0.001	0.24	0.16													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	10/08/2014			<0.001	<0.001	0.11	0.13													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	31/10/2014			<0.001	<0.001	0.17	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	6/03/2015			<0.001	<0.001	0.15	0.15													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	26/05/2015			<0.001	<0.001	0.14	0.16													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	13/09/2015	<0.01	<0.01	<0.001	<0.001	0.12	0.14									6.75	6.79	0.151	0.152	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	29/11/2015	<0.01	<0.01	<0.001	<0.001	0.15	0.16									7.34	6.56	0.146	0.14	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW58_D	King Seam	25/02/2016	<0.01	<0.01	<0.001	<0.001	0.2	0.16	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	7.88	7.71	7.46	0.16	0.152	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW58_D	King Seam	15/05/2016	0.04	<0.01	0.001	<0.001	0.16	0.15	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.17	5.4	11.4	5.57	0.158	0.144	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW58_D	King Seam	27/08/2016	0.57	<0.01	<0.001	<0.001	0.17	0.16	<0.0001	<0.0001	<0.001	<0.001	0.003	<0.001	<0.05	6.99	10.2	6.81	0.223	0.195	<0.000001	<0.000001	0.005	<0.001	<0.01	<0.01	<0.01	<0.01	0.11	0.12
GW58_D	King Seam	23/11/2016	0.07	<0.01	<0.001	<0.001	0.17	0.14	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	7.38	7.95	6	0.164	0.154	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.016	0.01
GW58_D	King Seam	21/02/2017	0.31	<0.01	<0.001	<0.001	0.14	0.12	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.13	6.97	7.89	7.1	0.147	0.193	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.007	<0.005
GW58_D	King Seam	15/05/2017	0.05	<0.01	<0.001	<0.001	0.16	0.15	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	7.12	7.34	6.98	0.15	0.139	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.008	0.009
GW58_D	King Seam	30/08/2017	0.01	<0.01	<0.001	<0.001	0.16	0.14	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.47	6.32	6.61	6.79	0.144	0.145	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.011	0.008
GW59_D	King Seam	3/06/2009					0.2														0.000001				<0.01		<0.01			
GW59_D	King Seam	26/08/2009					0.23														0.000002				<0.01		<0.01			
GW59_D	King Seam	22/06/2010			0.04	0.009	0.21	0.21													0.000002	<0.000001			<0.01	<0.01	0.04	<0.01		
GW59_D	King Seam	5/05/2011			0.014	0.005	0.2	0.21													<0.000001	<0.000001			<0.01	<0.01	0.03	<0.01		
GW59_D	King Seam	3/08/2011			0.014	0.006	0.21	0.22													0.000001	<0.000001			<0.01	<0.01	0.04	<0.01		
GW59B	King Seam	28/05/2014			0.014	0.006	0.19	0.18													0.000035	0.000036			<0.01	<0.01	0.02	<0.01		
GW59B	King Seam	11/08/2014			0.001	0.001	0.21	0.2													0.000005	0.000004			<0.01	<0.01	<0.01	<0.01		
GW59B	King Seam	1/11/2014			<0.001	<0.001	0.25	0.18													0.000012	0.000012			<0.01	<0.01	<0.01	<0.01		
GW59B	King Seam	7/03/2015			<0.001	<0.001	0.24	0.24													0.000025	0.000026			<0.01	<0.01	<0.01	<0.01		
GW59B	King Seam	26/05/2015			<0.001	<0.001	0.23	0.2													0.000041	0.000039			<0.01	<0.01	<0.01	<0.01		
GW59B	King Seam	14/09/2015	<0.01	<0.01	<0.001	<0.001	0.26	0.24									0.85	0.78	0.054	0.051	0.000066	0.000062			<0.01	<0.01	<0.01	<0.01		
GW59B	King Seam	30/11/2015	<0.01	<0.01	0.001	0.001	0.34	0.31									0.99	0.9	0.062	0.058	0.00008	0.000074			<0.01	<0.01	<0.01	<0.01		
GW59B	King Seam	25/02/2016	<0.01	<0.01	0.001	0.001	0.38	0.35	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	1.84	1.87	1.85	0.089	0.087	0.000081	0.000078	0.002	0.003	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW59B	King Seam	15/05/2016	0.26	<0.01	0.005	0.001	0.42	0.42	<0.0001	<0.0001	0.016	<0.001	0.005	<0.001	<0.05	0.33	1.16	0.19	0.047	0.041	0.000075	0.000069	0.053	0.005	<0.01	<0.01	<0.01	<0.01	0.049	<0.005
GW59B	King Seam	27/08/2016	0.29	<0.01	0.005	<0.001	0.43	0.36	0.0002	<0.0001	0.019	<0.001	0.008	<0.001	0.24	1.31	1.67	1.55	0.042	0.085	0.000073	0.00005	0.061	0.001	<0.01	<0.01	<0.01	<0.01	0.066	0.

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW60	Queen Seam	13/09/2015	<0.01	<0.01	0.001	0.001	0.22	0.21									14.9	13.2	0.491	0.511	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW60	Queen Seam	30/11/2015	<0.01	<0.01	0.001	0.001	0.2	0.21									13.6	12.6	0.479	0.466	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW60	Queen Seam	25/02/2016	<0.01	<0.01	0.002	0.002	0.27	0.22	<0.0001	<0.0001	0.001	0.001	<0.001	<0.001	0.1	14.2	13.8	14.3	0.525	0.519	<0.000001	<0.000001	0.004	0.005	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW60	Queen Seam	13/05/2016	<0.01	<0.01	0.002	0.002	0.23	0.21	<0.0001	<0.0001	0.001	0.001	<0.001	<0.001	<0.05	14.1	14.6	13.8	0.558	0.534	<0.000001	<0.000001	0.004	0.004	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW60	Queen Seam	25/08/2016	0.01	<0.01	0.001	0.002	0.23	0.21	<0.0001	<0.0001	0.001	0.001	<0.001	<0.001	<0.05	13.5	13.6	13.4	0.475	0.454	<0.000001	<0.000001	0.004	0.002	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW60	Queen Seam	21/02/2017	<0.01	<0.01	0.001	0.001	0.21	0.19	<0.0001	<0.0001	<0.001	0.002	<0.001	<0.001	1.1	12	13.8	13.1	0.471	0.466	<0.001	<0.001	0.004	0.004	<0.01	<0.01	<0.01	<0.01	<0.005	0.007
GW60	Queen Seam	11/05/2017	<0.01	<0.01	0.002	0.001	0.24	0.22	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	13.5	13	13.2	0.453	0.47	<0.001	<0.001	0.004	0.004	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW60	Queen Seam	30/08/2017	0.04	<0.01	0.001	0.001	0.2	0.2	<0.0001	<0.0001	0.002	0.002	0.005	0.002	1.08	9.92	12.4	11	0.58	0.573	<0.001	<0.001	0.007	0.006	<0.01	<0.01	<0.01	<0.01	0.018	0.012
GW61_D	OB	4/06/2009					0.11														<0.01				<15		<5			
GW61_D	OB	26/08/2009					0.11														<0.000001				<0.01		<0.01			
GW61_D	OB	2/12/2009					0.09														<0.000001				<0.01		<0.01			
GW61_D	OB	16/03/2010					0.09														<0.000001				<0.01		<0.01			
GW61_D	OB	21/06/2010			<0.001	<0.001	0.11	0.11													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	9/02/2011			<0.001	<0.001	0.12	0.11													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	3/05/2011			<0.001	<0.001	0.09	0.11													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	1/08/2011			<0.001	<0.001	0.12	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	1/11/2011			0.002	<0.001	0.09	0.07													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	8/03/2012			0.002	0.001	0.09	0.09													0.000001	0.000002			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	3/05/2012			0.003	0.002	0.12	0.09													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	14/08/2012			<0.001	0.002	0.13	0.11													0.000002	0.000003			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	6/11/2012			0.001	<0.001	0.11	0.11													0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	19/02/2013			0.004	<0.001	0.08	0.07													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	24/05/2013			0.002	0.001	0.11	0.12													0.000002	0.000002			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	3/08/2013			0.003	<0.001	0.11	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	6/11/2013			0.001	<0.001	0.16	0.21													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	19/02/2014			0.002	0.001	0.14	0.13													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	28/05/2014			0.002	0.001	0.13	0.11													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	9/08/2014			0.002	<0.001	0.12	0.11													0.000003	0.000002			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	5/11/2014			0.002	0.001	0.08	0.12													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	6/03/2015			0.001	0.001	0.13	0.09													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	23/05/2015			<0.001	0.001	0.08	0.09													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	15/09/2015	<0.01	<0.01	0.001	<0.001	0.1	0.05									2.9	2.48	0.184	0.191	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	30/11/2015	<0.01	<0.01	0.001	<0.001	0.1	0.11									2.86	2.69	0.174	0.171	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_D	OB	25/02/2016	0.02	<0.01	0.001	0.001	0.26	0.15	<0.0001	<0.0001	0.001	0.001	<0.001	<0.001	<0.05	2.99	3.04	2.95	0.19	0.18	<0.000001	<0.000001	<0.001	0.002	<0.01	<0.01	<0.01	<0.01	0.008	<0.005
GW61_D	OB	10/05/2016	<0.01	<0.01	0.001	<0.001	0.11	0.1	<0.0001	<0.0001	0.001	0.001	<0.001	<0.001	<0.05	3.07	3.02	2.9	0.188	0.172		<0.000001	<0.001	0.002	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW61_D	OB	25/08/2016	<0.01	<0.01	<0.001	<0.001	0.12	0.1	<0.0001	<0.0001	0.001	0.001	<0.001	<0.001	<0.05	2.9	2.96	2.84	0.174	0.169	<0.000001	<0.000001	0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW61_D	OB	23/11/2016	<0.01	<0.01	0.001	0.001	0.11	0.1	<0.0001	<0.0001	0.001	0.001	<0.001	<0.001	<0.05	3.06	3.08	2.37	0.183	0.175	<0.001	<0.001	0.002	0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW61_D	OB	23/02/2017	<0.01	<0.01	<0.001	<0.001	0.08	0.06	<0.0001	<0.0001	<0.001	0.001	<0.001	<0.001	<0.05	2.84	3.04	2.87	0.174	0.168	<0.001	<0.001	<0.001	0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW61_D	OB	18/05/2017	<0.01	<0.01	<0.001	<0.001	0.1	0.1	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	3.14	2.86	2.85	0.164	0.158	<0.001	<0.001	<0.001	0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW61_D	OB	30/08/2017	0.05	<0.01	0.002	<0.001	0.08	0.08	<0.0001	<0.0001	0.001	<0.001	0.005	<0.001	<0.05	2.83	4.05	2.78	0.169	0.168	<0.001	<0.001	0.002	0.001	<0.01	<0.01	<0.01	<0.01	0.017	0.014
GW61_S	Regolith	4/06/2009					0.16														<0.000001				<0.01		<0.01			
GW61_S	Regolith	26/08/2009					0.2														<0.000001				<0.01		<0.01			
GW61_S	Regolith	3/12/2009					0.28														<0.000001				<0.01		<0.01			
GW61_S	Regolith	16/03/2010					0.29														<0.000001				<0.01		<0.01			
GW61_S	Regolith	21/06/2010			0.007	<0.001	0.2	0.2													<0.000001	<0.000001			<0.01	<0.01	0.02	<0.01		
GW61_S	Regolith	22/06/2010			<0.001	<0.001	0.25	0.24													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	9/02/2011			<0.001	<0.001	0.19	0.17													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	10/02/2011			<0.001	<0.001	0.42	0.39													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	3/05/2011			<0.001	<0.001	0.22	0.3													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	4/0																												

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW61_S	Regolith	9/08/2014			<0.001	<0.001	0.22	0.2													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	10/08/2014			<0.001	<0.001	0.26	0.27													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	5/11/2014			<0.001	<0.001	0.29	0.3													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	6/03/2015			<0.001	<0.001	0.19	0.18													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	7/03/2015			<0.001	<0.001	0.28	0.25													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	23/05/2015			0.001	<0.001	0.17	0.18													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	24/05/2015			<0.001	<0.001	0.23	0.27													<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	15/09/2015	0.48	0.1	0.001	<0.001	0.6	0.46									0.37	0.06	1.24	1.21	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	30/11/2015	0.35	0.04	<0.001	<0.001	0.24	0.24									0.36	0.08	0.018	0.021	<0.000001	<0.000001			<0.01	<0.01	<0.01	<0.01		
GW61_S	Regolith	25/02/2016	0.76	0.08	<0.001	<0.001	0.39	0.29	0.0002	<0.0001	0.031	0.027	0.005	<0.001	0.05	<0.05	1.11	0.05	0.034	0.026	<0.000001	<0.000001	0.019	0.016	<0.01	<0.01	<0.01	<0.01	0.105	0.067
GW61_S	Regolith	15/05/2016	0.31	0.07	<0.001	<0.001	0.35	0.33	<0.0001	<0.0001	0.032	0.031	0.012	0.001	0.05	<0.05	0.17	0.05	0.018	0.014	<0.000001	<0.000001	0.018	0.017	<0.01	<0.01	<0.01	<0.01	0.08	0.072
GW61_S	Regolith	25/08/2016	0.51	0.05	<0.001	<0.001	0.25	0.24	<0.0001	<0.0001	0.025	0.024	0.002	<0.001	0.09	<0.05	0.36	0.09	0.012	0.01	<0.000001	<0.000001	0.015	0.012	<0.01	<0.01	<0.01	<0.01	0.058	0.053
GW61_S	Regolith	23/02/2017	0.18	0.06	<0.001	<0.001	0.29	0.26	<0.0001	<0.0001	0.026	0.026	0.001	<0.001	<0.05	<0.05	0.1	<0.05	0.012	0.011	<0.001	<0.001	0.014	0.014	<0.01	<0.01	<0.01	<0.01	0.044	0.051
GW61_S	Regolith	18/05/2017	0.34	0.02	<0.001	<0.001	0.29	0.29	<0.0001	<0.0001	0.024	0.022	0.002	<0.001	<0.05	0.8	0.93	0.64	0.031	0.027	<0.001	<0.001	0.014	0.012	<0.01	<0.01	<0.01	<0.01	0.054	0.026
GW61_S	Regolith	30/08/2017	0.28	0.01	<0.001	<0.001	0.28	0.27	<0.0001	<0.0001	0.023	0.021	0.003	<0.001	<0.05	1.48	1.66	1.29	0.058	0.056	<0.001	<0.001	0.014	0.012	<0.01	<0.01	<0.01	<0.01	0.066	0.013
GW63_D	Queen Seam	5/09/2015	0.19	<0.01	0.004	0.004	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			0.21	<0.05	0.08	0.065	0.000003	0.000002	0.005	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW63_D	Queen Seam	26/11/2015	0.14	<0.01	0.002	0.004	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			0.11	<0.05	0.071	0.068	0.000002	0.000002	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW63_D	Queen Seam	22/02/2016	0.18	<0.01	0.004	0.004	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001			0.18	<0.05	0.093	0.079	0.000002	0.000002	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW63_D	Queen Seam	18/05/2016	0.07	<0.01	0.004	0.004	0.06	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	0.15	0.15	<0.05	0.075	0.069	0.000001	0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW63_D	Queen Seam	20/08/2016	0.23	<0.01	0.004	0.004	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	<0.05	0.14	<0.05	0.066	0.057	0.000001	0.000001	0.042	<0.001	<0.01	<0.01	<0.01	<0.01	0.008	<0.005
GW63_D	Queen Seam	10/11/2016	0.16	<0.01	0.004	0.004	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	<0.05	0.14	<0.05	0.064	0.062	0.001	0.001	<0.001	0.002	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW63_D	Queen Seam	8/02/2017	0.08	<0.01	0.004	0.004	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	<0.05	0.09	<0.05	0.082	0.069	0.001	0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW64_D	Maronghi Creek beds	21/08/2016	0.02	<0.01	0.28	0.271	<0.05	0.06	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	<0.05	0.07	<0.05	0.204	0.188	<0.000001	<0.000001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.006	0.027
GW64_D	Maronghi Creek beds	11/11/2016	0.04	<0.01	0.286	0.136	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	<0.05	0.51	<0.05	0.18	0.179	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	0.037	<0.005
GW64_D	Maronghi Creek beds	7/02/2017	0.02	<0.01	0.381	0.212	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	0.06	0.14	<0.05	0.193	0.166	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
GW64_S	Maronghi Creek beds	21/08/2016																												
GW65	Maronghi Creek beds	28/11/2015	1.56	<0.01	0.084	0.067	<0.05	<0.05	<0.0001	<0.0001	0.003	0.002	0.002	<0.001			2.54	0.08	0.51	0.44	0.000005	0.000004	0.025	0.02	<0.01	<0.01	<0.01	<0.01	0.016	0.008
GW65	Maronghi Creek beds	23/02/2016	0.26	<0.01	0.042	0.028	<0.05	<0.05	<0.0001	<0.0001	0.001	<0.001	0.001	<0.001			1.1	0.32	0.606	0.541	0.000003	0.000002	0.006	0.005	<0.01	<0.01	<0.01	<0.01	0.013	0.007
GW65	Maronghi Creek beds	19/05/2016	0.07	<0.01	0.027	0.013	<0.05	<0.05	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.05	0.19	0.9	0.18	0.598	0.582	0.000001	0.000001	0.004	0.003	<0.01	<0.01	<0.01	<0.01	0.013	0.01
GW65	Maronghi Creek beds	19/08/2016	0.28	<0.01	0.025	0.02	<0.05	0.05	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.05	0.14	0.73	0.13	0.451	0.384	<0.000001	<0.000001	0.002	<0.001	<0.01	<0.01	<0.01	<0.01	0.016	0.011
GW65	Maronghi Creek beds	11/11/2016	1.56	<0.01	0.025	0.02	<0.05	<0.05	<0.0001	<0.0001	0.002	<0.001	0.002	<0.001	<0.05	0.33	3.5	0.3	0.474	0.378	<0.001	<0.001	0.008	<0.001	<0.01	<0.01	<0.01	<0.01	0.021	<0.005
GW65	Maronghi Creek beds	7/02/2017	2.41	<0.01	0.021	0.013	<0.05	<0.05	<0.0001	<0.0001	0.002	<0.001	0.003	<0.001	<0.05	0.45	4.41	0.39	0.551	0.423	<0.001	<0.001	0.009	<0.001	<0.01	<0.01	<0.01	<0.01	0.016	<0.005
GW66	Spoil	25/11/2016																												
GW66	Spoil	27/02/2017	0.02	<0.01	0.004	0.003	0.08	0.07	0.0001	<0.0001	0.318	0.32	<0.001	<0.001	<0.05	106	117	106	9.94	9.81	<0.001	<0.001	0.372	0.366	<0.01	<0.01	<0.01	<0.01	0.933	0.883
GW66	Spoil	15/05/2017	0.05	<0.01	0.004	0.004	0.1	0.1	0.0001	<0.0001	0.326	0.339	<0.001	<0.001	6	114	118	120	10.6	9.72	<0.001	<0.001	0.36	0.358	<0.01	<0.01	<0.01	<0.01	1.09	0.916
GW67	Regolith	29/11/2016																												
GW67	Regolith	22/02/2017	0.49	0.06	0.002	0.001	0.66	0.66	0.0016	0.0009	0.127	0.122	0.008	0.001	0.61	1.18	2.52	1.79	11	11.4	<0.001	<0.001	0.105	0.095	<0.01	<0.01	<0.01	<0.01	0.345	0.263
GW67	Regolith	19/05/2017	3.56	0.05	0.002	0.001	0.67	0.66	0.0039	0.0007	0.142	0.136	0.035	0.001	<0.05	2	5.38	1.7	9.92	9.37	<0.001	<0.001	0.107	0.094	<0.01	<0.01	<0.01	<0.01	0.511	0.246
GW67	Regolith	29/08/2017	0.2	0.09	0.001	0.001	0.72	0.7	0.0003	0.0003	0.076	0.074	0.002	0.002	0.62	1.06	2.03	1.68	8.58	8.45	<0.001	<0.001	0.072	0.069	<0.01	<0.01	<0.01	<0.01	0.167	0.164
GW68	Regolith	25/11/2016																												
GW68	Regolith	17/02/2017	54.8	<0.05	0.008	<0.005	0.18	0.55	0.0016	0.0008	0.226	0.172	0.045	<0.005	<0.05	1.54	26.3	1.22	6.77	6.45	<0.001	<0.005	0.074	0.022	<0.01	<0.05	0.07	<0.05	0.729	0.724
GW68	Regolith	17/05/2017	13.1	<0.01	0.003	<0.001	0.18																							

Appendix A-2 - Total Dissolved Metals/Metalloids

Site	Groundwater Unit Monitored	Sampled_Date-Time	Aluminium (Total)	Aluminium (Filtered)	Arsenic (Total)	Arsenic (Filtered)	Boron (Total)	Boron (Filtered)	Cadmium (Total)	Cadmium (Filtered)	Cobalt (Total)	Cobalt (Filtered)	Copper (Total)	Copper (Filtered)	Ferric Iron	Ferrous Iron	Iron (Total)	Iron (Filtered)	Manganese (Total)	Manganese (Filtered)	Molybdenum (Total)	Molybdenum (Filtered)	Nickel (Total)	Nickel (Filtered)	Selenium (Total)	Selenium (Filtered)	Vanadium (Total)	Vanadium (Filtered)	Zinc (Total)	Zinc (Filtered)
GW76	Spoil	6/09/2017	0.52	<0.01	0.021	0.02	<0.05	<0.05	<0.0001	<0.0001	0.035	0.033	0.002	<0.001	1.4	69.4	73	70.8	14	13.4	<0.001	<0.001	0.006	0.005	<0.01	<0.01	<0.01	<0.01	0.02	0.015
GW78	Regolith	29/11/2016																												
GW78	Regolith	7/03/2017	0.02	<0.01	<0.001	<0.001	0.08	0.07	0.0003	0.0003	0.043	0.042	0.015	<0.001	<0.05	0.77	0.86	0.78	12.5	12.3	<0.001	<0.001	0.014	0.015	<0.01	<0.01	<0.01	<0.01	0.029	0.022
GW78	Regolith	17/05/2017	<0.01	<0.01	<0.001	<0.001	0.09	0.09	0.0003	0.0002	0.042	0.04	<0.001	<0.001	<0.05	0.84	0.71	0.68	12.8	11.5	<0.001	<0.001	0.014	0.013	<0.01	<0.01	<0.01	<0.01	0.018	0.019

Appendix A-3 - Major Ions/ physical parameters

Site	pH (Lab)	pH (Field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
	pH_Units	pH_Units	uS/cm	uS/cm	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
All																		
Count	685	746	694	650	857	321	234	811	810	811	810	811	811	662	683	682	722	681
Count >LOR	684	745	681	649	856	319	215	780	808	810	808	808	804	1	13	675	715	333
% >LOR	99.9	99.9	98.1	99.8	99.9	99.4	91.9	96.2	99.8	99.9	99.8	99.6	99.1	0.2	1.9	99.0	99.0	48.9
Min	4.1	3.9	1	493	248	458	1	1	9	57	1	2	1	61	1	1	1	0.1
Max	8.6	8.9	20400	58970	14000	13300	557	762	700	3600	140	8530	1150	61	33	707	707	1.6
Mean	6.8	6.1	4203	3748	2489	2945	66	76	124	619	25	1239	257		13	149	148	0.2
Median	6.7	6.0	2750	2525	1610	1900	31	51	68	385	18	713	134		8	118	119	0.2
Standard Dev	0.8	0.8	4058	4269	2647	2716	90	104	139	659	21	1439	266			109	108	0.3

Alluvium

Count	47	33	45	5	39	17	13	47	47	47	47	47	47	45	47	47	47	21
Count >LOR	46	32	44	4	38	16	11	46	45	46	45	45	46	0	0	46	46	20
% >LOR	97.9	97.0	97.8	80.0	97.4	94.1	84.6	97.9	95.7	97.9	95.7	95.7	97.9	0.0	0.0	97.9	97.9	95.2
Min	5.0	5.0	1550	2691	1420	1620	1	23	34	391	2	582	123	0	0	5	21	0.1
Max	7.8	6.4	4807	3266	2760	2850	73	42	139	763	11	1410	497	0	0	127	127	0.3
Mean	6.2	5.8	3026	2979	1793	1946	17	32	69	486	5	839	182			78	80	0.2
Median	6.2	6.0	2866	2980	1645	1835	12	32	78	462	4	766	179			80	89	0.2
Standard Dev	0.7	0.4	627	328	379	305	20	4	31	82	3	198	53			38	37	0.1

Regolith

Count	190	155	195	128	216	81	68	217	217	217	217	217	217	176	179	179	184	190
Count >LOR	189	154	188	127	215	80	67	189	216	216	216	216	216	0	1	175	180	99
% >LOR	99.5	99.4	96.4	99.2	99.5	98.8	98.5	87.1	99.5	99.5	99.5	99.5	99.5	0.0	0.6	97.8	97.8	52.1
Min	4.1	3.9	416	790	260	458	4	1	10	57	1	85	25	0	6	2	2	0.1
Max	8.4	8.9	20400	21240	14000	13300	285	332	700	3600	140	8530	1150	0	6	344	344	1.6
Mean	6.2	5.8	6284	7223	4169	4447	68	61	189	1067	33	2108	371		6	75	77	0.2
Median	6.2	5.7	3245	4223	2450	2858	41	28	113	565	20	1185	263		6	66	68	0.2
Standard Dev	0.7	0.7	5791	5962	3986	3791	66	66	197	986	33	2130	328			66	68	0.2

Basalt

Count	9	3	9	3	10	8	5	9	9	9	9	9	9	9	9	9	9	9
Count >LOR	8	2	8	2	9	7	3	8	8	8	8	8	8	0	0	8	8	1
% >LOR	88.9	66.7	88.9	66.7	90.0	87.5	60.0	88.9	88.9	88.9	88.9	88.9	88.9	0.0	0.0	88.9	88.9	11.1
Min	7.4	6.7	2210	2300	1220	1460	4	61	123	207	7	368	36			563	563	0.2
Max	8.1	6.9	2360	2310	1440	1530	65	67	143	254	9	495	88			707	707	0.2
Mean	7.6	6.8	2286	2305	1297	1493	31	63	132	233	8	408	64			654	654	0.2
Median	7.5	6.8	2290	2305	1280	1500	23	62	131	234	8	383	66			664	664	0.2
Standard Dev	0.2	0.1	47	7	79	24	31	2	6	13	1	50	15			49	49	

Spoil

Count	57	28	63	27	66	38	27	70	70	70	70	70	70	68	70	70	70	57
Count >LOR	56	27	56	26	65	37	26	69	69	69	69	69	69	0	1	68	68	27
% >LOR	98.2	96.4	88.9	96.3	98.5	97.4	96.3	98.6	98.6	98.6	98.6	98.6	98.6	0.0	1.4	97.1	97.1	47.4
Min	4.7	4.5	1580	1729	899	1040	13	10	40	96	15	223	17	0	3	1	1	0.1
Max	8.4	6.5	14100	13100	8830	9160	557	220	292	2400	58	4580	1020	0	3	323	323	0.8
Mean	6.4	5.6	4903	4243	2779	3477	197	60	132	628	34	1188	459		3	159	160	0.2
Median	6.4	5.6	2780	3374	1720	1930	187	51	117	320	35	537	505		3	139	139	0.2
Standard Dev	0.6	0.4	4301	3019	2430	2994	157	49	72	739	13	1424	237			82	82	0.2

Coal Measures - All

Count	349	340	347	281	415	164	102	400	400	400	400	400	400	328	340	339	356	354
Count >LOR	348	339	346	280	414	162	88	399	399	399	399	398	393	1	9	336	353	144
% >LOR	99.7	99.7	99.7	99.6	99.8	98.8	86.3	99.8	99.8	99.8	99.8	99.5	98.3	0.3	2.6	99.1	99.2	40.7
Min	4.8	5.1	1	647	288	474	1	2	9	72	4	88	1	61	1	12	6	0.1
Max	8.6	7.8	11700	58970	8130	7540	182	762	540	1610	67	3950	880	61	33	542	542	1.6
Mean	7.1	6.4	3176	3024	1890	2279	35	91	99	416	22	894	185		15	171	170	0.2
Median	7.2	6.3	2145	1821	1165	1745	20	56	52	308	18	543	66		14	164	166	0.1
Standard Dev	0.7	0.6	2682	4046	1728	1910	40	133	115	310	13	877	216			90	90	0.3

Coal Measures - Background

Count	152	143	152	129	182	80	56	161	161	161	161	161	161	129	137	136	147	150
Count >LOR	151	142	151	128	181	79	49	160	160	160	160	160	155	0	4	135	146	61
% >LOR	99.3	99.3	99.3	99.2	99.5	98.8	87.5	99.4	99.4	99.4	99.4	99.4	96.3	0.0	2.9	99.3	99.3	40.7
Min	4.8	5.1	730	647	368	474	1	3	9	102	4	165	1	0	5	26	26	0.1
Max	8.6	7.5	11700	58970	8130	7540	121	762	540	1400	67	3950	633	0	25	542	542	1.6
Mean	7.2	6.2	3307	3241	1935	2402	33	123	103	399	20	971	137		13	190	187	0.2
Median	7.2	6.1	1740	1800	932	1130	21	39	32	241	15	410	54		10	200	197	0.1
Standard Dev	0.6	0.5	3389	5554	2155	2449	34	200	139	339	15	1141	166			114	112	0.3

Coal Measures - Mine-Affected

Count	198	198	196	153	234	85	47	240	240	240	240	240	240	200	204	204	210	205
Count >LOR	197	197	195	152	233	83	39	239	239	239	239	238	238	1	5	201	207	83
% >LOR	99.5	99.5	99.5	99.3	99.6	97.6	83.0	99.6	99.6	99.6	99.6	99.2	99.2	0.5	2.5	98.5	98.6	40.5
Min	4.8	5.1	1	1170	288	767	1	2	12	72	4	88	16	61	1	12	6	0.1
Max	8.6	7.8	9980	10720	6910	5750	182	178	532	1610	61	3650	880	61	33	268	268	1.6
Mean	7.1	6.6	3075	2841	1856	2162	38	70	96	427	23	843	216		16	158	157	0.3
Median	7.2	6.7	2710	1953	1660	1920	18	61	61	342	20	697	78		19	154	154	0.2
Standard Dev	0.7	0.7	1972	2057	1309	1196	46	44	97	290	11	639	238			66	68	0.3

Ace Seam

Count	18	15	18	10	19	5	3	19	19	19	19	19	19	17	17	17	17	19
Count >LOR	17	14	17	9	18	4	2	18	18	18	18	18	18	0	1	16	16	3
% >LOR	94.4	93.3	94.4	90.0	94.7	80.0	66.7	94.7	94.7	94.7	94.7	94.7	94.7	0.0	5.9	94.1	94.1	15.8
Min	4.8	5.1	855	647	445	556	6	3	13	160	7	203	21	0	5	91	91	0.1
Max	8.4	6.4	1060	1170	656	593	98	4	20	188	10	275	65	0	5	135	135	1.6
Mean	6.8	5.9	961	991	551	573	52	4	17	175	8	234	48		5	104	105	0.6
Median	6.7	5.9	955	1000	556	572	52	4	17	175	8	237	44		5	103	103	0.2
Standard Dev	0.7	0.3	67	148	69	15	65	1	2	9	1	19	12			11	10	0.8

King Seam - All

Count	65	45	66	35	74	37	20	72	72	72	72	72	72	59	63	63	63	72
Count >LOR	64	44	65	34	73	36	18	71	71	71	71	71	71	0	1	62	62	54
% >LOR	98.5	97.8	98.5	97.1	98.6	97.3	90.0	98.6	98.6	98.6	98.6	98.6	98.6	0.0	1.6	98.4	98.4	75.0

Appendix A-3 - Major Ions/ physical parameters

Site	pH (Lab)	pH (Field)	EC (lab)	EC (field)	TDS	TDS (Calc)	Acidity	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Alkalinity (Hydroxide)	Alkalinity (Carbonate)	Alkalinity (Bicarbonate)	Alkalinity (total)	Fluoride
	pH_Units	pH_Units	uS/cm	uS/cm	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
Min	4.8	5.7	1000	1040	466	650	2	5	27	129	4	243	31	0	25	54	54	0.1
Max	8.6	7.0	6460	5750	4080	4200	59	321	263	571	47	1950	880	0	25	287	287	1.6
Mean	7.0	6.2	2438	2099	1421	1744	22	58	91	284	16	565	202		25	163	164	0.2
Median	7.0	6.1	1780	1630	1000	1180	14	23	47	258	10	412	53		25	156	156	0.1
Standard Dev	0.5	0.4	1700	1166	1037	1201	18	95	79	127	12	453	265			77	78	0.3

King Seam - Mine Affected

Count	17	16	17	15	19	11	6	19	19	19	19	19	19	15	16	16	16	19
Count >LOR	16	15	16	14	18	10	4	18	18	18	18	18	18	0	0	15	15	17
% >LOR	94.1	93.8	94.1	93.3	94.7	90.9	66.7	94.7	94.7	94.7	94.7	94.7	94.7	0.0	0.0	93.8	93.8	89.5
Min	4.8	6.1	1190	1200	588	1370	2	7	27	194	7	243	33	0	0	138	138	0.1
Max	8.1	7.0	3340	3640	2170	2110	51	76	204	421	14	539	880	0	0	204	204	1.6
Mean	6.9	6.3	2473	2547	1525	1767	24	31	122	302	10	405	534			162	162	0.3
Median	6.9	6.2	2745	2793	1700	1815	22	30	148	323	10	434	698			158	159	0.2
Standard Dev	0.7	0.3	706	745	579	224	22	18	63	70	3	97	330			19	19	0.3

King Seam - Background

Count	49	30	50	21	56	27	15	54	54	54	54	54	54	45	48	48	48	54
Count >LOR	48	29	49	20	55	26	14	53	53	53	53	53	53	0	1	47	47	37
% >LOR	98.0	96.7	98.0	95.2	98.2	96.3	93.3	98.1	98.1	98.1	98.1	98.1	98.1	0.0	2.1	97.9	97.9	68.5
Min	6.5	5.7	1000	1040	466	650	2	5	27	129	4	254	31	0	25	54	54	0.1
Max	8.6	7.0	6460	5750	4080	4200	59	321	263	571	47	1950	376	0	25	287	287	1.6
Mean	7.1	6.1	2427	1786	1387	1735	21	67	81	278	17	619	89		25	163	165	0.2
Median	7.1	6.0	1720	1427	936	1125	14	7	37	238	10	405	52		25	95	95	0.1
Standard Dev	0.5	0.4	1922	1315	1151	1415	18	109	82	141	14	512	87			88	89	0.3

Queen Seam - All

Count	199	166	199	122	220	94	47	211	211	211	211	211	211	176	181	180	184	208
Count >LOR	198	165	198	121	219	93	36	210	210	210	210	210	205	1	6	179	183	47
% >LOR	99.5	99.4	99.5	99.2	99.5	98.9	76.6	99.5	99.5	99.5	99.5	99.5	97.2	0.6	3.3	99.4	99.5	22.6
Min	4.8	5.2	530	759	288	474	1	2	9	72	4	88	1	61	1	32	32	0.1
Max	8.6	7.8	11700	12040	8130	7540	123	762	540	1610	67	3950	878	61	33	542	542	1.6
Mean	7.4	6.7	3412	2987	2105	2467	22	108	111	431	20	1007	157		14	198	199	0.2
Median	7.6	6.9	2140	1750	1140	1400	12	56	37	298	17	520	58		11	219	219	0.1
Standard Dev	0.6	0.7	3142	2714	2128	2290	29	169	146	358	11	1090	207			98	98	0.4

Queen Seam - Mine Affected

Count	139	154	138	110	153	49	23	150	150	150	150	150	150	120	120	120	123	147
Count >LOR	138	153	137	109	152	48	18	149	149	149	149	149	149	1	4	119	122	37
% >LOR	99.3	99.4	99.3	99.1	99.3	98.0	78.3	99.3	99.3	99.3	99.3	99.3	99.3	0.8	3.3	99.2	99.2	25.2
Min	4.8	5.2	530	1170	288	767	1	2	12	72	4	88	16	61	1	32	32	0.1
Max	8.6	7.8	9980	10720	6910	5750	123	169	532	1610	38	3650	878	61	33	268	268	1.6
Mean	7.3	6.7	2912	2796	1763	2022	22	61	92	408	19	829	138		15	174	176	0.2
Median	7.6	6.9	2220	1750	1210	1805	12	55	42	296	18	569	57		14	217	216	0.1
Standard Dev	0.7	0.7	2166	2287	1504	1408	34	43	116	331	6	745	198			70	70	0.4

Queen Seam - Background

Count	61	13	62	13	68	46	25	62	62	62	62	62	62	57	62	61	62	62
Count >LOR	60	12	61	12	67	45	18	61	61	61	61	61	56	0	2	60	61	10
% >LOR	98.4	92.3	98.4	92.3	98.5	97.8	72.0	98.4	98.4	98.4	98.4	98.4	90.3	0.0	3.2	98.4	98.4	16.1
Min	6.5	5.7	730	759	368	474	1	8	9	102	5	165	1	0	6	65	65	0.1
Max	8.4	7.5	11700	12040	8130	7540	86	762	540	1400	67	3950	633	0	14	542	542	0.4
Mean	7.5	6.9	4536	4725	2880	2940	22	225	159	486	24	1441	208		10	245	245	0.2
Median	7.7	7.2	2070	1755	1080	1340	15	61	26	317	15	507	74		10	228	227	0.1
Standard Dev	0.5	0.6	4464	5036	2984	2898	25	275	195	414	19	1580	223			126	125	0.1

Appendix A-4 - Dissolved Metals/Metalloids summary statistics

Statistic	Aluminium (Filtered)	Arsenic (Filtered)	Boron (Filtered)	Cadmium (Filtered)	Chromium (hexavalent) (Filtered)	Chromium (III+VI) (Filtered)	Cobalt (Filtered)	Copper (Filtered)	Iron (Filtered)	Lead (Filtered)	Manganese (Filtered)	Molybdenum (Filtered)	Nickel (Filtered)	Selenium (Filtered)	Vanadium (Filtered)	Zinc (Filtered)
	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	mg/L	mg/L

King Seam - Mine Affected

Count	9	17	17	7	6	1	7	7	9	7	9	17	7	17	17	7
Count >LOR	0	8	16	0	0	0	0	0	8	0	8	13	6	0	0	3
% >LOR	0.0	47.1	94.1	0.0000	0.000	0.000	0.0	0.0	88.9	0.0	88.9	76.5	85.7	0.0	0.0	42.9
Min	0.00	0.001	0.18	0.0000	0.000	0.000	0.000	0.000	0.2	0.000	0.036	0.000	0.001	0.000	0.000	0.007
Max	0.00	0.009	0.42	0.0000	0.000	0.000	0.000	0.000	2.4	0.000	0.105	0.057	0.005	0.000	0.000	0.031
Mean		0.004	0.27						1.1		0.066	0.009	0.002			0.022
Median		0.003	0.24						0.9		0.060	0.000	0.002			0.029
Standard Dev		0.003	0.08						0.8		0.024	0.018	0.002			0.013

King Seam - Background

Count	34	52	52	32	30	1	32	32	34	32	34	52	32	52	52	32
Count >LOR	1	11	50	1	2	0	0	3	33	0	33	6	4	0	0	9
% >LOR	2.9	21.2	96.2	3.1	6.7	0.0	0.0	9.4	97.1	0.0	97.1	11.5	12.5	0.0	0.0	28.1
Min	0.01	0.001	0.07	0.0001	0.002	0.000	0.000	0.001	0.6	0.000	0.013	0.000	0.001	0.000	0.000	0.008
Max	0.01	0.001	0.34	0.0001	0.003	0.000	0.000	0.001	11.9	0.000	0.262	0.000	0.005	0.000	0.000	0.132
Mean	0.01	0.001	0.16	0.0001	0.003			0.001	6.1		0.135	0.000	0.003			0.036
Median	0.01	0.001	0.14	0.0001	0.003			0.001	6.8		0.152	0.000	0.002			0.010
Standard Dev		0.000	0.08		0.001			0.000	3.7		0.097	0.000	0.002			0.051

Queen Seam - All

Count	105	195	193	96	88	1	95	95	105	95	105	193	95	193	193	95
Count >LOR	7	46	119	1	3	0	10	7	97	1	104	63	21	0	0	26
% >LOR	6.7	23.6	61.7	1.0	3.4	0.0	10.5	7.4	92.4	1.1	99.0	32.6	22.1	0.0	0.0	27.4
Min	0.01	0.001	0.05	0.0003	0.001	0.000	0.001	0.001	0.1	0.001	0.002	0.000001	0.001	0.000	0.000	0.005
Max	0.02	0.004	0.28	0.0003	0.002	0.000	0.062	0.005	15.5	0.001	1.190	0.002000	0.054	0.000	0.000	0.104
Mean	0.02	0.002	0.13	0.0003	0.002		0.029	0.002	3.7	0.001	0.171	0.000129	0.015			0.021
Median	0.02	0.002	0.11	0.0003	0.002		0.026	0.001	3.3	0.001	0.094	0.000002	0.004			0.009
Standard Dev	0.01	0.001	0.07		0.001		0.029	0.001	4.0		0.246	0.000380	0.021			0.027

Queen Seam - Mine Affected

Count	38	128	126	29	22	1	28	28	38	28	38	126	28	126	126	28
Count >LOR	5	38	74	0	0	0	10	2	37	1	37	52	11	0	0	11
% >LOR	13.2	29.7	58.7	0.0000	0.000	0.000	35.7	7.1	97.4	3.6	97.4	41.3	39.3	0.0	0.0	39.3
Min	0.01	0.001	0.05	0.0000	0.000	0.000	0.001	0.002	0.2	0.001	0.018	0.000	0.002	0.000	0.000	0.005
Max	0.02	0.003	0.28	0.0000	0.000	0.000	0.062	0.005	15.5	0.001	1.190	0.002	0.054	0.000	0.000	0.104
Mean	0.02	0.002	0.15				0.029	0.004	5.1	0.001	0.310	0.000117	0.025			0.033
Median	0.02	0.002	0.17				0.026	0.004	1.2	0.001	0.098	0.000002	0.006			0.030
Standard Dev	0.01	0.001	0.07				0.029	0.002	5.6		0.352	0.000378	0.025			0.036

Queen Seam - Background

Count	68	68	68	68	67	1	68	68	68	68	68	68	68	68	68	68
Count >LOR	2	8	45	1	3	0	0	5	60	0	67	11	10	0	0	15
% >LOR	2.9	11.8	66.2	1.5	4.5	0.0	0.0	7.4	88.2	0.0	98.5	16.2	14.7	0.0	0.0	22.1
Min	0.01	0.001	0.05	0.0003	0.001	0.000	0.000	0.001	0.1	0.000	0.002	0.000	0.001	0.000	0.000	0.005
Max	0.02	0.004	0.15	0.0003	0.002	0.000	0.000	0.002	5.9	0.000	0.352	0.001	0.010	0.000	0.000	0.057
Mean	0.02	0.004	0.08	0.0003	0.002			0.001	2.8		0.095	0.000	0.004			0.013
Median	0.02	0.004	0.08	0.0003	0.002			0.001	3.7		0.093	0.000	0.003			0.008
Standard Dev	0.01	0.001	0.03		0.001			0.000	2.1		0.101	0.000	0.003			0.013

APPENDIX



Mine AMD Environmental Investigation – Surface Water



Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Suitably qualified person

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. This Statutory Declaration must be completed by the person who conducted the environmental evaluation and accompany the environmental report submitted to the Department of Environment and Heritage Protection (the department).

Oaths Act 1867

QUEENSLAND TO WIT

I

Kate Keating

Insert the name of the person making this declaration

of

Ecological Service Professionals

Insert the street address of the person making this declaration

Unit 1, 16 Industry Place, Wynnum. 4178 Queensland

in the State of Queensland do solemnly and sincerely declare that:

- I am the suitably qualified person and author of an environmental report entitled
Environmental Investigation Report – Meandu Mine, Surface Waters.

Insert title of the environmental report

In accordance with the environmental evaluation issued by the department under the Act to:

TEC Coal Pty Ltd

21 December 2016

Insert name of recipient of the notice

Insert date of the notice

A copy of my report is attached to this statutory declaration and marked "A".

I possess the following qualifications and experience relevant to this environmental evaluation:

Bachelor of Marine Studies (Biology and Ecology, Honours I)

I have not knowingly included any false, misleading or incomplete information in the report; and

I have not knowingly failed to reveal any relevant information or document to the department.

I certify that:

Statutory Declaration
Suitably qualified person

- The report addresses the relevant matters for the evaluation and is factually correct; and
- The opinions expressed in it are honestly and reasonably held.

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at

BRISBANE.

Insert location

this

12th

day of

September

in the year

2018

Insert day (e.g. 18th)

Insert month

Insert year

Signed

(Person making this declaration)

Signed

~~<INSERT Justice of the Peace / Commissioner
for Declarations / Lawyer>~~

ANGELEENA PRASSLER

Printed name and registration number (if applicable)



Environmental Investigation Report – Meandu Mine

Surface Waters



CONFIDENTIAL

Prepared for: TEC Coal Pty Ltd

Prepared by Ecological Service Professionals Pty Ltd

September 2018

Document Control

CONFIDENTIAL

Report Title: Environmental Investigation Report – Meandu Mine: Surface Waters
Project Reference: 1704
Client: Stanwell Corporation Limited
Client Contact: Javier Cabrera
Version Number: 1704.002V5
Date Submitted: 06/09/2018



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Acronyms and Abbreviations

Term	Definition
AMD	Acid and Metalliferous Drainage
AUSRIVAS	Australian River Assessment System
AWQG	Australian Water Quality Guidelines
BMRG	Burnett Mary Regional Group
BOM	Bureau of Meteorology
CP	Compliance Point
EHP	Former Queensland Department of Environment and Heritage Protection
DES	Queensland Department of Environment and Science (formerly Department of Environment and Heritage Protection)
DNRM	Former Queensland Department of Natural Resources and Mines
DNRME	Queensland Department of Natural Resources, Mines and Energy (formerly Department of Natural Resources and Mines)
DTA	Direct toxicity assessments
EA	Environmental Authority
EC	Electrical Conductivity
EPP (Water)	Environmental Protection (Water) Policy 2009
ESP	Ecological Service Professionals
EV	Environmental Value
HEV	High ecological value
SQGV	Sediment Quality Guideline Value
SQG-High	Sediment Quality Guideline High
MD	Moderately disturbed
ML	megalitres
mm	millimetres
NATA	National Association of Testing Authorities, Australia
nMDS	non-metric Multi-Dimensional Scaling; a tool to visualise the differences in the composition of an assemblage
NTU	Nephelometric Turbidity Units
PERMANOVA	Permutational analysis of variance
PERMDISP	Permutational dispersion; a test for significant differences in the variance between samples among factor groups



Term	Definition
PET	Plecoptera / Ephemeroptera / Trichoptera; macroinvertebrate taxa considered sensitive to disturbance
PRIMER	Plymouth Routines in Multivariate Ecological Research; a statistical software package
QA/QC	Quality Assurance / Quality Control
QWQG	Queensland Water Quality Guidelines
RD	Retention Dam
SD	Slightly disturbed
SIGNAL 2	Stream Invertebrate Grade Average Level – version 2; a measure of the relative abundance of tolerant versus sensitive macroinvertebrate taxa in a sample
SMD	Slightly to moderately disturbed
TDS	Total Dissolved Solids
WQO	Water Quality Objective

Executive Summary

TEC Coal Pty Ltd a subsidiary of Stanwell Corporation Limited (Stanwell) were issued with a notice to conduct or commission an environmental evaluation under Section 326B of the *Environmental Protection Act 1994* (EP Act) (the Notice) by the former Department of Environment and Heritage Protection (EHP) (now Department of Environment and Science (DES)) on 21 December 2016. The grounds for the environmental evaluation relate to the identification of acid and metalliferous drainage (AMD) at Meandu Mine and the potential for this AMD to cause environmental harm. This report has been prepared for Stanwell and describes the findings from an aquatic ecology assessment aimed at investigating the potential for AMD-related environmental harm from operations at the Meandu Mine site on water quality, sediment quality and aquatic flora and fauna in the receiving environment. Key indicators of AMD at Meandu Mine, including electrical conductivity, pH, cobalt, iron, manganese, nickel and zinc, are assessed.

Meandu Mine has operated since 1978 and supplies coal to the adjacent Tarong and Tarong North power stations. AMD was identified in overland flow to a retention dam (RD7) on the western side of Meandu Mine, where it was mixed with other mine affected water and ultimately either re-used on-site or released in accordance with the mine's Environmental Authority (EA) to the CP3 release point on Meandu Creek, upstream of Meandu Creek Dam.

Environmental Values and Water Quality Objectives

There are currently no assigned EVs in Schedule 1 of the Environmental Protection Policy (Water) for Meandu Creek. Relevant EVs were assigned from those outlined in Section 6 (2) of the policy, with reference to other relevant sources, such as the Burnett Mary Water Quality Improvement Plan, available literature, previous technical reports and field surveys.

Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam form part of the water management systems for Meandu Mine and the Tarong power stations, and thus, the industrial use EV was assigned. Current compliance limits outlined in the Environmental Authorities's (EA's) for Meandu Mine and Tarong power stations are considered appropriate for management of these waters (i.e. published WQOs do not apply to this reach).

EVs assigned to Meandu Creek downstream of Meandu Creek Dam were aquatic ecosystems (moderately disturbed), irrigation, farm supply, stock watering, human consumption, primary recreation, secondary recreation, and industrial use. Published water quality objectives (WQOs) have been assigned to this reach to manage these EVs. In general, the most stringent WQOs (mainly associated with protecting moderately disturbed aquatic ecosystems) were assigned.

Meandu Creek Upstream of and Within Meandu Creek Dam

The results of historical surface water monitoring completed at Meandu Mine and the Tarong and Tarong North power stations, and of the March 2017 survey, demonstrate that electrical conductivity levels and the concentrations of major ions (including sulfate), nitrate and some dissolved metals are higher in Meandu Creek adjacent to Meandu Mine than at comparative sites within the region. This may be indicative of an AMD-related impact; however,



concentrations of the key AMD indicators (cobalt, iron, manganese, nickel, and zinc) in the water were below levels likely to cause environmental harm or toxicity (acute or chronic) to flora and fauna.

Site CM2 was a narrow pool downstream of the CP3 release point on Meandu Creek and upstream of Meandu Creek Dam. This site had relatively high concentrations of cobalt, manganese, nickel and zinc in the sediment. In particular, concentrations of dilute acid extractable nickel and zinc (representative of the bioavailable fraction) exceeded the sediment quality guidelines at this site; there are no sediment quality guideline values for cobalt and manganese. Furthermore, there was a molar limitation of acid volatile sulfides compared to simultaneously extracted metals, indicating metals are unlikely to be bound in sulfide complexes in the sediment and may be dissolved and thus bioavailable to aquatic flora and fauna. It is likely that the presence of dense rushes and the slowing of water as it enters the dam are causing a build-up of fine sediments in this area with elevated levels of some metals. Further lines of evidence (e.g. toxicity and bioaccumulation) at site CM2 could be implemented to understand the potential impacts of elevated concentrations of metals at this site.

A similar range of macroinvertebrate taxa were generally recorded at sites in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) and at the ephemeral comparative sites. However, there were some sensitive taxa recorded at comparative sites not found at sites on Meandu Creek upstream of Meandu Creek Dam. Diversity and abundance of fish, and diversity of aquatic plants were also lower at sites upstream of Meandu Creek Dam than at comparative sites. While it is possible that the impacts from AMD to water and sediment quality are affecting the composition of aquatic communities in this section of the creek, differences at these sites may also be due to a range of other factors including the upstream location in the catchment and a lack of connectivity with downstream reaches (particularly due to the presence of Meandu Creek Dam); along with poorer habitat quality as a result of the construction of diversions and mine water management systems.

Overall, based on the information presented in this report, there is currently no evidence that mine impacted water is having a negative impact on the industrial use environmental value of Meandu Creek upstream of Meandu Creek Dam. Where water quality conditions (e.g. pH, water hardness and electrical conductivity) are monitored and managed in accordance with the site's EA and Meandu Creek REMP, there is a low risk of potential for environmental harm to the industrial use environmental value in this reach.

Meandu Creek Downstream of Meandu Creek Dam

The results of historical surface water monitoring completed at Meandu Mine and the Tarong power stations, and of the March 2017 survey, demonstrated that electrical conductivity levels and the concentrations of major ions (including sulphate) and some dissolved metals are higher in the water at sites in Meandu Creek downstream of Meandu Creek Dam than at comparative sites within the region. However, dissolved (i.e. bioavailable) metal concentrations in water at sites in Meandu Creek downstream of Meandu Creek Dam were below relevant WQOs where available, and therefore likely to be of low risk to aquatic flora and fauna. The results of aquatic flora and fauna surveys confirm this, with no impacts detected to communities in the receiving environment.

Results of the surveys completed in March 2017 and April 2018 indicated some areas in Meandu Creek downstream of Meandu Creek Dam had sediment-bound metals. However, this was restricted to reaches close to (i.e. within 500 m of) Meandu Creek Dam (site MC500). While this site had relatively high levels of some metal that are indicative of AMD (cobalt, manganese, nickel and zinc) or power station activities (e.g. nickel and zinc) compared to comparative sites, further assessment indicated that these metals are unlikely to be bioavailable. The dilute acid extractable metal (i.e. bioavailable) concentration was below relevant guidelines (except for nickel at site MC500). In addition, the molar excess of acid-volatile sulfides over simultaneously extracted metals indicated that metals are likely to be bound in sulfide complexes and have limited bioavailability to aquatic flora and fauna. Furthermore, the results of the aquatic flora and fauna surveys demonstrate that this is not resulting in negative impacts to the aquatic ecosystem EVs of Meandu Creek downstream of Meandu Creek Dam.

Aquatic flora and fauna communities in Meandu Creek downstream of Meandu Creek Dam were in a similar or better condition than would be expected in the broader catchment. The perennial flow regime, resulting from the consistent releases from Meandu Creek Dam, allows for stable and diverse aquatic habitats to occur, which in turn are colonised by a diverse range of macroinvertebrates (including some sensitive and very sensitive taxa), along with aquatic plants, fish and turtles, where habitat is suitable. This confirms that the quality of water released from Meandu Creek Dam, and the sediment quality in Meandu Creek downstream of Meandu Creek dam, is suitable for protecting the downstream aquatic ecosystem.

Conclusions

Overall, based on the information presented in this report, it is unlikely that concentrations of contaminants in water and sediment from mine impacted water are having a negative impact on (or causing environmental harm to) the environmental values of Meandu Creek downstream of Meandu Creek Dam. Stanwell is committed to proactive long term resolution of the AMD issue and development of potential engineering options that may be implemented at Meandu Mine to mitigate any potential environmental impacts associated with AMD. Some initial measures have been made by Stanwell to manage AMD including interim lime dosing and changes to monitoring and operations. These measures further reduce the risk of environmental harm.

Where water quality conditions remain unchanged (i.e. remain within the historical range and / or meet WQOS where applicable), no further lines of investigation are considered necessary to prevent environmental harm on aquatic environmental values occurring from AMD at Meandu Mine. Ongoing monitoring in the Meandu Mine and Tarong power stations EAs, including compliance monitoring and the Meandu Creek REMP, to ensure water quality conditions specified remain unchanged is recommended. It is recommended that key AMD indicators (including concentrations of cobalt, nickel, iron, manganese and zinc) are included in the Meandu Creek REMP. In the event that a change in water quality conditions of key parameters is detected (e.g. pH falls below the WQO or hardness decreases so that water is no longer extremely hard), the procedures outlined in the Meandu Mine EA and Meandu Creek REMP are sufficient to ensure environmental values in the receiving environment are protected.

A summary of investigation outcomes in relation to the relevant surface water quality and aquatic ecology requirements of the Notice are summarised in Table 0.1 overleaf.

Table 0.1 The Notice requirements and summary of corresponding investigation outcomes, including the relevant section of this report where each requirement is addressed

Reference of Notice	Details of Notice Requirement	Summary of Investigation Outcomes
B2	The characterise of Meandu Creek must:	There are currently no assigned EVs in Schedule 1 of the EPP (Water) for Meandu Creek. Relevant EVs were assigned from those outlined in Section 6 (2) of the policy, with reference to other relevant sources, such as the Burnett Mary WQIP (BMRG 2015), available literature, previous technical reports and field surveys.
(i)	- identify any environmental values (EVs) and water quality objectives (WQOs) scheduled for Meandu Creek under the Environmental Protection (Water) Policy 2009 (EPP Water)	Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam form part of the water management systems for Meandu Mine and the Tarong power stations, and thus, the industrial use EV was assigned, as discussed in Section 3.1.1. Current compliance limits outlined in the EA's for Meandu Mine and Tarong power stations are considered appropriate for management of these waters (published WQOs do not apply to this reach), as discussed in Section 3.3.1.
(ii)	- if none are identified, propose EVs/WQOs where required for Meandu Creek	EVs assigned to Meandu Creek downstream of Meandu Creek Dam are discussed in Section 3.1.3, and are: • aquatic ecosystems (moderately disturbed) • irrigation • farm supply • stock watering • human consumption • primary recreation • secondary recreation, and • industrial use. Published water quality objectives (WQOs) have been assigned to this reach to manage these EVs. The most stringent WQO (mostly associated with protecting moderately disturbed aquatic ecosystems) was generally assigned. The source of assigned WQOs for Meandu Creek downstream of Meandu Creek Dam is discussed in Section 3.3.2 and outlined in Table 3.2.



Reference of Notice	Details of Notice Requirement	Summary of Investigation Outcomes
(iii)	- provide a description of the existing qualities, characteristics and resilience of Meandu Creek, and	Meandu Creek upstream of Meandu Creek Dam, adjacent to Meandu Mine, is an intermittent waterway with several disjointed, non-flowing pools along the channel, and has been diverted in several places. Meandu Creek Dam is a large earth filled constructed dam. Meandu Creek downstream of Meandu Creek Dam exhibits long periods of continual flow from Meandu Creek Dam releases, characteristic of a perennial waterway. Overall, aquatic communities of Meandu Creek downstream of Meandu Creek Dam are highly resilient to current mining and power station activities as they have previously shown rapid adapted and colonisation to changing conditions and are generally in a similar or better condition than would be expected in the broader catchment. Existing water quality, sediment quality as well as aquatic habitat, flora and fauna are detailed in Sections 4 to 10.
(iv)	- with reference to items (i) to (iii) above determine the mine-affected water release quality that must be achieved to protect the relevant EVs of Meandu Creek.	Based on the information presented in this report, there is currently no evidence that mine-affected water is having a negative impact on the environmental values of the receiving environment, as discussed in Section 11. Thus, current release conditions within Meandu Mine's EA and the monitoring requirements outlined in the Meandu Creek REMP are considered sufficient to protect the relevant EVs of Meandu Creek.
B4	Determine whether AMD at Meandu Mine has impacted on or has the potential to impact on the environmental values of surface waters including Meandu Creek. The studies must include:	Based on the information presented in this report, there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment, as discussed in Section 11. Water quality conditions, including hardness and pH, are likely to be reducing the toxicity of metals in water. Further, metals in sediments in Meandu Creek downstream of Meandu Creek Dam are likely to be immobilised by the availability of sulfide complexes and are unlikely to cause acute or chronic toxicity to aquatic flora and fauna. Where water quality conditions remain unchanged (i.e. remain within the historical range and / or comply with WQOs where applicable, are monitored and managed in accordance with the current EA and / or Meandu Creek REMP), potential AMD impacts on aquatic environmental values are considered unlikely.
(i)	- water quality investigations to determine any impacts on environmental values of surface waters (Meandu Creek) that have	The results of historical surface water monitoring completed at Meandu Mine and the Tarong and Tarong North power stations, and of the March 2017 survey, demonstrated that electrical conductivity levels and the concentrations of major ions (including sulfate) and some dissolved metals are higher in Meandu Creek adjacent to and downstream of Meandu Mine than at comparative sites within the region (as discussed in Section 4). This may be indicative of an AMD-related impact; however, other



Reference of Notice	Details of Notice Requirement	Summary of Investigation Outcomes
	occurred as a result of AMD at Meandu Mine	factors such as operation of the Tarong power stations and catchment inputs also influence some of these parameters. Regardless of this, based on the information presented in this report, there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment.
(ii)	- water quality investigations to determine future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine	Future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine are discussed in Section 11.4, and are considered unlikely given: - the information presented in this report shows there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment. - AMD issues at Meandu Mine will be managed through the implementation of changes to the mining and placement of mined materials, with Stanwell committed to proactive long term resolution of the AMD issue and development of potential engineering options that may be implemented at Meandu Mine to mitigate any potential environmental impacts associated with AMD. This includes initial measures including interim lime dosing and changes to monitoring and operations. Further changes are potentially required to the way mining, mine waste, mine water, landform design and rehabilitation are managed at Meandu Mine. - water quality will continue to be managed in line with the Meandu Mine and Tarong power stations EAs, including compliance monitoring and the Meandu Creek REMP.
(iii)	- identify short term and long term measures including (if relevant) further lines of investigation, monitoring requirements, and operational or mine planning measures that should be developed and/ or implemented to prevent environmental harm occurring from AMD at Meandu Mine.	In addition to long term and short term commitment to managing AMD at Meandu Mine outlined above, the following measures are recommended and are discussed in Section 11.5: - include key AMD indicators in the Meandu Mine REMP - further assess the toxicity of metals at cite CM2 (downstream of release point CP3 and upstream of Meandu Creek Dam) in line with the <i>Revision of the Sediment Quality Guidelines</i>, including further sediment toxicity test and bioavailability testing at site CM2.



1 Introduction

Meandu Mine is located approximately 30 km south of Kingaroy in the South Burnett region of Southern Queensland. The mine was established in 1978 and currently supplies over 7 million tonnes of coal to the adjacent Tarong and Tarong North power stations (referred to as the Tarong power stations) each year.

On 21 December 2016, the former Department of Environment and Heritage Protection (EHP) (now Department of Environment and Science (DES)) issued TEC Coal Pty Ltd (a subsidiary of Stanwell Corporation Limited (Stanwell)) with a notice to conduct or commission an environmental evaluation under Section 326B of the *Environmental Protection Act 1994* (EP Act) (the Notice).

The grounds for the environmental evaluation relate to the identification of acid and metalliferous drainage (AMD) at Meandu Mine and the potential for this AMD to cause environmental harm. As the full nature and extent of the AMD was unknown, EHP (now DES) required an environmental investigation be undertaken to determine whether environmental harm has occurred as a result of AMD at the Meandu Mine. AMD was identified as reporting by overland flow to retention dam 7 (RD7) in the retention dam network on the western side of the mine, where it is mixing with other mine affected water. Water from RD7 flows to RD8 where it is either re-used for site purpose or reports to the Meandu Creek Dam via release point CP3. AMD reporting to RD7 is believed to be originating from two closely associated seepage locations:

1. Bullgang Corner, located approximately 600 m south-east of RD7; and
2. a covered (vegetated) coal rejects area between Ramp 7 and the western side of the North West (NW) A tailings void (NWA tailings). This coal rejects area is assumed to be rehabilitated in the current Plan of Operations for Meandu Mine. This area will need to be evaluated to determine if remedial works are necessary in the future.

Specifically, the Notice determined that investigations are undertaken to:

1. Determine whether environmental harm has occurred as a result of AMD at Meandu Mine.
2. Identify and characterise the AMD and material with potential to generate AMD in the North-West (NW) tailings void/ spoil dump and rehabilitated rejects to assess the extent of environmental harm likely to be caused by the AMD; and to determine the effects of AMD ingress to stored historical tailings (e.g. potential dissolution of metal contaminants in the tailings which may be transported to the receiving environment in the seepage).
3. Identify other locations at Meandu Mine where AMD is occurring; and to identify potential AMD source materials at Meandu Mine.
4. Determine the potential for AMD related environmental harm (acute and/or chronic impacts on the aquatic ecosystem and other relevant water quality objectives (WQO's))



that could occur from future (ongoing) activities at Meandu Mine, including potential impacts from:

- build-up of metals in sediment downstream of Meandu Creek Dam
- elevated metal concentrations in Meandu Creek waters
- alteration of the pH of Meandu Creek Dam waters and release of sediment bound contaminants to the downstream environment
- elevated salinity levels in Meandu Creek waters.

To address the requirements of the Notice, Stanwell has commissioned an Environmental and Engineering Evaluation into AMD at the Meandu Mine site. This investigation incorporates studies across of range of technical disciplines including:

- mine planning historical and life of mine (future) (Xenith Consulting)
- material classification assessments (geochemical) (RGS Environmental Pty Ltd)
- hydrogeological assessments (JBT Consulting)
- surface water quality, sediments and aquatic ecology investigations (Ecological Services Professionals Pty Ltd)
- water modelling and development of engineering solutions (Golders Associates Pty Ltd).

Based on the environmental investigations undertaken in response to the Notice, there is currently no evidence of negative impacts to the environmental values of Meandu Creek as a result of AMD from Meandu Mine. Overall, aquatic ecological community in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam.

Future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine are considered unlikely given:

- the information presented in this environmental investigation shows there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment.
- the static and kinetic geochemical data combined with the geological model, overburden model and material balances, site-based evaluations and the long-term water quality data, indicate that the potential for acidic drainage to be produced in pits is very low or unlikely (other than from the North-West Backfilled Pit).
- the geochemical characterisation, based over 14 months data of kinetic leach column testing, established that the AMD issues at Meandu Mine are considered relatively minor and able to be managed through the implementation of changes to the mining and placement of mined materials.

Stanwell is committed to proactive long term resolution of the AMD issue and development of potential engineering options that may be implemented at Meandu Mine to mitigate any potential environmental impacts associated with AMD. Some initial measures have been made by Stanwell to manage AMD including interim lime dosing and changes to monitoring

and operations. Further changes are potentially required to the way mining, mine waste, mine water, landform design and rehabilitation are managed at Meandu Mine.

1.1 Information Sources

The work contained in this report commenced in January 2017 following issuing of the Notice. It is based on:

- two field surveys (March 2017 and April 2018), and
- water quality sampling data from both the Meandu Mine and Tarong power stations (October 1978 to August 2017) supplied by Stanwell.

Water quality sampling and monitoring by Stanwell has continued beyond these date ranges, but is not included in this report.

1.2 Specific Notice Requirements

The grounds of the Notice of relevance to this report are:

- Section A, item 1, to determine whether environmental harm has occurred as a result of AMD and Meandu Mine, and
- Section A, item 4, to determine the potential for AMD-related environmental harm that could occur from future (ongoing) activities at Meandu Mine, including:
 - build-up of metals in sediment downstream of Meandu Creek Dam
 - elevated metal concentrations in Meandu Creek waters
 - alteration of the pH of Meandu Creek Dam waters and release of sediment-bound contaminants to the downstream environment, and
 - elevated salinity levels in Meandu Creek waters.

The requirements (Section B) of the Notice of relevance to this report are outlined in Table 1.1.

1.3 Scope of Works

This report describes the findings of a surface water quality and aquatic ecology assessment aimed at addressing the Notice requirements and investigating the potential for AMD-related environmental harm from operations at the Meandu Mine site on water quality, sediment quality and aquatic flora and fauna in the receiving environment.

This report contributes to the Environmental and Engineering Evaluation, the aim of which is to identify the scope and extent of AMD impacts, based on historic and current operations. Specifically, it includes:

- characterising the EVs and associated WQOs for surface waters (particularly Meandu Creek)
- undertaking water quality, sediment quality and aquatic ecology monitoring and investigations to determine if any impacts on EVs of surface waters (Meandu Creek) have occurred as a result of AMD from the Meandu Mine

- identifying short-term and long-term measures (if relevant) including further lines of investigation, monitoring requirements, and operational or mine planning measures that should be developed and/or implemented to prevent environmental harm occurring from AMD at Meandu Mine.

Table 1.1 The Notice requirements and relevant section of this report where each requirement is addressed

Reference of Notice	Details of Notice Requirement	Section of this report
B2	The characterise of Meandu Creek must:	
(i)	- identify any environmental values (EVs) and water quality objectives (WQOs) scheduled for Meandu Creek under the Environmental Protection (Water) Policy 2009 (EPP Water)	Section 3
(ii)	- if none are identified, propose EVs/WQOs where required for Meandu Creek	Section 3
(iii)	- provide a description of the existing qualities, characteristics and resilience of Meandu Creek, and	Sections 4 to 10
(iv)	- with reference to items (i) to (iii) above determine the mine-affected water release quality that must be achieved to protect the relevant EVs of Meandu Creek	Section 11.5
B4	Determine whether AMD at Meandu Mine has impacted on or has the potential to impact on the environmental values of surface waters including Meandu Creek. The studies must include:	
(i)	- water quality investigations to determine any impacts on environmental values of surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine	Sections 4.2, 4.3 and summarised in Sections 11.1 to 11.3
(ii)	- water quality investigations to determine future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine	Section 11.4
(iii)	- identify short term and long term measures including (if relevant) further lines of investigation, monitoring requirements, and operational or mine planning measures that should be developed and/ or implemented to prevent	Section 11.5

Reference of Notice	Details of Notice Requirement	Section of this report
	environmental harm occurring from AMD at Meandu Mine.	

1.4 Background

1.4.1 Waterways in the vicinity of Meandu Mine

Meandu Mine is located near the headwaters of Meandu Creek, within the Barker Creek catchment, part of the Burnett Basin. Most of the water licensed to be discharged from Meandu Mine is directed to Meandu Creek Dam via Meandu Creek (Figure 1.1), with some water also discharging to Black Creek Dam.

Cooling water blowdown is also discharged to Meandu Creek Dam from the adjacent Tarong and Tarong North power stations according to EA licence conditions (EPPR00971913¹). Meandu Creek Dam also receives stormwater runoff from the Tarong power stations (Figure 1.1) as well as stormwater runoff from the Meandu Mine and from the upper Meandu Creek catchment.

Black Creek Dam is located immediately upstream of the Ash Dam for the Tarong power stations (Figure 1.1). This 1,350 ML dam was constructed in 1987 and intercepts runoff from the upstream catchment. Water in Black Creek Dam is used at the Tarong and Tarong North power stations. Black Creek Dam is an integral part of the ash disposal system because of its effect on the Ash Dam water balance. In 2015, the Black Creek Dam diversion channel was constructed to direct overflows from the Black Creek Dam around the Ash Dam to Meandu Creek. As Black Creek has been substantially modified from its natural state and is used for industrial purposes, it was de-gazetted as a watercourse under the *Water Act 2000* by the former Department of Natural Resources and Mines (DNRM), now Department of Natural Resources, Mines and Energy (DNRME).

Water from Meandu Creek Dam is released to the Meandu Creek via a release valve at the dam wall (Figure 1.1, monitoring site W3). Under normal operating conditions, there is a continual release of water; in the absence of rainfall and catchment inflows, these releases are the main source of water for Meandu Creek downstream of Meandu Creek Dam. Release volumes are regulated by water levels within the dam, as well as the needs of downstream water users, who are licenced by the DNRM (now DNRME) to take water when releases are being made from Meandu Creek Dam. Water release needs for these users are determined in conjunction with the Meandu and Barkers Creek Water Advisory Committee.

¹ The current EA took effect on 22 August 2017; the power stations formerly operated under EAs EPPR00971913 – Tarong and EPPR00330713 – Tarong North.

Meandu Creek is a tributary of Barker Creek, which flows to the Bjelke-Petersen Dam (Lake Barambah) some 100 km downstream of the Meandu Creek Dam. Waterways in the Barker Creek catchment have an ephemeral or intermittent flow regime, only flowing after rainfall. However, the waters of the receiving environment (including Meandu Creek, and Barker Creek downstream of the confluence with Meandu Creek) have a perennial flow regime as a result of releases from Meandu Creek Dam (except during extreme drought conditions when releases may cease).

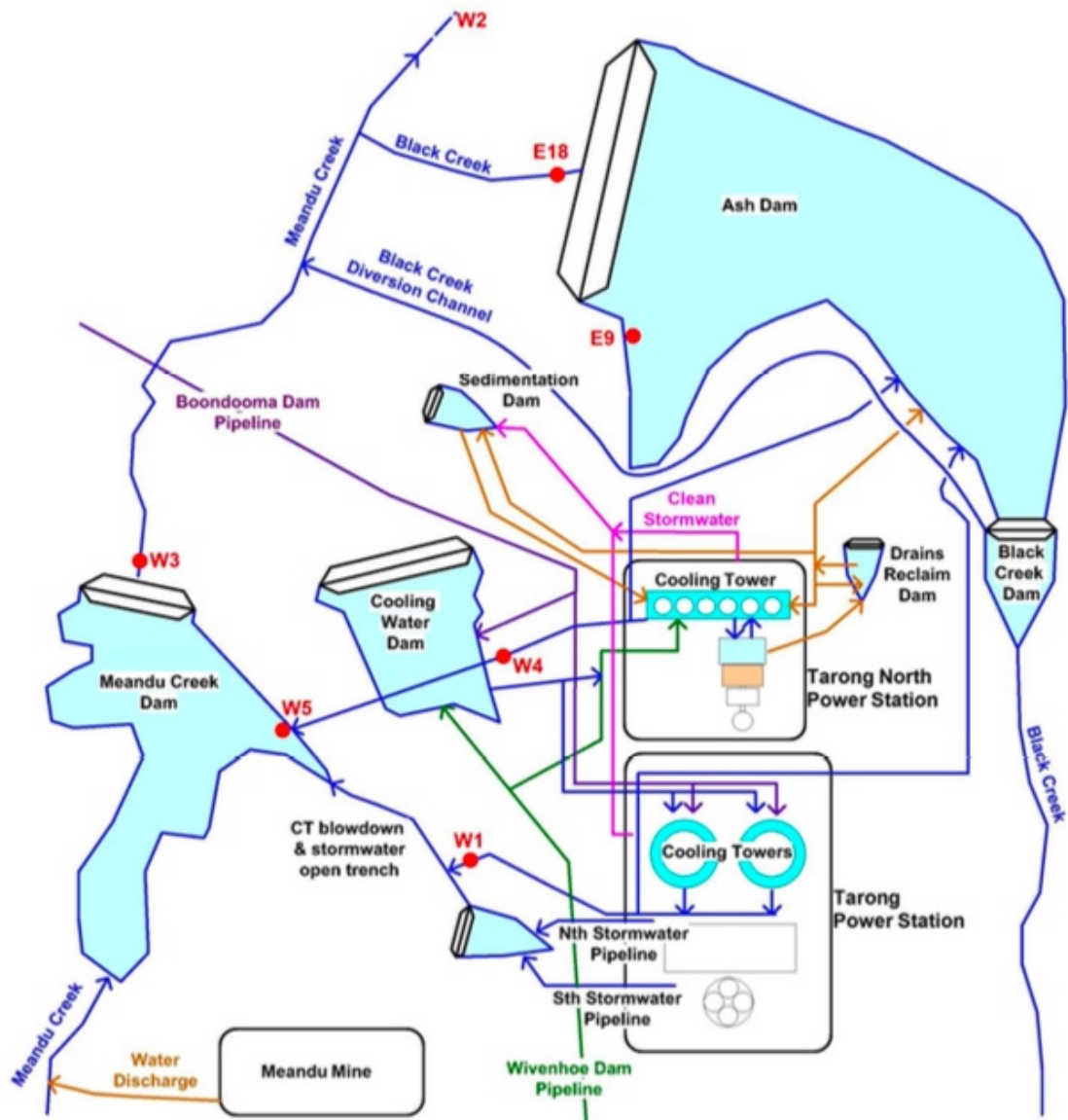


Figure 1.1 Schematic diagram of the water discharges to Meandu Creek Dam and Meandu Creek from Meandu Mine and the Tarong and Tarong North power stations (Stanwell 2016)

1.4.1.1 Potential Influences on Water Quality in Meandu Creek

There are several influences on the water quality in Meandu Creek Dam and Meandu Creek downstream of the dam. For the most part, water quality in the Meandu Creek downstream of the dam is highly influenced by discharges from Meandu Creek Dam, which under normal operating conditions equates to a constant release that averages 18 ML/day; these discharges are the main source of water for Meandu Creek downstream of the dam. Water from Meandu Creek Dam is released at discharge point W3 and enters Meandu Creek approximately 150 m downstream. The dam itself receives discharges from (Figure 1.1; for a description and map of site locations, refer to Section 2.2.1):

- Runoff from undisturbed catchments and managed forest operations upstream of Meandu Mine.
- Discharges from Meandu Mine via the Meandu Creek channel represented by site CP3 (Meandu Creek upstream of Meandu Creek Dam), and from release point CP4 located on a tributary that runs into Meandu Creek Dam.
- Cooling water blowdown from the Tarong power station and Tarong North power station via licenced discharge points W1 and W4, respectively. Cooling water blowdown contains relatively high concentrations (compared to the raw water used) of dissolved salts due to the evaporative cooling process, and may also contain higher concentrations of some contaminants, including arsenic, chromium and copper due to the use of CCA-treated timber in the cooling towers.
- Stormwater runoff from the Tarong power stations and Meandu Mine.

Downstream of Meandu Creek Dam, water quality in Meandu Creek may also be influenced by:

- Drainage from the Black Creek diversion channel (constructed to direct overflows from the Black Creek Dam around the Ash Dam) that enters Meandu Creek approximately 1.25 km downstream of Meandu Creek Dam. Black Creek receives predominantly runoff from the adjacent land as well as surface water discharge from Meandu Mine retention dam RD17 (via discharge point CP2). However, Black Creek Dam rarely overtops.
- Drainage from the remaining natural reach of Black Creek below the power station Ash Dam, which receives water from the Ash Dam Toe Drain (E18) that enters Meandu Creek approximately 3 km downstream of Meandu Creek Dam.
- Catchment runoff from adjacent land uses, including cropping for reaches >15 km downstream of Meandu Creek Dam.
- Potential releases from the Nanango Wastewater Treatment Plant to Barker Creek approximately 25 km downstream of Meandu Creek Dam (however, the current operating regime of this facility is not known).

1.4.2 Potential Impacts of Acid Mine Drainage on Surface Water Quality and Aquatic Ecosystems

Acid mine drainage or acid and metalliferous drainage (AMD) is produced from exposed sulfidic materials and is commonly associated with mine waste (Sullivan et. al. 2014). Water impacted by AMD is typically characterised by² (Dhir 2018; Commonwealth of Australia 2016):

- low pH (acidic)
- high electrical conductivity
- high concentrations of ions, particularly dissolved anions, including:
 - sulfate
 - nitrate
 - chloride
 - magnesium
- low dissolved oxygen, and
- high concentrations of metals and metalloids, including:
 - aluminium
 - arsenic
 - cadmium
 - cobalt
 - copper
 - iron
 - lead
 - manganese
 - mercury
 - nickel
 - zinc.

As some of the metals and metalloids listed above are also indicators of general mining activities and / or ash seepage, the following parameters are considered to be key indicators of AMD for Meandu Mine:

- cobalt
- iron

² Composition of AMD water based on results from six different metalliferous mine sites in the Northern Territory (Commonwealth of Australia 2016).

- manganese
- nickel, and
- zinc.

The high concentration of metals associated with AMD may also lead to metal contamination in stream sediments (Taylor & Cox 2003). For example, where AMD is characterised by low pH there is a higher potential for metals to dissolve within AMD wastewater and be transported downstream and deposited.

Overall, AMD has the potential to impact aquatic ecosystems, riparian vegetation and applicable human uses in receiving environment waterways. AMD can cause visual, chemical and physical changes to receiving environment waterways that can be harmful to flora and fauna, and the changes associated with AMD can have significant flow-on effects to aquatic ecosystems both directly and indirectly.

Primarily, aquatic ecosystems can be significantly impacted by changes in water quality. The contaminants associated with AMD (especially metals) can be toxic to aquatic flora and fauna in high concentrations (ANZECC & ARMCANZ 2000a). Certain contaminants may bring about changes to the diversity and abundance of flora and fauna in receiving environment waterways in instances where survival and/or reproduction is affected. Contaminants may also impact the health of flora and fauna. For example, high concentrations of certain metals, such as aluminium can impact fish, amphibians and crustaceans in terms of their respiratory function, growth and breeding abilities (ANZECC & ARMCANZ 2000a). Similarly, plant species may not tolerate high concentrations of contaminants and their growth may be stunted or impaired, while other noxious plant species or filamentous algae may thrive and begin to dominate the ecosystem (ANZECC & ARMCANZ 2000a). Effects are not limited to in-stream vegetation; altered water quality may also affect the health and presence of riparian vegetation (Chambers et al. 1991; Commonwealth of Australia 2016).

Metal contamination in sediment can be harmful to benthic organisms (such as macroinvertebrates) that live in the benthic zone (Lenntech 2017). Bioaccumulation in plants and animals may also become an issue as a result of metals in sediments (in particular with copper contamination) and the accumulation can progress up the food chain to higher-level organisms (Chambers et al. 1991; Lenntech 2017; ANZECC & ARMCANZ 2000a).

Indirectly, changes to water and sediment quality associated with AMD can lead to changes in the overall habitat (by significantly changing or reducing the habitat and protection available from aquatic and riparian vegetation) and influence the composition of communities in the aquatic ecosystem.

Finally, long-term discharges of AMD can impact the range of environmental values in the receiving environment, in particular aquatic ecosystems, stock watering, irrigation and human consumption values.

In summary, impacts of AMD may include (Commonwealth of Australia 2016):

- contamination of water quality and sediment quality

- poor health and possible death of fish and other aquatic organisms
- reduction of in-stream and riparian vegetation
- promotion of noxious plant growth
- visual changes to waterways: AMD may cause waterways to become red coloured or unnaturally clear, or introduce precipitates on the surface or water or bank edges, and
- loss of environmental values associated with the waterways.

1.4.3 Description of the Receiving Environment

For the purpose of this assessment, Meandu Creek has been divided into four reaches based on differences in the existing qualities and pressures. The reaches comprise:

- Meandu Creek upstream of the Meandu Mine – relatively undisturbed poorly defined channels that are naturally ephemeral (i.e. they convey runoff after rainfall, but water rarely pools)
- Meandu Creek upstream of Meandu Creek Dam - adjacent to Meandu Mine, typical intermittent waterway with several disjointed, non-flowing pools along the channel, and has been diverted in several places
- Meandu Creek Dam – large earth filled constructed dam (3,000 ML storage capacity), and
- Meandu Creek downstream of Meandu Creek Dam - long periods of continual flow from Meandu Creek Dam releases, characteristic of a perennial waterway (as opposed to ephemeral or intermittent waterways, typical in the region).

AMD was identified as reporting as surface flows in the retention dam network on the western side of the mine, where it mixes with other mine affected water and is either re-used for site purpose or reports to the Meandu Creek Dam via release point CP3. Thus, Meandu Creek downstream of CP3 is considered the surface water receiving environment of potential AMD-related impacts. Release point CP3 is located in the Meandu Creek upstream of Meandu Creek Dam reach. Water from CP3 flows into Meandu Creek Dam where it gets diluted with cooling water blowdown and storm water from the Tarong and Tarong North power stations and released via licensed discharges to Meandu Creek downstream of Meandu Creek Dam. The Meandu Creek Receiving Environment Monitoring Program (REMP) is undertaken by the Tarong and Tarong North power stations for water released from Meandu Creek Dam, with the receiving environment of the REMP including the reach of Meandu Creek downstream of Meandu Creek Dam.

2 Methods

2.1 Desktop Review

2.1.1 Review of Rainfall and Flow Data

Rainfall data from January 2007 to June 2017 were obtained from the Bureau of Meteorology (BOM) for the Tarong Rainfall Station (Station Number 40199).

Release volume data for Meandu Creek Dam, provided by Stanwell, were summarised. This included a graph of the release volume over time, discussion of the range of daily release volumes, and calculation of the average mean daily release volume. A new continuous flow meter was installed on 6 August 2015. Prior to this, flow rates were estimated only and are not included in the graphs or calculations.

Flows at two DNRME gauging stations on Barker Creek were also reviewed to provide context for the survey results: Station 136203A at Brooklands, upstream of the confluence with Meandu Creek; and 136209A at Kings Bridge Road, downstream of the confluence with Meandu Creek (DNRME 2017).

2.1.2 Environmental Values and Water Quality Objectives

A comprehensive review of environmental values (EVs), the appropriate level of protection for aquatic ecosystems, and the appropriate water quality objectives (WQOs) was completed. The most current versions of the following resources were reviewed in conjunction with results from the current field survey (described in Section 2.2):

- Queensland Water Quality Guidelines (QWQG) (EHP 2013)
- Australian Water Quality Guidelines (AWQG) (ANZECC & ARMCANZ 2000a)
- Water Quality Improvement Plan (WQIP) for the Burnett Mary Region (BMRG 2015)
- Model water conditions for coal mines in the Fitzroy Basin (EHP, n.d.), and
- previous technical reports and aquatic ecological studies relating to the EVs and WQOs relevant to Meandu Creek.

2.1.3 Review of Historical Water Quality Data

2.1.3.1 Meandu Creek Upstream of Meandu Creek Dam

Surface water quality monitoring has been undertaken at Meandu Mine since 1978. Water quality has been monitored at numerous sites throughout the mine water system and in Meandu Creek, as well as in groundwater bores. Stanwell provided a complete historical water quality monitoring database for review. The focus of our review has been on sites in Meandu Creek upstream of Meandu Creek Dam, and site CP1 (Meandu Creek Dam, where Meandu Creek enters the dam). A summary of the sites reviewed is provided in Table 2.1 and the approximate site locations (where known) are shown in Figure 2.1.

Where possible, all available data for each site on Meandu Creek was pooled and summary statistics (including minimums, maximums and 20th, 50th (median), 80th and 95th percentiles) were calculated³. However, there is a lack of certainty around the monitoring site locations and a lack of consistency in parameters monitored for historical data collected in the 1970s, 1980s and early 1990s. Therefore, summary statistics were also calculated for each site for the past 4 years only (2013–2017) (i.e. since elevated EC levels at CP3 were noted and additional sampling undertaken).

All available data for key parameters (i.e. those that are relevant to AMD such as pH, electrical conductivity, the concentrations of ions (e.g. sulfate) and the concentrations of dissolved metals) were also graphed for interpretation of trends over time.

Where a value was presented as less than the laboratory limit of reporting (LOR), the value was halved for data analysis and graphing purposes, in accordance with the guidance presented in the *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC & ARMCANZ 2000b).

Table 2.1 Summary of surface water quality monitoring sites, including site locations (where known) and sampling date ranges

Location	Site	Description	Easting (GDA96)	Northing (GDA96)	Sampling Date Range
Compliance Sites					
Meandu Creek Dam	CP1	Meandu Creek Dam at Meandu Creek Inflow	390115	7037000	1997–2017
Meandu Creek upstream of Meandu Creek Dam	CP3	Meandu Creek at V-Notch Weir	388852	7035461	2000–2017
	CP4	Meandu Creek tributary (clean water drain)	389093	7035708	2003–2017
Meandu Creek Sites					
Meandu Creek upstream of Meandu Creek Dam	RD7 Creek Crossing	Main Meandu Creek crossing behind RD7	NA	NA	2014–2015
Meandu Creek Dam (adjacent to mine)	Meandu Creek-1	Waterhole behind RD9	388852	7035461	2014–2017
	Meandu Creek-2	Waterhole to the west of RD9	389093	7035708	2014–2017

³ Data for some parameters (e.g. dissolved metals) was not available prior to 2013, and in these cases, summary statistics and graphs from 1978 to 2017 have not been presented.

Location	Site	Description	Easting (GDA96)	Northing (GDA96)	Sampling Date Range
	Meandu Creek-3	Waterhole west of RD10	388772	7035459	2015–2017
	Meandu Creek-4	Main waterhole on bend downstream of RD14B	388211	7034016	2015–2016
	Meandu Creek-5	Waterhole west of RD7 and RD8 between main creek crossing behind RD7 and CP3	389825	7036283	2015–2017
	Meandu Creek-6	Waterhole opposite Ramp 7 fill point near RD10	NA	NA	2015–2017
	CKMB	Meandu Creek - below RD2	NA	NA	1978–2008
	CKMC	Meandu Creek - just opposite RD14	NA	NA	1978–1994
	CKMD	Small gully draining into Meandu Creek, just below RD14	NA	NA	1978–1995
	CKMM	Meandu Creek - just opposite RD14	NA	NA	1983–1999
	CKMR	Was on Meandu Creek in vicinity of where RD11 and RD12 have since been built.	NA	NA	1986–1992
	CKMU	NA	NA	NA	1985–1990
Meandu Creek upstream of Meandu Mine	CKME	Meandu Creek draining forestry catchment – Just below (100 – 200m) southern lease boundary.	NA	NA	1978–1999
	CKMF	Meandu Creek - Forestry dam – in forest catchment well above site 'E'.	NA	NA	1988–2005

NA Indicates site location not provided in water quality database

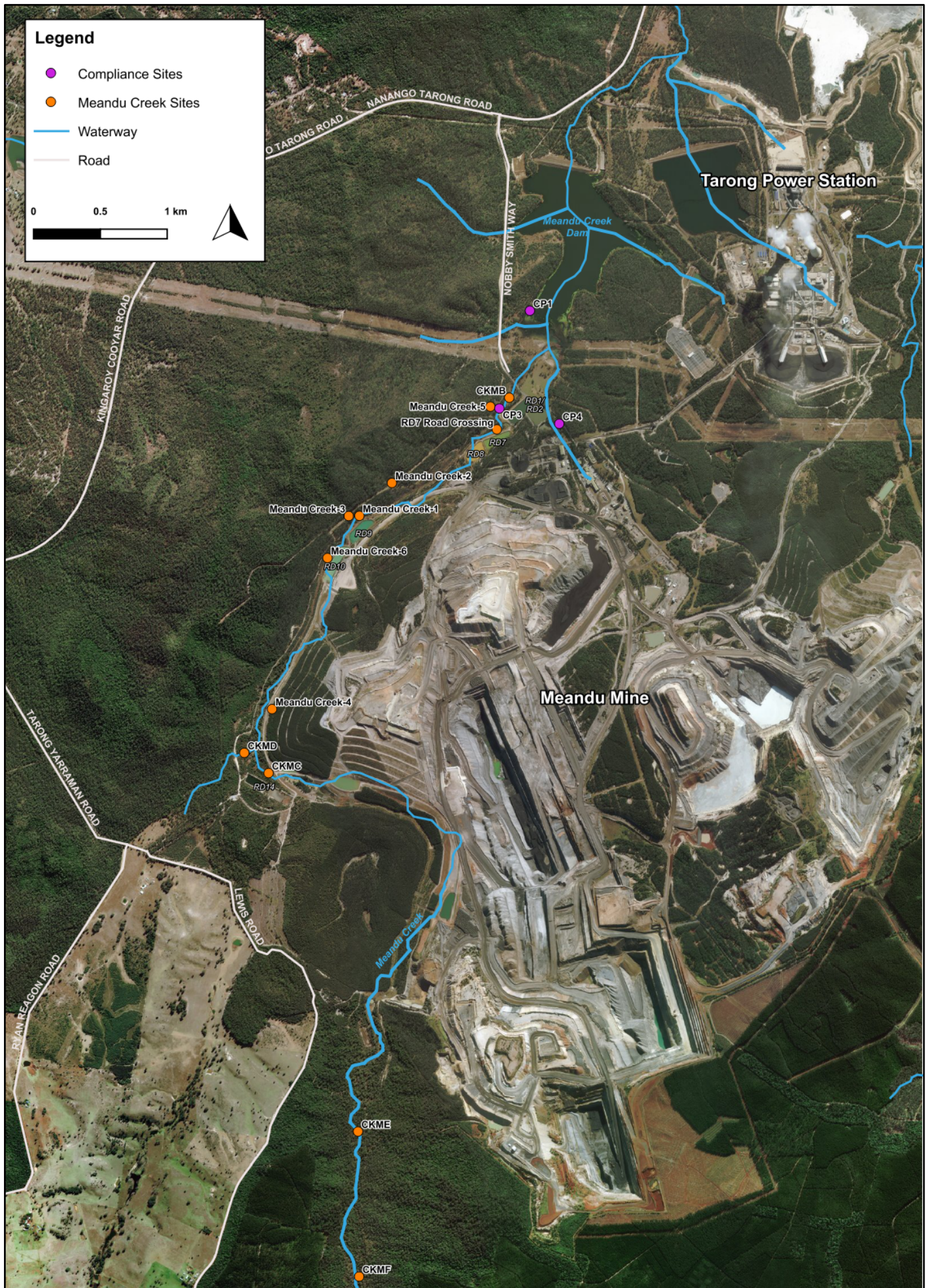


Figure 2.1 Approximate location of historical water quality monitoring sites

2.1.3.2 Meandu Creek Downstream of Meandu Creek Dam

Surface water quality monitoring has been undertaken by operators of the Tarong power stations (i.e. Stanwell and previously Tarong Energy) at the Meandu Creek Dam release point (site W3) since 1985; and in Meandu Creek downstream of the dam at sites W2 and SW16 since 1984 and 1998, respectively. Water quality is monitored regularly in accordance with the Meandu Creek Monitoring Protocol (Stanwell 2016), which was recently updated to the Meandu Creek Receiving Environment Monitoring Program (ESP 2018). The site locations are shown in Table 2.2 and Figure 2.2. Summary statistics were calculated for all available data for each of these sites, as well as for the past 4 years only (2013–2017) (i.e. since the potential AMD was identified). The results for Meandu Creek downstream of Meandu Creek Dam (sites W2 and SW16) were compared with the relevant water quality objectives (WQOs), as outlined in Section 3.3.

Data for key parameters (i.e. those that are relevant to AMD such as pH, electrical conductivity, the concentrations of ions (e.g. sulfate) and the concentrations of dissolved metals) were also graphed for interpretation of trends over time.

A one-off survey of water quality at five sites in Meandu Creek Dam (near the centre of the dam and in the vicinity of the dam wall) was completed in December 2016 (ESP 2016). Samples were collected from within 0.5–1.0 m of the bottom of the dam (i.e. the samples were representative of bottom waters). These results were compared with the historical water quality results.

2.1.4 Review of Previous Aquatic Ecology Studies

The results of previous monitoring and other studies completed in Meandu Creek were reviewed based on reports provided by Stanwell. Data available for the following ecological parameters was reviewed and summarised:

- sediment quality
- aquatic macroinvertebrates, and
- freshwater fish.



2.2 Field Survey

2.2.1 Timing and Sites

A field survey was completed from 23 to 29 March 2017. There were some light showers immediately prior to and at the beginning of the field survey (8 mm of rainfall was recorded at BOM station 40199 from 22 to 25 March); however, weather conditions were mostly fine for the duration of the survey.

Aquatic ecology surveys were completed at 33 sites distributed throughout the region. The locations of the sites are described in Table 2.2 and shown on Figure 2.2, and are described further below.

An additional sediment quality survey was also completed from 11 to 14 April 2018, to assess within-site variation and the bioavailability of metals in the sediment. Samples were collected from a sub-set of sites sampled in March 2017 (Table 2.2). No rain was recorded for one month prior to the survey (0 mm of rainfall was recorded at BOM station 40199 from 11 March to 11 April) and weather conditions were fine for the duration of the survey.

2.2.1.1 Sites on Meandu Creek Upstream of Meandu Mine

Two (2) upstream sites on Meandu Creek at varying distances upstream of mining operations were selected based on sites previously sampled as part of the Meandu Creek Monitoring Protocol (Stanwell 2016). These upper reaches of Meandu Creek are a stream order 2, with poorly defined channels that are naturally ephemeral (i.e. they convey runoff after rainfall, but water rarely pools). The two selected sites were dry during the survey. Due to the characteristics of Meandu Creek upstream of mining operations (i.e. dry) the upstream sites provided little context for the results of surveys within other reaches of Meandu Creek. Additionally, due to the varying characteristics between the sections of Meandu Creek (i.e. the 'intermittent' section upstream of Meandu Creek Dam verses the 'perennial' section downstream of Meandu Creek Dam), it was necessary to include a variety of comparative sites to allow an assessment of the results at potentially impacted sites in the context of conditions at sites within the region that are not influenced by water released from Meandu Mine or the Tarong power stations (Table 2.2, Figure 2.2).

2.2.1.2 Comparative Sites

Five (5) comparative sites were surveyed. Three of these were selected based on sites previously sampled on Barker Creek as part of the Meandu Creek Monitoring Protocol (Stanwell 2016). While Barker Creek is a similar stream order to Meandu Creek, it is an intermittent creek generally characterised by disconnected pools with a substantial number of dry reaches. It was identified that these sites were suitable for comparison with the results from the intermittent reaches of Meandu Creek upstream of Meandu Creek Dam. However, two of the three sites were dry and could not be used for full aquatic surveys. As a result, a fourth additional site on Barker Creek nearby to (but disconnected from) an already established site (site C1) was also added (site C1B) to provide additional comparative data (Table 2.2, Figure 2.2).

A fifth comparative site was also adopted (site SW36). Although technically downstream of Meandu Mine, site SW36 on Barambah Creek (downstream of Bjelke-Petersen Dam) was considered a good option for a comparative site for the receiving environment sites in Meandu Creek (i.e. sites downstream of the Meandu Creek Dam), based on shared habitat characteristics (i.e. site SW36 is located on a perennial waterway downstream of a dam, with a similar flow regime and aquatic habitat). It is located approximately 100 km downstream of the Meandu Creek Dam discharge point, and has been considered a comparative site in previous aquatic environmental studies for the Tarong power stations (EMPS 2013) (Figure 2.2).

2.2.1.3 Sites on Meandu Creek Upstream of Meandu Creek Dam (adjacent to Meandu Mine)

Four (4) sites on Meandu Creek upstream of Meandu Creek Dam and adjacent to Meandu Mine were selected based on sites currently monitored by the mine as part of their standard monitoring protocol. The section of Meandu Creek running upstream of Meandu Creek Dam adjacent to Meandu Mine is in the upper reaches of the catchment, and has been diverted in several places. This section of the creek exhibits characteristics of a typical intermittent waterway with several disjointed, non-flowing pools along the channel. The selected sites included both natural sections of the creek and diverted sections of the creek, where there are semi-permanent pools of water that are periodically pumped out, currently into RD7, for water management (Table 2.2, Figure 2.2).

2.2.1.4 Black Creek Sites

Two (2) sites on Black Creek were included in the survey, to gain an understanding of the current water and sediment quality conditions of Black Creek, and to identify any additional influences that may be impacting the aquatic ecosystems in the Meandu Creek receiving environment. Sites were selected on Black Creek at Black Creek Dam, and at the most downstream section of Black Creek before the confluence with Meandu Creek (Table 2.2, Figure 2.2).

2.2.1.5 Meandu Creek Dam Sites

Thirteen (13) sites on Meandu Creek Dam were surveyed. These sites are established monitoring sites under the Meandu Creek REMP (ESP 2018), and are located at various points around the dam that capture runoff from various sources including Meandu Mine and the Tarong power stations (Table 2.2, Figure 2.2).

2.2.1.6 Sites on Meandu Creek Downstream of Meandu Creek Dam

Seven (7) sites on Meandu Creek and Barker Creek (downstream of the confluence with Meandu Creek) were selected based on sites previously sampled as part of the Meandu Creek Monitoring Protocol. The seven selected sites ranged in distance from 500 m downstream of the Meandu Creek Dam discharge location (W3), to 25 km downstream. Sites were closer together nearer to the discharge location, to assist in determining the spatial extent of any impacts associated with releases from the dam (Table 2.2, Figure 2.2).

As a result of releases from Meandu Creek Dam, this reach experiences long periods of continual flow, making it more characteristic of a perennial waterway as opposed to ephemeral or intermittent waterways, which are typical in the region.

2.2.2 Indicators

The following aquatic indicators were selected to be included in this investigation as potential indicators of AMD impacts to aquatic ecosystems:

- water quality
- sediment quality
- aquatic habitat
- aquatic plants
- macroinvertebrate communities, and
- fish.

Not all indicators were surveyed at each site, depending on the aquatic habitat present and available data from other studies e.g. routine water quality monitoring completed under the Meandu Creek REMP (ESP 2018), and fish surveys completed in Meandu Creek Dam in December 2016 and December 2017. The indicators surveyed at each site are shown in Table 2.2.

Table 2.2 Survey sites and indicators surveyed at each site

Location	Site	Latitude	Longitude	Water Quality	Sediment Quality		Habitat Assessment	Macro-invertebrates	Aquatic Plants	Fish
					March 2017	April 2018				
Comparative Sites										
Barker Creek	C1	-26.736724°	151.815103°	Y	Y	Y	Y	Y	Y	Y
Barker Creek	C1B	-26.736555°	151.818892°	Y	Y	N	Y	Y	Y	Y
Barker Creek	C2/SW19	-26.692762°	151.888744°	–	Y	N	Y	–	–	–
Barker Creek	C3	-26.662700°	151.903900°	–	Y	N	Y	–	–	–
Barambah Creek	SW36	-26.282367°	151.948231°	Y	Y	Y	Y	Y	Y	Y
Meandu Creek upstream of Mine										
Meandu Creek	MCUS1	-26.846744°	151.880330°	–	Y	Y	Y	–	–	–
Meandu Creek	MCUS2	-26.838946°	151.881531°	–	Y	Y	Y	–	–	–
Meandu Creek upstream of Meandu Creek Dam (adjacent to Mine)										
Meandu Creek Diverted Reach	MCA1/MC6	-26.800733°	151.879360°	Y	Y	Y	Y	Y	Y	Y
Meandu Creek Diverted Reach	MCA2/MC1	-26.799459°	151.880654°	Y	Y	Y	Y	Y	N	N
Meandu Creek Diverted Reach	MCA3/MC5	-26.792420°	151.890616°	Y	Y	Y	Y	Y	Y	Y
Meandu Creek Diverted Reach	CM2	-26.787198°	151.895296°	Y	Y	Y	Y	Y	N	N
Black Creek Sites										
Black Creek	BC1	-26.777153°	151.924883°	Y	Y	N	Y	N	N	N



Location	Site	Latitude	Longitude	Water Quality	Sediment Quality		Habitat Assessment	Macro-invertebrates	Aquatic Plants	Fish
					March 2017	April 2018				
Black Creek	BC2	-26.767687°	151.906181°	Y	Y	N	Y	N	N	N
Meandu Creek Dam Sites										
Meandu Creek Dam	MCDS1	-26.786492°	151.897305°	N	Y	N	Y	N	N	N
Meandu Creek Dam	MCDS2	-26.784770°	151.896517°	N	Y	Y	Y	N	N	N
Meandu Creek Dam	MCDS3	-26.780493°	151.903700°	N	Y	Y	Y	N	N	N
Meandu Creek Dam	MCDS4	-26.778604°	151.893056°	N	Y	Y	Y	N	N	N
Meandu Creek Dam	MCDS5	-26.778129°	151.901610°	N	Y	Y	Y	N	N	N
Meandu Creek Dam	MCDS6	-26.776377°	151.896799°	N	Y	N	Y	N	N	N
Meandu Creek Dam	MCDS7	-26.779361°	151.897474°	N	Y	N	Y	N	N	N
Meandu Creek Dam	MCDS8	-26.779574°	151.901596°	N	Y	N	Y	N	N	N
Meandu Creek Dam	MCDS9	-26.778344°	151.894366°	N	Y	N	Y	N	N	N
Meandu Creek Dam	MCD1	-26.786492°	151.897305°	N	N	N	Y	Y	N	N
Meandu Creek Dam	MCD2	-26.784770°	151.896517°	N	N	N	Y	Y	N	N
Meandu Creek Dam	SWI1	-26.780996°	151.904600°	N	N	N	Y	Y	N	N
Meandu Creek Dam	SWI2	-26.779099°	151.903301°	N	N	N	Y	Y	N	N
Meandu Creek downstream of Meandu Creek Dam										
Meandu Creek Discharge Point	MCDOUT	-26.772352°	151.897394°	Y	Y	Y	Y	Y	N	N



Location	Site	Latitude	Longitude	Water Quality	Sediment Quality		Habitat Assessment	Macro-invertebrates	Aquatic Plants	Fish
					March 2017	April 2018				
Meandu Creek	MC500	-26.769601°	151.899701°	Y	Y	Y	Y	Y	Y	Y
Meandu Creek	MC2	-26.761000°	151.904700°	Y	Y	N	Y	Y	N	N
Meandu Creek	MC5/W2	-26.746354°	151.910242°	Y	Y	Y	Y	Y	Y	Y
Meandu Creek	MC15	-26.693999°	151.912298°	Y	Y	N	Y	Y	Y	Y
Meandu Creek	MC20/SW16	-26.647803°	151.948303°	Y	Y	Y	Y	Y	Y	Y
Meandu Creek	MC25	-26.645062°	151.984436°	Y	Y	N	Y	Y	Y	Y
Bjelke-Peterson Dam Sites										
Bjelke-Peterson Dam	BPD1	-26.342653°	152.022252°	N	N	Y	N	N	N	N
Bjelke-Peterson Dam	BPD2	-26.329795	151.989721	N	N	Y	N	N	N	N

Y indicates parameter sampled at this site

N indicates parameter not planned for survey at this site

– indicates parameter unable to be sampled due to dry site



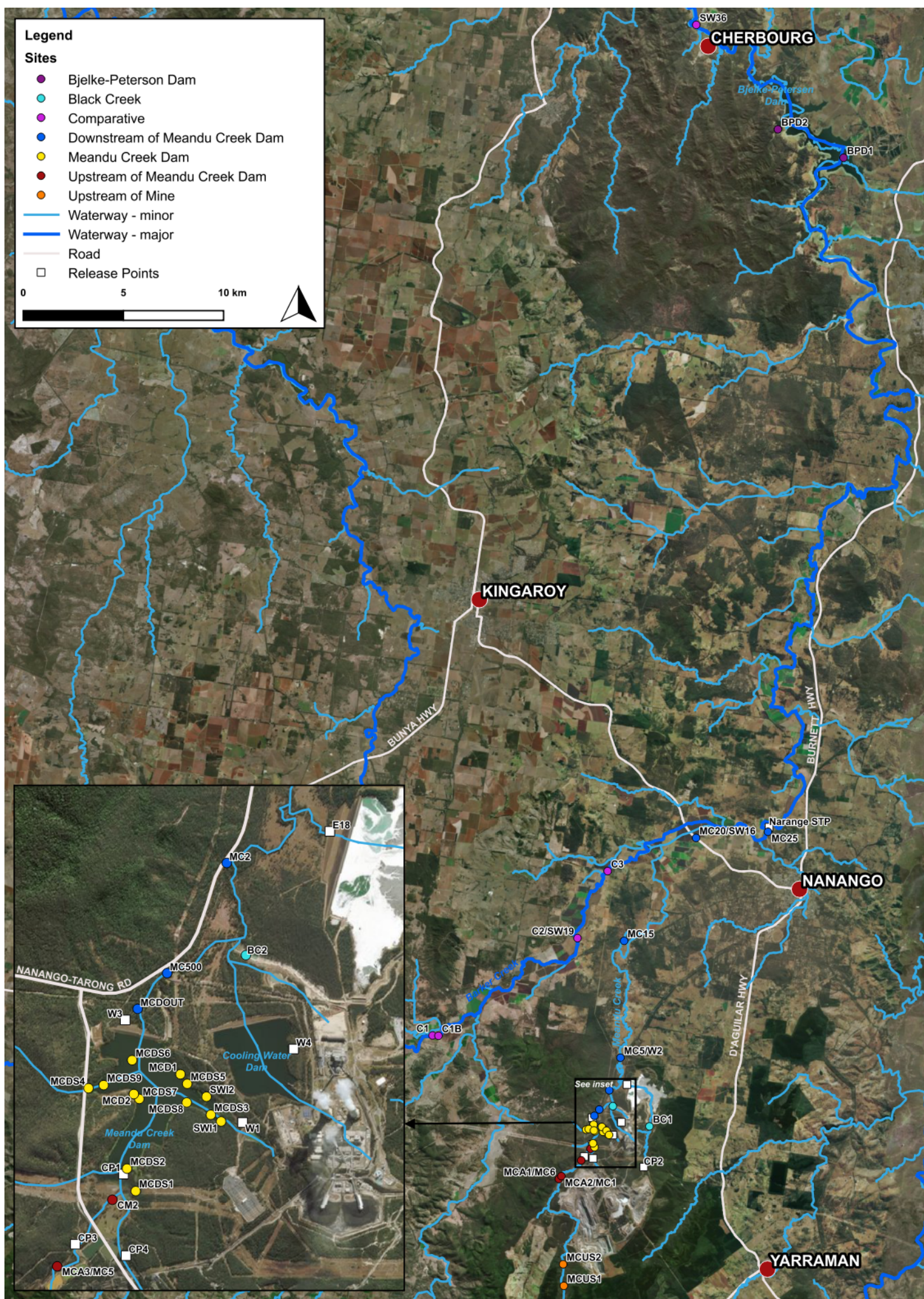


Figure 2.2 Waterway sites sampled during the field surveys

2.2.3 Water Quality

At each site that held sufficient water, physicochemical water quality was measured in situ using a SmarTroll multiparameter hand-held water quality meter. The following parameters were recorded:

- temperature (°C)
- conductivity (µS/cm)
- pH (pH units), and
- dissolved oxygen (% saturation).

Turbidity (NTU) was also measured at each site using a Hach 2100Q portable turbidity meter.

In addition to physical water quality profiles, grab samples were collected at each site from 30 cm below the surface. All water quality sampling was undertaken in accordance with the *Monitoring and Sampling Manual* (DEHP 2013), and the most current versions of other appropriate Australian Standards. All samples were held under the appropriate storage conditions and delivered to ALS Environmental (a NATA-accredited laboratory) within the required holding times for analysis of:

- total dissolved solids (TDS)
- fluoride
- nutrients (total nitrogen, total phosphorus, oxides of nitrogen⁴)
- total hardness
- major cations (calcium, magnesium, sodium, potassium)
- major anions (chloride, sulfate, alkalinity (hydroxide, carbonate, bicarbonate, total alkalinity)); and
- total and dissolved metals and metalloids (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, lead, iron, manganese, mercury, molybdenum, nickel, selenium, vanadium, and zinc).

A Chain of Custody and Certificate of Analysis for water quality samples are provided in Attachment A.

The water quality results from physicochemical in situ measurements and grab samples were reviewed. All parameters that were below or equal to the LOR at all sites were considered low risk and not considered further. Where results for parameters were above the LOR, the results were compared to the relevant WQOs (Section 3.3), graphed and spatial trends were assessed.

⁴ Nitrate and nitrite could not be analysed separately for logistical reasons related to short holding times



2.2.3.1 Quality Assurance / Quality Control

Quality assurance / quality control (QA/QC) measures for water quality sampling and analyses were in accordance with the *Monitoring and Sampling Manual* (DEHP 2013), and the most current versions of other appropriate Australian Standards. This included the use of powder-free nitrile gloves, which were worn during sample container handling, to reduce the risk of sample contamination during collection.

A duplicate field sample (i.e. sample split into two) and field method blank were collected from one site during the survey, to determine the variability in results associated with field sampling. An acceptable level of variation between the sample and the field duplicate according to the relevant guidelines was less than 20%, where the values were more than five to ten times the laboratory limit of reporting (DEHP 2013).

The SmarTroll Multiparameter hand-held water quality meter and Hach turbidity meter were calibrated prior to field sampling.

2.2.4 Sediment Quality

2.2.4.1 March 2017 Survey

At each site, a single sediment sample was collected from within low-flow stream banks using either a small trowel (for sites on creeks) or a benthic grab sampler operated from a vessel (for sites on Meandu Creek Dam).

Samples were held under the appropriate storage conditions until they were delivered to ALS Environmental (a NATA-accredited laboratory) for analysis of total metals and metalloids (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, lead, iron, manganese, mercury, molybdenum, nickel, selenium, vanadium, and zinc).

As Meandu Creek Dam is a relatively homogeneous environment, all sites on the dam were considered to be representative of sediment quality in the dam (i.e. there was little variation in results for each parameter among sites). To aid in the interpretation of results, median concentrations of each parameter were calculated for the dam and compared to guidelines and the results from other sites.

The sediment quality results were reviewed and compared with the relevant Sediment Quality Guideline Values (SQGVs) outlined in the *Revision of the Sediment Quality Guidelines* (Simpson et al. 2013; Table 2.3). All parameters that were below or equal to the SQGV (where available) at all sites, or showed no apparent difference between locations were considered low risk and not considered further. Where results for parameters were above the SQGV at one or more sites, or showed a difference between locations, the results were graphed and spatial trends assessed.

2.2.4.2 April 2018 Survey

At each site, three replicate single sediment samples were collected from within low-flow stream banks using either a small trowel (for sites on creeks) or a benthic grab sampler operated from a vessel (for sites on Meandu Creek Dam and Bjelke-Peterson Dam).



Samples were held under the appropriate storage conditions until they were delivered to ALS Environmental (a NATA-accredited laboratory) for analysis of:

- total metals and metalloids (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, lead, iron, manganese, mercury, molybdenum, nickel, selenium, vanadium, and zinc)
- dilute acid extractable metals and metalloids (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, vanadium, and zinc)
- simultaneously extracted metals (cadmium, copper, nickel, lead, and zinc)
- acid volatile sulfides
- total organic carbon, and
- particle size distribution.

The sediment quality results were reviewed, and total metals and metalloids that were below or equal to the SQGV at all sites were considered low risk and not considered further. Where results were above the SQGV, mean concentrations ($\pm$ standard error) of total metals and metalloids were calculated, graphed and compared to the March 2017 results, and the relevant SQGVs (Simpson et al. 2013; Table 2.3). In addition, 95th percentile values were also calculated and compared to the relevant SQGVs.

Where concentrations of total metals or metalloids exceeded the SQGV, or showed a spatial trends (e.g. decreasing concentration with distance from the dam), mean concentrations of acid dilute extractable metals (considered to represent the potential bioavailable concentration of a metal) were graphed and compared to the SQGVs. In addition, 95th percentile concentrations of acid dilute extractable metals were also calculated and compared to the SQGVs. Where the 95th percentile concentrations of dilute acid extractable metals or metalloids were below the SQGV, it was considered to be of low risk. Where the maximum concentrations of dilute extractable metals or metalloids were above the SQGV, the bioavailability was further investigated in accordance with the *Revision of the Sediment Quality Guidelines* (Simpson et al. 2013).

To further determine the bioavailability of metals and metalloids, the sum of the molar mass concentrations of simultaneously extracted cadmium, copper, nickel, lead and zinc was divided by the concentration of acid volatile sulfides at each site. Where sediments contained a molar excess of acid volatile sulfides over simultaneously extracted metals, it was predicted that pore-water concentrations of metals would be negligible and should not cause direct toxicity to benthic organisms (Simpson & Batley 2016). Particle size distribution and total organic carbon results were also used to inform the interpretation of the metals results.



Table 2.3 Sediment quality parameters measured at sites during the field survey and relevant trigger values

Parameter	Unit	SQGV ^A	SQG - High ^A
Metals and Metalloids			
Aluminium	mg/kg	–	–
Arsenic	mg/kg	20	70
Boron	mg/kg	–	–
Cadmium	mg/kg	1.5	10.0
Chromium	mg/kg	80	370
Cobalt	mg/kg	–	–
Copper	mg/kg	65	270
Iron	mg/kg	–	–
Lead	mg/kg	50	220
Manganese	mg/kg	–	–
Mercury	mg/kg	0.15	1.00
Molybdenum	mg/kg	–	–
Nickel	mg/kg	21	52
Selenium	mg/kg	–	–
Vanadium	mg/kg	–	–
Zinc	mg/kg	200	410

– no SQG exists for this parameter

^A Source: Simpson et al. 2013

2.2.4.3 Quality Assurance / Quality Control

Strict QA/QC protocols were adhered to throughout each stage of sampling, in accordance with the *Monitoring and Sampling Manual* (DEHP 2013). Powder-free nitrile gloves were worn during sample container handling, to reduce the risk of sample contamination during collection. Samples were transferred into suitable glass jars, held under the appropriate conditions (e.g. in eskies on ice in the field and during transport; refrigerated at other times) and delivered to ALS Environmental (a NATA-accredited laboratory) within the required holding times.



In March 2017, one field replicate sample was collected from one site and analysed for the parameters listed above to determine any small-scale (i.e. within-site) variation; in April 2018, three replicate samples were collected from each site. An acceptable level of variation between the sample and the field replicate was less than 50% where results were more than 10 times the limit of reporting, as per the guidelines outlined in the *Queensland Monitoring and Sampling Manual* (DEHP 2013).

A Chain of Custody and Certificate of Analysis for sediment quality samples are provided in Attachment B.

2.2.5 Aquatic Habitat

At each site, habitat observations were made based on the Australian River Assessment System (AUSRIVAS) habitat assessment protocol, modified where required to suit the purposes of this study. Observations for aquatic habitat value included:

- features of the water body, including bank height, estimate of flow, estimated width and depth of any standing water present
- details of the riparian zone (e.g. width, canopy height, species present) and adjacent land use
- details of surrounding land use and disturbance, and how it may be impacting on aquatic habitat and communities
- aquatic habitat types present and their relative percent cover within the reach
- details of the sediment types present (e.g. relative percent cover of different grain sizes, presence of anoxic sediments)
- details regarding any evidence of AMD and associated impacts (if present) on aquatic ecosystems, including visual indicators such as:
 - orange or white precipitates coating rocks and sediment
 - algal filaments throughout the beds of the channels
 - any visual signs of poor health in aquatic vegetation, and
- overall habitat condition and value.

Habitat assessments were completed on an electronic template to a field tablet, to improve efficiency in data entry and to avoid transcription errors. Georeferenced photographs of the reach and key habitat features were also taken at each site.

2.2.6 Aquatic Plants

Aquatic plant communities at each site were assessed along a single 100 x 10 m belt transect that extended along one bank and the adjacent channel bed. The following were assessed visually and recorded in each 10 m section:

- taxonomic richness
- growth form of each species (e.g. emergent, submerged, floating, etc.)



- total percent cover of each species
- whether the species was native or exotic.

The total taxonomic richness and percent cover were then calculated for each site.

2.2.7 Aquatic Macroinvertebrates

At each site, five replicate macroinvertebrate samples were collected from a 30 cm x 30 cm area within each habitat type (edge, bed and riffle where present, i.e. riffle only present at downstream sites MCDOUT and MC5/W2) using a standard triangular AUSRIVAS dip net. Samples were transferred into labelled sample jars, preserved in a 70% ethanol solution and transported to ESP's laboratory for processing.

Once at the laboratory, individual samples were logged into a register for tracking, as per ESP's laboratory quality procedure. The first 100 individuals of each macroinvertebrate taxa were picked from each sample; where over 100 individuals from a particular taxa were present in a sample, the number of individuals remaining in the picking tray was estimated.

Macroinvertebrates were then identified to the lowest practical taxonomic level (i.e. family level for most taxonomic groups, sub-family for Chironomids and higher level for worms, mites and microcrustaceans), and counted, to comply with standard AUSRIVAS methodology. Identification of macroinvertebrates was completed by Susan Jones of Stream Macroinvertebrate Identifications, who has over 10 years experience in freshwater macroinvertebrate identification and is AUSRIVAS-accredited.

Appropriate QA/QC checks were completed in accordance with the recommendations in the AUSRIVAS manual and / or *Monitoring and Sampling Manual* (DEHP 2013). A second ecologist checked approximately 80% of picked samples, and at least 5% of samples were re-identified and counted by a second ecologist. An error rate of <10% was considered acceptable, as per the Laboratory Identification QA/QC guidelines outlined in the *Queensland AUSRIVAS Sampling and Processing Manual* (DNRM 2001) and *Monitoring and Sampling Manual* (DEHP 2013).

2.2.7.1 Data Analysis

2.2.7.2 Macroinvertebrate Indices

Standard macroinvertebrate indices were calculated for each replicate sample, including taxonomic richness, abundance, and the presence of sensitive taxa through calculation of Plecoptera / Ephemeroptera / Trichoptera (PET) richness and SIGNAL 2 scores (Chessman 2003), as described below.

Differences in each index between comparative sites, sites on Meandu Creek upstream of Meandu Creek Dam, dam sites (edge habitat only) and sites on Meandu Creek downstream of Meandu Creek Dam were analysed using permutational analysis of variance (PERMANOVA) in PRIMER with the following two factors: Locations (comparative, Meandu Creek upstream of Meandu Creek Dam, dam and Meandu Creek downstream of Meandu Creek Dam) and Site (nested in Location) (Anderson et al. 2008). The data were converted to a Euclidian distance similarity matrix prior to testing. The results for each habitat were



analysed separately, although riffle habitat was excluded from the analysis, as it was only present at two sites. A 95% confidence level was used to determine significance (i.e. results were considered to be significant at $p < 0.05$). The results were displayed on graphs to aid in interpretation.

Abundance

Abundance of macroinvertebrates is the total number of animals at each site.

Taxonomic Richness

Taxonomic richness is a count of the number of different macroinvertebrate taxa present at each site. Taxonomic richness does not take into account the relative abundance of each taxon, so rare and common taxa are considered equally.

PET Richness

PET richness indicates the number of macroinvertebrate taxa at a site that belong to the orders Plecoptera, Ephemeroptera and Trichoptera (i.e. PET taxa). These taxa are considered to be particularly sensitive to changes in their environment, and are therefore good indicators of habitat degradation and water quality. Low PET scores generally indicate poor habitat condition, and high PET scores generally indicate good habitat condition. However, PET taxa are often naturally rare in ephemeral Queensland rivers and creeks (preferring clear, fast-flowing streams), therefore low PET richness is not necessarily indicative of anthropogenic impacts.

SIGNAL 2 Score

Stream Invertebrate Grade Number – Average Level (SIGNAL) 2 scores of macroinvertebrates are based on the sensitivity of each macroinvertebrate taxa to pollution or habitat degradation. A sensitivity grade number is allocated to each different macroinvertebrate taxa based on their sensitivity to various pollutants, and this number is weighted for abundance (so that the relative abundance of tolerant or sensitive taxa can be considered, and not just the presence / absence of taxa). A low SIGNAL score indicates that taxa are tolerant to a range of environmental conditions and a high score indicates that taxa are more sensitive to such conditions.

2.2.7.3 Assemblage Composition

Multivariate statistics were completed in PRIMER to compare macroinvertebrate assemblage composition between locations. The data for all samples were converted to a Bray Curtis similarity matrix prior to testing. Differences in assemblage composition between comparative sites, sites on Meandu Creek upstream of Meandu Creek Dam, dam sites (edge habitat only) and sites on Meandu Creek downstream of Meandu Creek Dam were analysed using PERMANOVA with the following two factors: Locations (comparative, Meandu Creek upstream of Meandu Creek Dam, dam and Meandu Creek downstream of Meandu Creek Dam), and Site (nested in Location) (in line with Anderson et al. 2008). The results for each habitat were analysed separately, although riffle habitat was excluded from the analysis, as it



was only present at two sites. A 95% confidence level was used to determine significance (i.e. results were considered to be significant at $p < 0.05$).

Differences in the multivariate dispersion (essentially a measure of variance among the samples) were compared among the locations using the Permutational Dispersion (PERMDISP) routine (Anderson 2004). Differences in the composition of macroinvertebrate assemblages were visualised using non-metric Multi-Dimensional Scaling ordinations (nMDS), using averaged site data for clarity (Clarke & Warwick 2001). The taxa contributing to any differences among locations were identified using the Similarity Percentages (SIMPER) routine (Clarke & Warwick 2001).

2.2.7.4 Correlation with Environmental Variables

The BIOENV routine (Clarke & Warwick 2001) was used to correlate the macroinvertebrate assemblage composition to the results for those water quality and sediment quality parameters that could indicate a potential impact from AMD or other site-related impacts, to determine whether there were significant correlations between the two (which may indicate an effect on macroinvertebrate assemblage composition as a result of AMD). The parameters included in the analysis were:

- Water quality:
 - water temperature
 - electrical conductivity (total dissolved solids, hardness and most major ions were not included as they were closely correlated with electrical conductivity)
 - potassium
 - oxides of nitrogen
 - total and dissolved arsenic, boron, iron, manganese, molybdenum and nickel
 - total aluminium
- sediment quality: arsenic, cobalt, copper, lead, manganese, molybdenum, nickel and zinc.

Statistical differences were determined using the Pearson's rank correlation coefficient (r).

2.2.7.5 Comparison to Biological WQOs

The QWQGs includes biological WQOs for key macroinvertebrate indices. These WQOs have been derived from samples collected using the standard AUSRIVAS methodology, where a single sample is collected at each site from a 10 m section of the reach, with the aim of collecting as many of the present taxa as possible. While quantitative sampling was completed for this assessment, the results from all five replicates from each habitat at each site were pooled for comparison to the WQOs, to provide an indicative assessment of the overall condition and health of the macroinvertebrate communities.

SIGNAL 2 scores can be interpreted in conjunction with the number of families found in the sample. This is achieved using a SIGNAL 2 / family bi-plot (Chessman 2003). The plots are divided into quadrants, with each quadrant indicative of environmental conditions that may



influence a community (Figure 2.3). Quadrant boundaries for the SIGNAL 2 / Family Bi-plot used for this assessment are based on the upper (80th percentile) WQO values for taxonomic richness and SIGNAL scores.

Table 2.4 Biological WQOs for taxonomic richness, PET richness and Signal scores ^a

Indicator	Composite ^b	Edge
Taxonomic Richness	12 – 21	21 – 33
PET Taxa	2 – 5	2 – 5
Signal Score	3.33 – 3.85	3.31 – 4.20

^a Central coast region biological guidelines from the QWQG, based on the 20th – 80th percentile range recorded at reference sites (DEHP 2013)

^b Mixture of all bed habitats within the site (e.g. sandy pool, rocky pool, riffle, run, cascade)

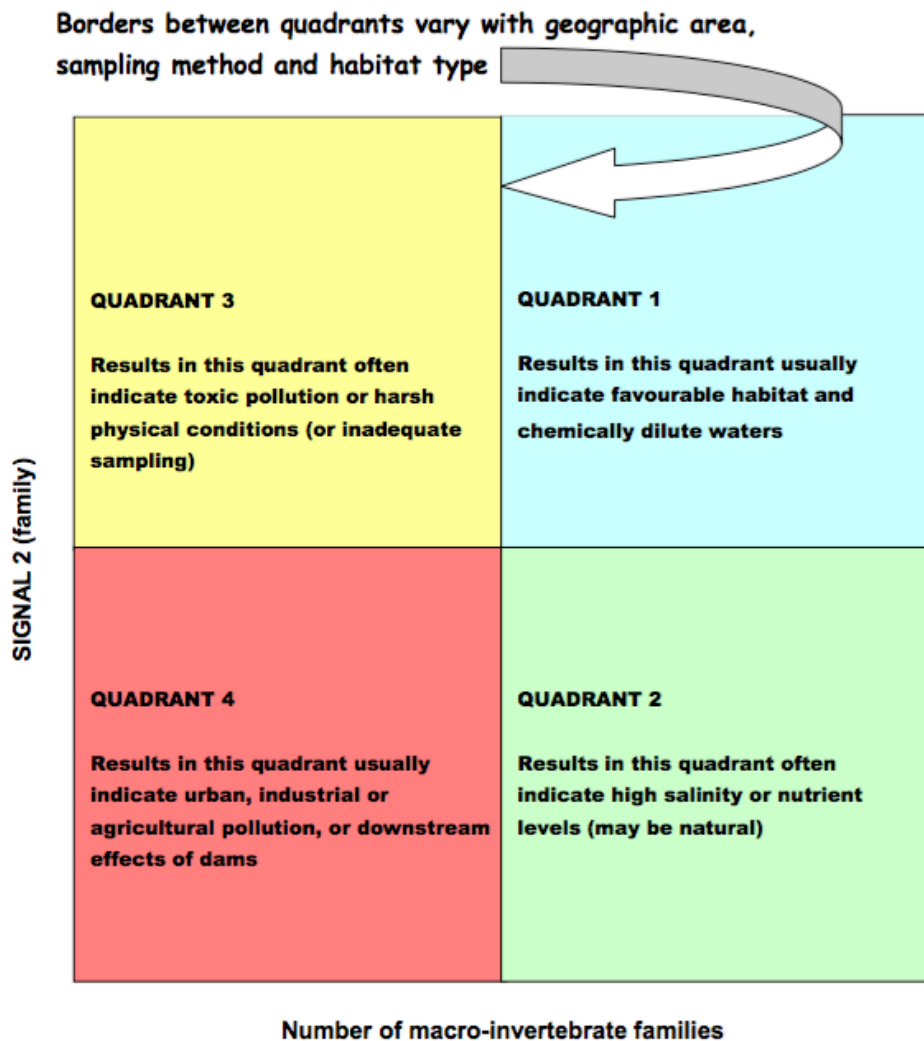


Figure 2.3 Quadrant diagram for SIGNAL2 / Family Bi-plot (Chessman 2003)



2.2.8 Fish

Fish communities at each site were assessed in accordance with the *Monitoring and Sampling Manual 2009* (DEHP 2013), using a combination of methods depending on the habitat characteristics of the site, including fyke nets and baited traps. Fishing effort at each site is summarised in Table 2.5. All native fish caught were identified to a species level, measured, and recorded. All exotic fish caught were identified to a species level, recorded and euthanized as conditioned in General Fisheries Permit No. 173341 issued to ESP.

The abundance of fish species caught at each site was calculated and tabulated. Life history stages of native fish were determined using length measurements (based on information in Pusey et al. 2014), and graphed for each site.

Fishing was completed in accordance with General Fisheries (No. 173341), Scientific Purposes (No. WISP14986614) and Animals Ethics (No. CA 2014/07/794) permits issued to ESP.

Table 2.5 Fishing effort at each site in March 2017

Location	Site	Gear Type	No.	Start	End	Total Hours
Comparative	C1	Box trap	5	15:30, 26/03/17	09:30, 27/03/17	90
		Fyke net	2	15:30, 26/03/17	09:30, 27/03/17	36
	C1B	Box trap	5	15:30, 26/03/17	08:30, 27/03/17	85
		Fyke net	2	15:30, 26/03/17	08:30, 27/03/17	34
	SW36	Box trap	5	15:30, 23/03/17	10:00, 24/03/17	92.5
		Fyke net	2	15:30, 23/03/17	09:00, 24/03/17	35
Meandu Creek upstream of Meandu Creek Dam (adjacent to mine)	MCA1	Box trap	3	15:00, 27/03/17	09:30, 28/03/17	55.5
		Fyke net	1	15:00, 27/03/17	09:30, 28/03/17	18.5
	MCA3	Box trap	3	16:00, 27/03/17	10:30, 28/03/17	55.5
		Fyke net	2	16:00, 27/03/17	10:30, 28/03/17	37
Meandu Creek downstream of Meandu Creek Dam	MC500	Box trap	5	15:15, 25/03/17	09:30, 26/03/17	91.25
		Fyke net	2	15:15, 25/03/17	09:30, 26/03/17	36.5
	MC5/W2	Box trap	5	16:15, 25/03/17	09:00, 26/03/17	83.75
		Fyke net	2	16:15, 25/03/17	09:00, 26/03/17	33.5
	MC15	Box trap	5	16:00, 24/03/17	09:00, 25/03/17	85
		Fyke net	2	15:45, 24/03/17	09:30, 25/03/17	35.5



Location	Site	Gear Type	No.	Start	End	Total Hours
	MC20	Box trap	5	17:00, 24/03/17	11:30, 25/03/17	92.5
		Fyke net	2	16:40, 24/03/17	10:40, 25/03/17	36
	MC25	Box trap	5	15:00, 23/03/17	13:30, 24/03/17	112.5
		Fyke net	2	15:00, 23/03/17	12:30, 24/03/17	43

2.2.9 Other Aquatic Vertebrates

Other aquatic vertebrates were not specifically targeted for this investigation, but incidental captures or sightings were noted.



3 Environmental Values and Water Quality Objectives

3.1 Environmental Values

The quality of natural waters in Queensland is protected under the *Environmental Protection (Water) Policy 2009* (EPP (Water)). The purpose of the EPP (Water) is to achieve the objectives of the *Environmental Protection Act 1994* in relation to water quality while allowing for ecologically sustainable development. Section 6 of the EPP (Water) lists the categories into which waters can be classified and their associated Environmental Values (EVs). EVs, and the associated water quality objectives (WQOs) required to maintain the identified EVs, are progressively being determined for each water basin in Queensland. As Meandu Creek and other waterways in the vicinity of Meandu Mine and the Tarong power stations (part of the Burnett River Basin) are not yet listed in Schedule 1 of the EPP (Water), the relevant EVs must be assigned from those outlined in Section 6 (2) of the policy, with reference to other relevant sources for the area such as the Burnett Mary Water Quality Improvement Plan (BMRG 2015). The Burnett Mary Water Quality Improvement Plan outlines draft EVs for the Burnett catchment, including Meandu Creek upstream of Meandu Creek Dam; waters of Meandu Creek Dam; and Meandu Creek downstream of Meandu Creek Dam, as described below.

3.1.1 Meandu Creek Upstream of Meandu Creek Dam and Meandu Creek Dam

Meandu Creek Dam and Meandu Creek upstream of the dam has been significantly modified through the creation of the dam and diversions to facilitate mining operations. Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam form part of the overall site water management systems for Meandu Mine and the Tarong power stations. Water is managed to protect the integrity of water quality and aquatic ecosystems in the receiving environment (i.e. Meandu Creek downstream of Meandu Creek Dam). Public access to Meandu Creek Dam and Meandu Creek within the Meandu Mine lease is prohibited.

Although the aquatic ecosystems EV is listed in the Burnett Mary WQIP as applying to waters of Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam, these waters are highly disturbed, and form part of the onsite water management systems for the Meandu Mine and Tarong power stations. Therefore, the aquatic ecosystems EV is not considered to be applicable to this reach.

Based on the above, 'industrial use' is the EV currently applicable to Meandu Creek upstream of Meandu Creek Dam, and the waters of Meandu Creek Dam.

3.1.2 Black Creek and Black Creek Dam

Black Creek has been substantially modified from its natural state through the creation of Black Creek Dam (which receives runoff from Meandu Mine and the Tarong power stations), construction of the Ash Dam and construction of the diversion channel. Similar to Meandu Creek Dam, Black Creek Dam forms part of the overall site water management systems for Meandu Mine and Tarong power stations. Water is managed for industrial use and to protect the integrity of water quality and aquatic ecosystems in Meandu Creek downstream of Meandu Creek Dam. Public access to Black Creek and Black Creek Dam is prohibited.



As such, 'industrial use' is the EV currently applicable to Black Creek and Black Creek Dam.

3.1.3 Meandu Creek Downstream of Meandu Creek Dam

The Burnett Mary Water Quality Improvements Plan (WQIP) identifies the EVs relevant to the major waterways in the catchment, including those within the Burnett River Basin. The following EVs are considered appropriate for Meandu Creek downstream of Meandu Creek Dam (i.e. the receiving environment), based on the WQIP as well as findings from available literature, previous technical reports and the current field survey:

- aquatic ecosystems
- irrigation
- farm supply
- stock watering
- human consumption
- primary recreation
- secondary recreation, and
- industrial use.

While drinking water is identified as an EV for Barker Creek (from Nanango Weir to the Bjelke-Peterson Dam storage) and Barambah Creek in the Burnett Mary WQIP, it is highly unlikely that water from Meandu Creek is used for human consumption. While Nanango Weir and Bjelke-Petersen Dam are downstream of Meandu Creek, they are unlikely to be influenced by discharges from Meandu Creek Dam given that long distance downstream (>100 km) and dilution from other water sources in the catchment.

3.2 Aquatic Ecosystem Condition and Level of Protection

For waters ascribed the 'aquatic ecosystems' EV, the EPP (Water) categorises waterways into four different levels of aquatic ecosystem condition. A level of protection is ascribed to each category (summarised in Table 3.1), which informs the management goals and WQOs for the associated water resource.



Table 3.1 Definitions of aquatic ecosystem condition, and their associated management intent

Ecosystem Condition	Definition	Management Intent
Level 1 Highly ecological value (HEV) ecosystems	Ecosystems in which the biological integrity of the water is effectively unmodified or highly valued.	No change from the natural condition (i.e. the measures for the indicators for all environmental values are maintained).
Level 2 Slightly disturbed (SD) ecosystems ^A	Ecosystems that have the biological integrity of high ecological value waters with slightly modified physical or chemical indicators but effectively unmodified biological indicators.	The measures for the slightly modified physical or chemical indicators are progressively improved to achieve the WQOs for high ecological value water.
Level 3 Moderately disturbed (MD) ecosystems ^A	Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity.	To achieve specified WQOs, such that: - if the measures for indicators of the environmental values achieve the WQOs for the water—the measures for the indicators are maintained at levels that achieve the WQOs for the water; or - if the measures for indicators of the environmental values do not achieve the WQOs for the water—the measures for indicators of the environmental values are improved to achieve the WQOs for the water.
Level 4 Highly disturbed (HD) ecosystems	Ecosystems that are significantly degraded by human activity and have lower ecological value than high ecological value waters or slightly or moderately disturbed waters.	The measures for the indicators of all environmental values are progressively improved to achieve the WQOs for the water.

Source: EPP (Water) (DEHP 2010)

^A The QWQG (DEHP 2013) and the AWQG (ANZECC & ARMCANZ 2000a) do not distinguish between slightly and moderately disturbed systems; see below

The Queensland Water Quality Guidelines (QWQG; DEHP 2013), consistent with the approach outlined in the Australian Water Quality Guidelines (AWQG; ANZECC & ARMCANZ 2000a), does not distinguish between slightly disturbed and moderately disturbed systems. Instead, these two categories are combined into a single category, slightly to moderately disturbed (SMD) systems, which are defined as ecosystems in which:

- aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity, and
- the biological communities remain in a healthy condition and ecosystem integrity is largely retained.



Typically, freshwater systems would have slightly to moderately cleared catchments and / or reasonably intact riparian vegetation. Slightly to moderately disturbed systems could include rural streams receiving runoff from land disturbed to varying degrees by grazing or pastoralism (DEHP 2013).

The AWQG encourages the derivation of WQOs based on an understanding of local biological effects (e.g. through direct toxicity assessments – DTA) or local or regional reference site data.

3.2.1 Meandu Creek Upstream of Meandu Creek Dam, Meandu Creek Dam and Black Creek / Black Creek Dam

As described above, the waters of Meandu Creek upstream of Meandu Creek Dam, Meandu Creek Dam and Black Creek Dam (including the Black Creek diversion) are managed for industrial use. While these reaches support aquatic species and communities (refer Sections 6 – 10), there is no specific management intent with respect to aquatic ecosystems under current operations. Rather, the management intent with respect to aquatic ecosystems is to protect the integrity of aquatic ecosystems in the downstream waterways (Meandu Creek downstream of Meandu Creek Dam).

3.2.2 Meandu Creek Downstream of Meandu Creek Dam

There have been several previous assessments of EVs relevant to the Project area; most of these assessments classify the aquatic ecosystems of Meandu Creek as “highly disturbed”, for the following reasons (IMEMS 2011):

- Land use in the upper and lower catchments has been modified by forestry and primary industry activities.
- The upper catchment accommodates Meandu Mine and the Tarong power stations, all with licensed water discharges into Meandu Creek.
- The Meandu Creek Dam, constructed on Meandu Creek, collects catchment stormwater runoff as well as licensed water discharges from the Tarong power stations and Meandu Mine.
- Due to controlled released from Meandu Creek Dam, lower Meandu Creek now experiences long periods of continual flow rather than the original intermittent flow typical of ephemeral streams in the area.
- The majority of water flowing in lower Meandu Creek consists of water discharged from Meandu Creek Dam for much of the year.

Although the flow regime and water quality have been substantially modified due to the construction of the Meandu Creek Dam in 1982 (and subsequent licensed water discharges), it is likely that the aquatic floral and faunal communities inhabiting downstream reaches have adapted to these altered conditions over time. More continuous flows and altered water quality conditions may have changed the composition of these communities; however, results from the current field surveys in March 2017 indicate that aquatic habitats in Meandu Creek are in moderate to good condition and support a diverse assemblage of aquatic flora



and fauna (see Sections 6 to 10 for a detailed discussion of aquatic flora and fauna field survey results).

That is, the aquatic ecosystems of the Meandu Creek downstream of Meandu Creek Dam are not significantly degraded or of a lower ecological value than surrounding waters (as would be the case for highly disturbed waters). Therefore, the system is currently considered to meet the definition of 'moderately disturbed' (i.e. the biological integrity of the water is adversely affected by human activity to a relatively small but measurable degree).

3.3 Water Quality Objectives

Water quality objectives (WQOs) are quantitative measures established to protect the EVs assigned to a particular waterway. Achieving the relevant WQOs ensures that the corresponding EVs and uses of the waterway will be protected.

3.3.1 Meandu Creek Upstream of Meandu Creek Dam, Meandu Creek Dam and Black Creek / Black Creek Dam

The waters of Meandu Creek upstream of Meandu Creek Dam, Meandu Creek Dam and Black Creek / Black Creek Dam form part of the onsite water management systems for the Meandu Mine and Tarong power stations. Currently these waters are managed with the aim of protecting the aquatic values of the downstream waterways of Meandu Creek downstream of Meandu Creek Dam. As such, current compliance limits outlined in the EA's for the mine and Tarong power stations are considered appropriate for management of these waters; published WQOs do not strictly apply while the mine and power stations are operational, but may provide a general guideline against which water quality / aquatic ecosystem health can be compared.

3.3.2 Meandu Creek Downstream of Meandu Creek Dam

In order to assign WQOs to the Meandu Creek downstream of Meandu Creek Dam, current published WQOs for all relevant EVs were compiled based on the following sources:

- The Burnett Mary WQIP, which default to the QWQGs (see below).
- The QWQG (EHP 2013) for physico-chemical parameters and nutrients in central east coast upland waters. These values are designed to protect aquatic ecosystems, and apply to slightly-moderately disturbed systems such as the receiving environment.
- The AWQG (ANZECC & ARMCANZ 2000a) for toxicants to protect aquatic ecosystems; using the trigger values outlined in Table 3.4.1 of the AWQG that are applicable to slightly-moderately disturbed systems.
- The AWQG for values to protect the human consumer, stock watering and farm supply EVs
- The Guidelines for Managing Risks in Recreational Waters (NHMRC 2008) for protection of the primary recreation EV



- The Department of Environment and Science (DES) Model Mining Conditions (ver 6.01, 07/03/17)
- Site specific data, where no other guideline was available or where other guidelines were considered inappropriate.

In most instances, the most stringent WQO for each parameter was considered appropriate to protect all EVs in the receiving environment. However, in some cases (e.g. pH, percent saturation of dissolved oxygen, electrical conductivity and turbidity), less stringent WQOs were adopted given the known ambient water quality conditions in comparative waterways in the wider region, or long-term water quality values in the receiving environment that have been demonstrated to support diverse and healthy aquatic ecosystems (e.g. electrical conductivity). Where parameters were assigned WQOs the Meandu Creek REMP for Tarong and Tarong North power stations, this approach is consistent with the recent review of WQO for this reach (ESP 2018).

Table 3.2 outlines the source of the WQOs for Meandu Creek downstream of Meandu Creek Dam, with highlighted values the proposed WQOs to protect the EVs for Meandu Creek downstream of Meandu Creek Dam.

Note that WQOs for the following EVs have not been included in the assessment:

- Industrial use – no WQOs are provided in the AWQG; although they have been outlined in previous versions of these guidelines, they vary depending on industry (ANZECC & ARMCANZ 2000a).
- Secondary recreation – guidelines generally relate to bacteria, cyanobacteria and algae concentrations, which are not relevant to this assessment.



Table 3.2 Water quality parameters measured at sites during the field survey and relevant published EVs and associated WQOs (with highlighted cells denoting appropriate WQO for protection of all EVs applicable to the receiving environment)

Parameter	Unit	Aquatic Eco-systems ^A	Farm Supply ^B	Stock Watering ^C	Human Consumption ^D	Primary Recreation ^E	Fitzroy Basin Model Water Conditions ^G	Site-specific Data
Physicochemical								
Temperature	°C	–	–	–	–	16 – 34	–	–
Dissolved oxygen	% saturation	90 – 110	–	–	–	>80	–	70 – 110 ^O
pH	pH units	6.5 – 7.5	6.0 – 9.0	–	–	6.5 – 8.5 ^H	6.5 – 9.0	–
Electrical conductivity	µS/cm	1120 ^I	–	–	–	–	1000	2037 ^P
Turbidity	NTU	25	–	–	–	–	–	–
Total dissolved solids	mg/L	–	–	2000	–	–	–	–
Fluoride	µS/cm	–	–	2000	–	–	2000	–
Major Anions								
Chloride	mg/L	–	–	–	–	–	–	–
Sulfate	mg/L	–	–	1000 ^J	–	–	250	–



Parameter	Unit	Aquatic Eco-systems ^A	Farm Supply ^B	Stock Watering ^C	Human Consumption ^D	Primary Recreation ^E	Fitzroy Basin Model Water Conditions ^G	Site-specific Data
Alkalinity	mg/L	–	–	–	–	–	–	–
Major Cations								
Calcium	mg/L	–	–	1000	–	–	–	–
Magnesium	mg/L	–	–	–	–	–	–	–
Sodium	mg/L	–	–	–	–	–	–	–
Potassium	mg/L	–	–	–	–	–	–	–
Nutrients								
Oxides of nitrogen	mg/L	0.015	–	–	–	–	–	–
Total nitrogen	mg/L	0.25	–	–	–	–	–	–
Total phosphorus	mg/L	0.03	–	–	–	–	–	–
Dissolved Metals and Metalloids								
Aluminium	µg/L	55	–	5000	–	–	55	–
Arsenic	µg/L	13 ^K	–	500	–	–	13	–



Parameter	Unit	Aquatic Eco-systems ^A	Farm Supply ^B	Stock Watering ^C	Human Consumption ^D	Primary Recreation ^E	Fitzroy Basin Model Water Conditions ^G	Site-specific Data
Boron	µg/L	370	–	5000	–	–	370	–
Cadmium	µg/L	0.2 ^L	–	10	–	–	0.2	–
Chromium	µg/L	1.0 ^L	–	1000	–	–	1.0	–
Cobalt	µg/L	90 ^N	–	1000	–	–	90	–
Copper	µg/L	1.4 ^L	–	400	1000	–	2.0 ^M	–
Iron	µg/L	300 ^N	–	NA	–	–	300	–
Lead	µg/L	3.4 ^L	–	100	–	–	4.0	–
Manganese	µg/L	1900	–	NA	–	–	1900	–
Mercury	µg/L	0.06	–	2	–	–	0.2 ^L	–
Molybdenum	µg/L	34 ^N	–	150	–	–	34	–
Nickel	µg/L	11 ^L	–	1000	–	–	11	–
Selenium	µg/L	5	–	20	–	–	10 ^M	–
Vanadium	µg/L	–	–	–	–	–	10 ^M	–



Parameter	Unit	Aquatic Eco-systems ^A	Farm Supply ^B	Stock Watering ^C	Human Consumption ^D	Primary Recreation ^E	Fitzroy Basin Model Water Conditions ^G	Site-specific Data
Zinc	µg/L	8 ^L	–	20000	5000	–	8	–

Highlighted cells denote appropriate WQO for protection of all EVs applicable to the receiving environment

– no WQO exists for this parameter

NA parameter is not sufficiently toxic, so no WQO exists

^A Source: WQOs for aquatic ecosystem protection for slightly to moderately disturbed upland streams in the Central Coast region, as outlined in the QWQG (EHP 2013)

^B Source: WQOs for general farm use, as outlined in ANZECC & ARMCANZ (2000a)

^C Source: WQOs for livestock drinking water, as outlined in ANZECC & ARMCANZ (2000a)

^D Source: WQOs for human consumption, as outlined in ANZECC & ARMCANZ (2000a)

^E Source: Guidelines for Managing Risks in Recreational Waters (NHMRC 2008)

^F Source: Meandu Creek Monitoring Protocol (Stanwell 2016)

^G Source: Model water conditions for coal mines in the Fitzroy Basin (EHP)

^H a pH range of 5.0 – 9.0 is considered acceptable in recreational waters with very poor buffering capacity

^I preliminary guideline value for the Southern Divide salinity zone from QWQG (EHP 2013) has been chosen in preference to the Fitzroy Basin Model Condition, as it is specific to the region

^J WQO for stock watering (ANZECC & ARMCANZ 2000a) has been chosen in preference to the Fitzroy Basin Model Condition, as the model condition is based on the Australian Drinking Water Guideline, and drinking water has not been identified as an EV for the study area

^K trigger value for AsV used, as it is the most stringent trigger value available for arsenic outlined in ANZECC & ARMCANZ (2000a)

^L hardness modified trigger value (HMTV) should be applied for these parameters, see Section 3.3.2.1

^M Based on LOR for ICPMS laboratory analysis method (CV FMIS method for mercury)

^N low-reliability trigger value from ANZECC & ARMCANZ (2000a)

^O based on the observed values and trends at the site over 10 years of monitoring data, the relative background DO of other sampling points in the Meandu Creek/Barker Creek catchment and the fact that, even at 70% saturation, the DO does not tend to fall below 6 mg/L.

^P calculated using 80th percentile of data from receiving environment sites W2 and SW16 (2007-2017); historical biological monitoring (using macroinvertebrates as an indicator) has confirmed no adverse impact to biological diversity at these sites.



3.3.2.1 Hardness-Modified Trigger Values

Increasing hardness results in decreased toxicity of some metals. The default trigger values for toxicants outlined in the AWQG are for 'soft' waters (i.e. hardness of 0–59 mg CaCO₃/L). The waters of Meandu Creek have high hardness (Section 4) and are considered 'extremely hard', as median hardness in Meandu Creek typically falls between 300 and 400 mg CaCO₃/L (JBT Consulting 2014).

As such, where the default trigger value is exceeded, hardness-modified trigger values (HMTV) should be applied for the following metals in accordance with Table 3.4.4, Volume 1 of the AWQG (ANZECC & ARMCANZ 2000a):

- cadmium: $\text{HMTV} = \text{TV} (H/30)^{0.89}$
- chromium: $\text{HMTV} = \text{TV} (H/30)^{0.82}$
- copper: $\text{HMTV} = \text{TV} (H/30)^{0.85}$
- lead: $\text{HMTV} = \text{TV} (H/30)^{1.27}$
- nickel: $\text{HMTV} = \text{TV} (H/30)^{0.85}$, and
- zinc: $\text{HMTV} = \text{TV} (H/30)^{0.85}$.



4 Water Quality

4.1 Environmental Conditions

Rainfall and runoff, as well as mine and power station operations, influence water quality in the study area. Water quality downstream of Meandu Creek Dam is also heavily influenced by the quality of water released from the dam (mainly sourced from cooling water) under normal operating conditions.

4.1.1 Rainfall

The long-term yearly average rainfall for the Tarong Rainfall Station is 730.2 mm with a wet-season (November to March) average of 447.6 mm (BOM 2017). Since the higher than average rainfall and flooding in early 2013 associated with ex-tropical cyclone Oswald, the subsequent period (through until June 2017) has experienced below-average rainfall (JBT Consulting 2017). There was a large rainfall event in March 2017 (Figure 4.1), which was associated with rainfall from ex-tropical cyclone Debbie. This event occurred after completion of the March 2017 field survey (i.e. it did not influence these results).

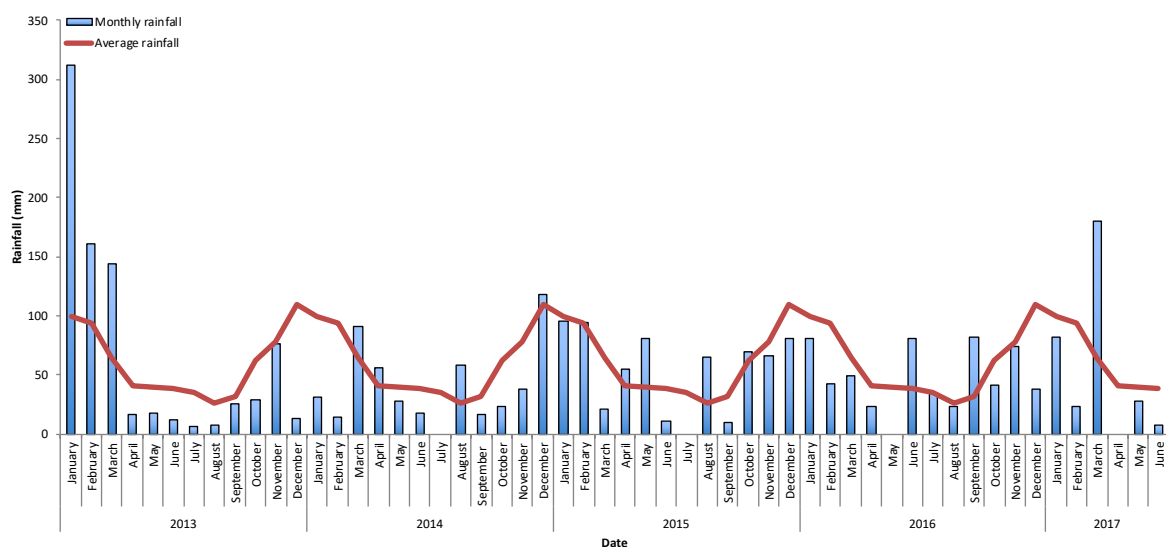


Figure 4.1 Monthly rainfall at the Tarong Rainfall Station compared with the long-term average monthly rainfall

4.1.2 Flows

4.1.2.1 Releases from Meandu Creek Dam

Water releases from Meandu Creek Dam are managed based on dam levels and water levels in the receiving environment. Discharges occur daily during normal operating conditions, only ceasing during maintenance works or during drought conditions. Discharges have historically averaged around 15 to 20 ML/day (JBT Consulting 2014). During large rainfall events, such as those that occurred during the 2010–2011 and 2012–2013 wet



seasons, water also flows over the dam spillway as an uncontrolled release (JBT Consulting 2014).

Releases from Meandu Creek Dam occurred consistently over the four years prior to the March 2017 survey, only ceasing for the installation of a new flow meter at the outlet in August 2015. Prior to installation of the new meter, flow was monitored in Barker Creek at Kings Bridge Road, and release volumes were adjusted as required to ensure supply to downstream water users. Since this meter was installed, daily flows have ranged from 4.5 to 46.3 ML/day, with an average of 18 ML/day. Release volumes were generally higher between August 2015 and May 2016 than they were between May 2016 and May 2017 (Figure 4.2).

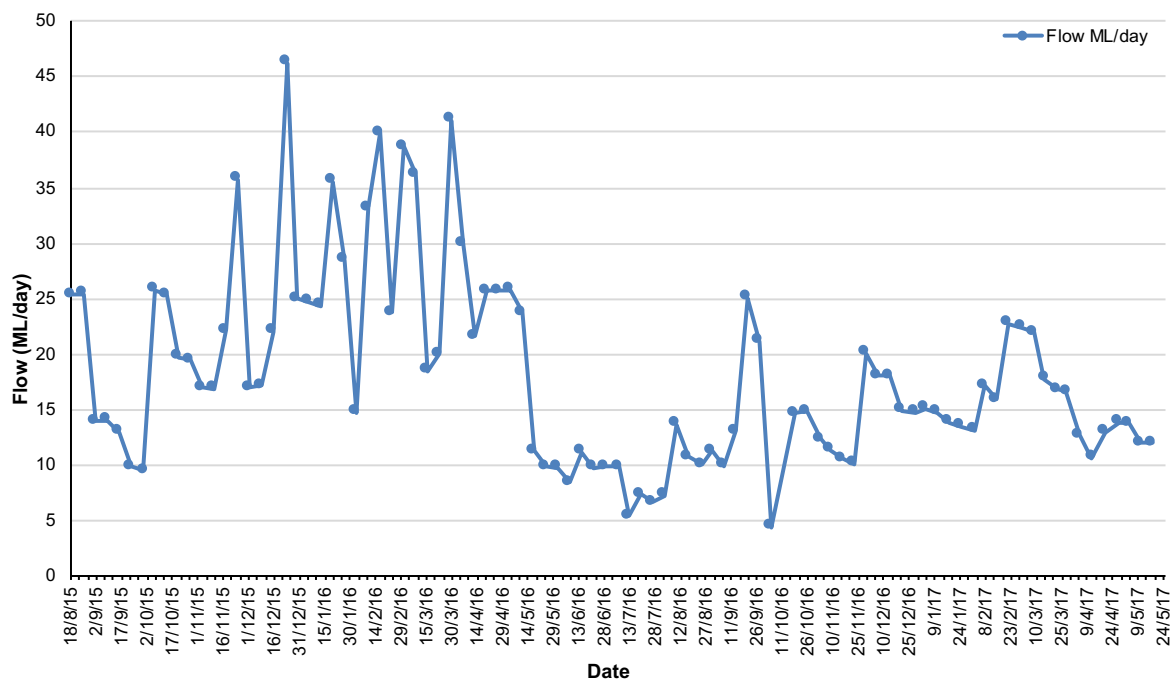


Figure 4.2 Flow released from Meandu Creek Dam since the new flow meter was installed in August 2015

4.1.2.2 Catchment Flows

Data from the DNRME gauging stations demonstrates that flow in Barker Creek upstream of the confluence of Meandu Creek (at comparative site C1B) is typical of an ephemeral / intermittent creek, with only episodic high flow events (Figure 4.3). Flow recorded by DNRME in Barker Creek downstream of the confluence of Meandu Creek reflects the perennial releases from Meandu Creek Dam and other sources (e.g. the Nanango Wastewater Treatment Plant), with a low baseflow evident with peaks in flow during rainfall events (Figure 4.4).



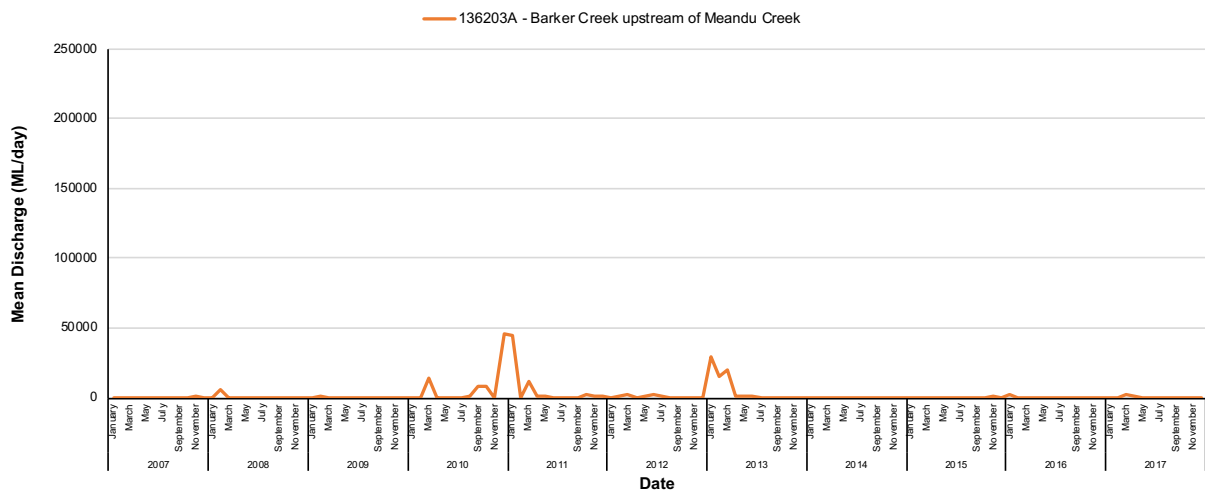


Figure 4.3 Flow in Barker Creek upstream of the Meandu Creek confluence (DNRM 2017)

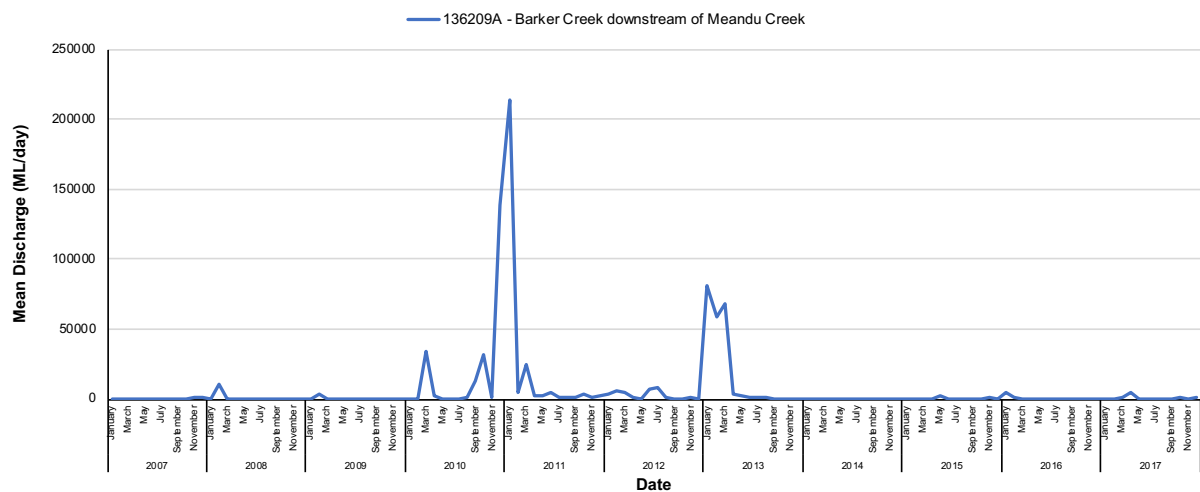


Figure 4.4 Flow in Barker Creek downstream of the Meandu Creek confluence (DNRM 2017)



4.2 Historical Water Quality

4.2.1 Meandu Creek Upstream of Meandu Creek Dam

Summary statistics for sites on Meandu Creek upstream of Meandu Creek Dam during the past 40 years (i.e. since water quality monitoring began in 1978) are presented in Table 4.1, and summary statistics for the past four years (i.e. since elevated electrical conductivity levels at CP3 were noted and additional sampling undertaken) presented in Table 4.2. The following trends were identified:

- Median pH was higher at the Meandu Mine compliance points CP3 and CP1 (which are located near the inflow and within Meandu Creek Dam, respectively) than in Meandu Creek adjacent to Meandu Mine. While there have been occasions where the pH at the compliance points and Meandu Creek sites has been low (e.g. approximately 4 pH units) (Figure 4.5), there has been little change in the median pH in recent years compared to the long-term median.
- Electrical conductivity levels were higher in Meandu Creek adjacent to Meandu Mine than at the Meandu Mine compliance points CP3 and CP1. There has been an increase in median electrical conductivity levels at both compliance points in the past four years compared with the long-term median. However, median electrical conductivity at the compliance points was below the water contaminant limit of 2500 $\mu\text{S}/\text{cm}$ listed in Table C2 of the Meandu Mine EA EPML00709113.
- Similarly, concentrations of sodium and chloride were higher in Meandu Creek adjacent to Meandu Mine than at the compliance points. Median concentrations in the past four years were generally similar to the long-term median.
- Concentrations of sulfate, oxides of nitrogen and most metals (including cobalt, iron, manganese, molybdenum, nickel and zinc) were higher at the compliance points than in Meandu Creek adjacent to the mine.

While the WQOs for moderately disturbed aquatic ecosystems are not directly applicable to the industrial use waters of Meandu Creek upstream of Meandu Creek Dam and adjacent to the mine (see Section 3.3), they still provide guidelines below which the environmental values of Meandu Creek are unlikely to be adversely impacted. The summary statistics mostly complied with the WQOs (applicable to Meandu Creek downstream of Meandu Creek Dam), and the EA compliance limits where applicable, with the following exceptions (Table 4.1 and Table 4.2):

- The median, 80th and 95th percentile values for all time periods and the 20th percentile for the last four years for electrical conductivity in Meandu Creek adjacent to the mine, as well as the 95th percentile value long-term and the 80th and 95th percentile values in the past four years for electrical conductivity at the compliance points.
- The median, 80th and 95th percentile values for oxides of nitrogen at both locations and the 20th percentile at the Meandu Mine compliance points across all time periods.
- The 95th percentile concentrations of cobalt, iron and zinc at the compliance sites, and the 80th and 95th percentile concentrations of manganese at the compliance sites



and sites on Meandu Creek adjacent to Meandu Mine (dissolved metals results are only available for 2012 onwards).

These parameters are discussed further below. Graphs for all parameters investigated (including major anions and cations, and metals and metalloids) are summarised in Attachment C.



Table 4.1 Summary of surface water quality results for compliance sites and Meandu Creek sites upstream of Meandu Creek Dam from 1978 to 2017

Parameter	Units	EA Limit*	WQO^	Compliance Sites ^							Meandu Creek Sites ^						
				Count	Min.	Max.	Median	20th %ile	80th %ile	95 %ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95 %ile
Physico-chemical																	
Specific EC	µS/cm	2500	2037	8547	51	5901	1621	1350	1850	2270	1678	69	9370	2240	1048	3460	4500
TDS	mg/L		2000	40	9	1730	1075	879	1259	1325	969	4	7580	1380	710	2281	2782
pH	pH units	5.5–9.0	6.5–9.0	8246	3.18	9.83	7.85	7.19	8.41	8.87	1822	3.37	9.33	6.96	6.58	7.43	7.83
Major Ions																	
Calcium	mg/L		1000	43	3	130	49	29	59	74	400	0.5	172	36	15	54	75
Sodium	mg/L		NA	47	36	418	210	151	237	259	401	2.5	1220	375	106	660	765
Potassium	mg/L		NA	47	3	27	19	13	22	25	401	0.5	61	13	8	18	26
Chloride	mg/L		NA	56	45	796	356	250	409	4567	403	0.5	3300	770	189	1278	1484
Sulfate	mg/L		1000	56	44	523	260	174	445	510	427	0.5	1310	93	41	197	398
Magnesium	mg/L		NA	43	6	288	55	39	75	85	244	1	399	51	16	79	123
Fluoride	mg/L		2	45	0.05	1.00	0.20	0.10	0.49	0.50	72	0.05	0.50	0.20	0.20	0.30	0.40
Nutrients																	
Ammonia	mg/L		NA	19	0.005	0.760	0.270	0.086	0.434	0.670	24	0.010	0.860	0.040	0.020	0.174	0.401
Nitrate	mg/L		NA	28	0.030	14.270	0.770	0.422	1.254	4.570	118	0.005	11.300	0.390	0.030	0.858	1.956
Nitrite	mg/L		NA	24	0.005	0.050	0.005	0.005	0.020	0.039	24	0.005	0.005	0.005	0.005	0.005	0.005



Parameter	Units	EA Limit*	WQO [^]	Compliance Sites ^A							Meandu Creek Sites ^B						
				Count	Min.	Max.	Median	20th %ile	80th %ile	95 %ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95 %ile
Oxides of N	mg/L		0.015	24	0.030	1.460	0.750	0.362	0.882	1.284	34	0.005	3.160	0.028	0.005	0.460	1.568

NA not applicable (e.g. no relevant WQO, insufficient samples collected to complete calculation)

* Water contaminant limit for CP3 and CP4 from Meandu Mine EA EPML00709113

[^] WQO not directly applicable to Meandu Creek upstream of Meandu Creek Dam (adjacent to mine), but is presented for comparison; shaded cells indicate exceedance of the WQO to assist in interpretation only

^A data pooled from sites CP1, CP3, CP4

^B data pooled from sites CKMB, CKMC, CKMD, CKME, CKMF, CKMM, CKMR, CKMU, Meandu Creek-1, Meandu Creek-2, Meandu Creek-3, Meandu Creek-4, Meandu Creek-5, Meandu Creek-6, RD7 Creek Crossing



Table 4.2 Summary of surface water quality results for compliance sites and Meandu Creek sites upstream of Meandu Creek Dam from 2013 to 2017

Parameter	Units	EA Limit*	WQO ^	Compliance Sites ^							Meandu Creek Sites ^B						
				Count	Min.	Max.	Median	20th %ile	80th %ile	95th %ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95th %ile
Physico-chemical																	
pH	pH units	5.5–9.0	6.5–9.0	167	3.18	8.13	7.09	6.72	7.50	8.00	481	3.37	9.33	7.04	6.60	7.55	8.25
Specific EC	µS/cm	2500	2037	183	381	3660	1951	1420	2546	3367	508	123	5770	3049	2428	3854	5060
TDS	mg/L		2000	32	9	1730	1095	847	1268	1365	39	320	3110	1990	1584	2214	2957
Major Ions																	
Calcium	mg/L		1000	26	6	130	52	37	59	61	47	8	91	47	34	59	81
Sodium	mg/L		NA	29	52	418	202	178	231	281	47	50	879	593	481	665	836
Potassium	mg/L		NA	29	5	27	19	16	21	25	47	6	16	10	9	11	14
Chloride	mg/L		NA	38	68	796	356	287	434	456	49	65	1580	932	801	1068	1370
Sulfate	mg/L		1000	38	72	523	277	185	473	516	73	76	1310	184	129	400	997
Magnesium	mg/L		NA	26	11	288	67	52	80	92	49	14	132	77	50.6	102.8	124
Fluoride	mg/L		2	38	0.05	1	0.2	0.15	0.5	0.52	49	0.05	0.4	0.2	0.2	0.3	0.36
Dissolved metals and metalloids																	
Aluminium	mg/L		0.055	31	<LOR	0.080	<LOR	<LOR	<LOR	0.015	49	<LOR	0.050	<LOR	<LOR	<LOR	0.032
Cobalt	mg/L		0.09	29	<LOR	0.230	0.013	<LOR	0.085	0.196	49	<LOR	0.019	0.001	<LOR	0.003	0.008
Copper	mg/L		0.127**	31	<LOR	0.005	<LOR	<LOR	0.002	0.003	49	<LOR	0.023	<LOR	<LOR	0.0014	0.003



Parameter	Units	EA Limit*	WQO [^]	Compliance Sites ^A							Meandu Creek Sites ^B						
				Count	Min.	Max.	Median	20th %ile	80th %ile	95th %ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95th %ile
Iron	mg/L		0.300	31	0.025	11.90	0.025	0.025	0.050	2.440	54	<LOR	3.340	<LOR	0.025	0.084	0.225
Manganese	mg/L		1.9	31	<LOR	11.20	0.8110	0.039	5.820	8.970	49	0.006	9.480	0.8650	0.096	2.500	4.076
Molybdenum	mg/L		0.034	31	5 ⁻⁷	0.003	4 ⁻⁶	5 ⁻⁷	0.002	0.0025	49	5 ⁻⁷	0.025	5 ⁻⁷	5 ⁻⁷	0.0005	0.0005
Nickel	mg/L		0.955**	31	<LOR	0.215	0.017	0.004	0.119	0.168	49	<LOR	0.040	0.001	<LOR	0.002	0.0238
Zinc	mg/L		0.723**	31	<LOR	1.440	0.0280	<LOR	0.320	0.999	49	<LOR	0.012	<LOR	<LOR	0.005	0.0086
Nutrients																	
Ammonia	mg/L		NA	21	0.005	0.760	0.170	0.040	0.410	0.660	24	0.010	0.860	0.040	0.020	0.174	0.401
Nitrate	mg/L		NA	29	0.005	5.200	0.720	0.248	1.016	3.028	24	0.005	0.920	0.020	0.005	0.034	0.459
Nitrite	mg/L		NA	26	0.005	0.050	0.005	0.005	0.010	0.038	24	0.005	0.005	0.005	0.005	0.005	0.005
Oxides of N	mg/L		0.015	26	0.005	1.460	0.625	0.200	0.840	1.238	24	0.005	0.920	0.020	0.005	0.034	0.459

NA not applicable (e.g. no relevant WQO criteria, no data available, insufficient samples collected to complete calculation)

* Water contaminant limit for CP3 and CP4 from Meandu Mine EA EPML00709113

[^] WQO not directly applicable to Meandu Creek upstream of Meandu Creek Dam (adjacent to mine), but is presented for comparison; shaded cells indicate exceedence of the WQO to assist in interpretation of results only

** hardness modified trigger value based on a hardness of 400 mgCaCO₃/L (extremely hard)

^A data pooled from sites CP1, CP3, CP4

^B data pooled from sites CKMB, CKMC, CKMD, CKME, CKMF, CKMM, CKMR, CKMU, Meandu Creek-1, Meandu Creek-2, Meandu Creek-3, Meandu Creek-4, Meandu Creek-5, Meandu Creek-6, RD7 Creek Crossing



4.2.1.1 Electrical Conductivity

Electrical conductivity in Meandu Creek upstream of Meandu Creek Dam (including compliance sites) was generally high, when compared with the electrical conductivity levels at historical comparative sites CKME and CKMF (draining forestry areas upstream of the mine) (Figure 4.6).

Electrical conductivity levels in Meandu Creek adjacent to Meandu Mine are highly variable over time, likely in response to rainfall and runoff as well as operation of the mine. Electrical conductivity levels were relatively high (up to 5,000 $\mu\text{S}/\text{cm}$) in the 1980s and 1990s, when a number of sites were monitored. More recent monitoring at different sites in Meandu Creek adjacent to Meandu Mine has shown similar results, with electrical conductivity levels of up to 6,000 $\mu\text{S}/\text{cm}$, and a general trend of increasing electrical conductivity at these sites between 2014 and 2017.

Electrical conductivity levels at the compliance sites are generally lower than those at the sites in Meandu Creek adjacent to the mine, and only occasionally exceed 3,000 $\mu\text{S}/\text{cm}$ (Figure 4.6). High electrical conductivity levels at CP1 (in Meandu Creek Dam) in 2007 and 2008 were likely related to the drought conditions experienced at this time, with levels decreasing after drought-breaking rain in the second half of 2008 (EMPS 2013). Electrical conductivity levels have been increasing at site CP1 since early 2013 (Figure 4.6), noting that rainfall has been below average during this period (Section 4.1.1). Given this site is within Meandu Creek Dam, electrical conductivity will also be influenced by cooling water blowdown from the Tarong power stations.

4.2.1.2 Major Anions and Cations

Concentrations of most major anions and cations have varied substantially over time and between sites on Meandu Creek upstream of Meandu Creek Dam. Concentrations of all anions and cations at each site generally showed similar patterns over time (as shown in an example graph of calcium below; Figure 4.7; graphs for all other anions and cations are provided in Attachment C.). Concentrations of ions on Meandu Creek adjacent to Meandu Mine and at the compliance sites during historical monitoring were higher than those recorded upstream of the mine (e.g. historical monitoring sites CKME and CKMF). There was a general trend of increasing ion concentrations at site CKMB (Meandu Creek adjacent to the mine) through the 1990s and 2000s, when this site was consistently monitored (Figure 4.7, Attachment C). Concentrations of ions in Meandu Creek adjacent to the mine measured more recently (since 2015) have generally been within the range recorded during historical monitoring.

4.2.1.3 Sulfate

Concentrations of sulfate on Meandu Creek adjacent to Meandu Mine and at the compliance sites during historical monitoring were higher than those recorded upstream of the mine (e.g. historical monitoring sites CKME and CKMF). There was a general trend of increasing ion concentrations at site CKMB (Meandu Creek adjacent to the mine) through the 1990s and 2000s, when this site was consistently monitored (Figure 4.8). There has also been a general trend of increasing sulfate concentrations at compliance points CP3 and CP4 in the past 10 years, although this trend was not observed at site CP1 in Meandu Creek Dam (Figure 4.8).



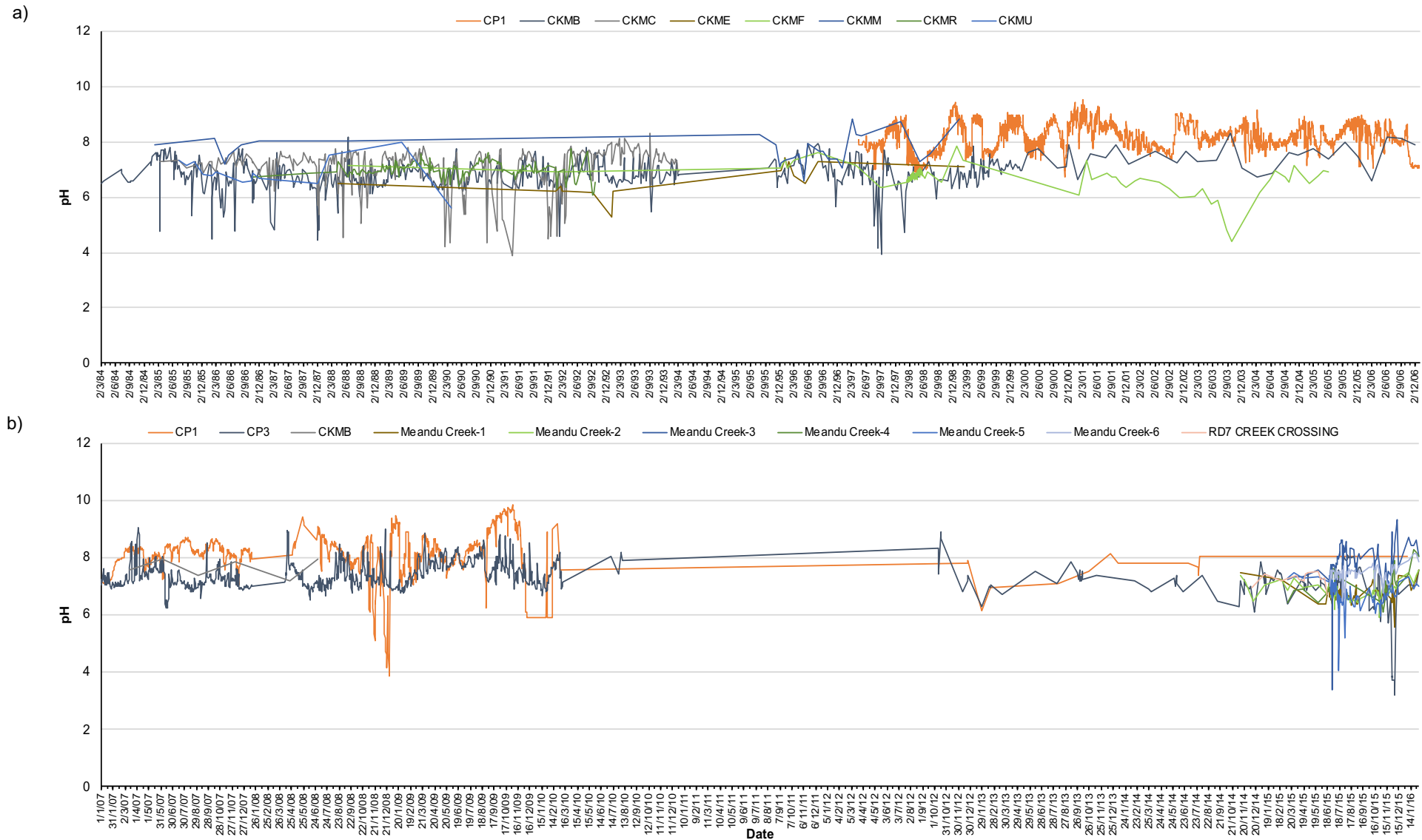


Figure 4.5 pH in water at sites on Meandu Creek from a) 1984 to 2006 and b) 2007 to 2017



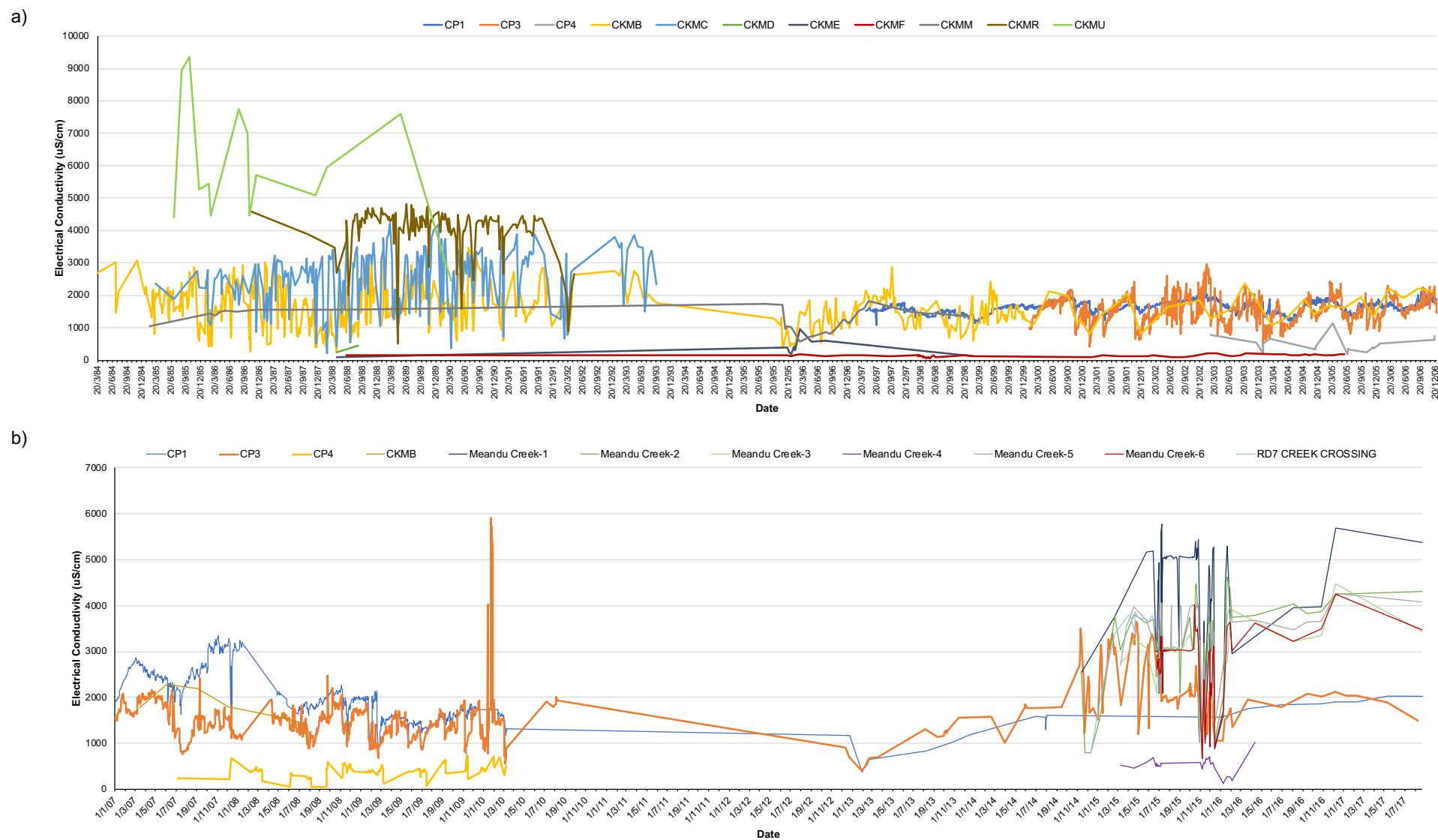


Figure 4.6 Electrical conductivity in water at sites on Meandu Creek from a) 1984 to 2006 and b) 2007 to 2017



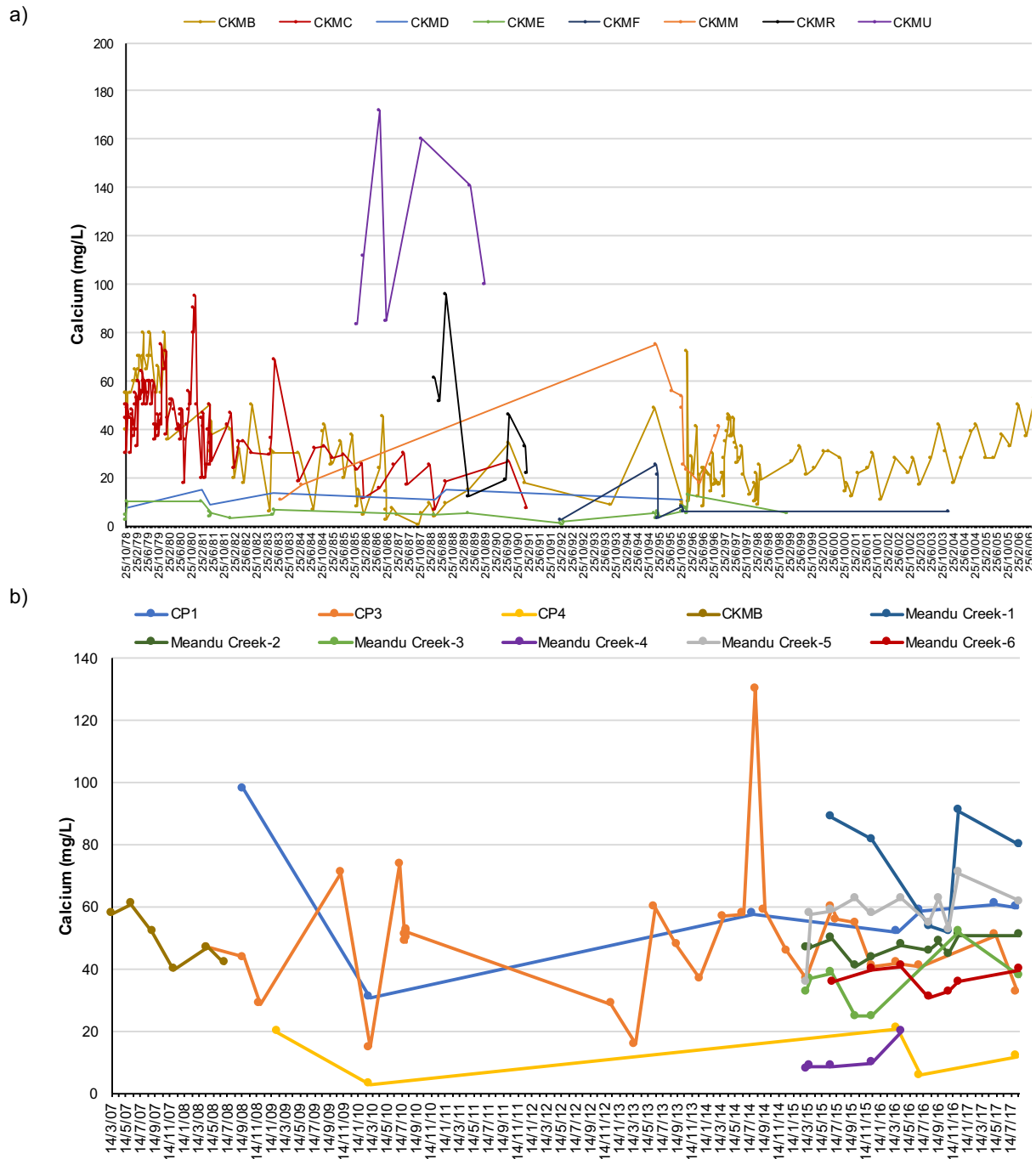


Figure 4.7 Calcium concentrations in water at sites on Meandu Creek from a) 1984 to 2006 and b) 2007 to 2017



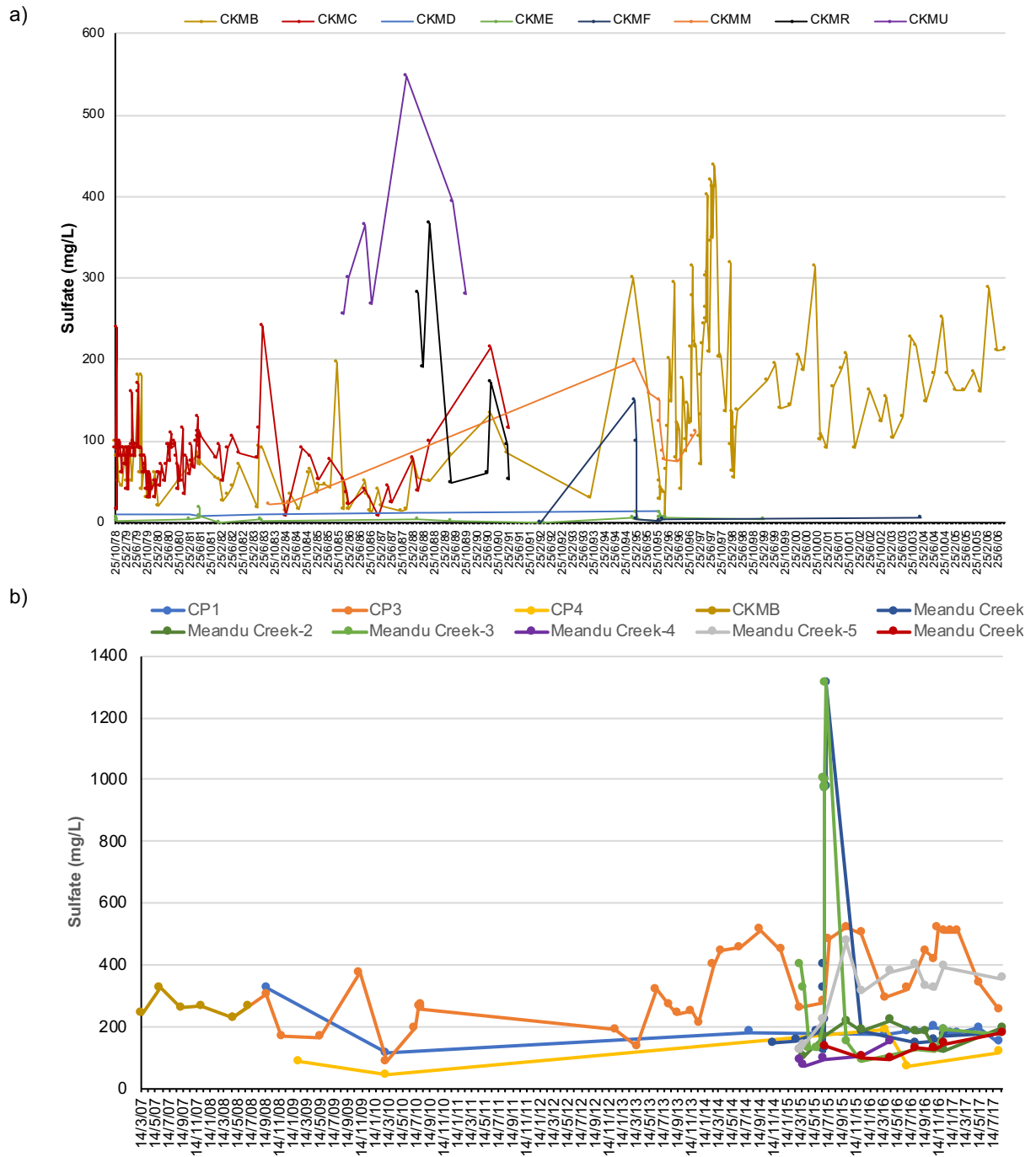


Figure 4.8 Sulfate concentrations in water at sites on Meandu Creek from a) 1984 to 2006 and b) 2007 to 2017



4.2.1.4 Metals and Metalloids

Since routine monitoring of the concentrations of dissolved metals commenced in 2012, the concentrations of most metals have been low (e.g. below the WQO) at sites on Meandu Creek upstream of Meandu Creek Dam (including compliance sites) (Table 4.2 and graphs provided in Attachment C). While the concentrations of some dissolved metals (including aluminium, iron and copper) peaked at some sites in 2015, this trend did not continue in 2016 and 2017 (refer graphs in Attachment C). As outlined above, while the WQOs are not directly applicable to the highly disturbed waters of Meandu Creek upstream of Meandu Creek Dam and adjacent to the mine (see Section 3.3); concentrations of most dissolved metals were below the WQOs.

Dissolved Manganese

Historically, the concentration of dissolved manganese has varied among sites on Meandu Creek upstream of Meandu Creek Dam (Figure 4.9). While not directly applicable to the highly disturbed waters of Meandu Creek upstream of Meandu Creek Dam, the concentration of dissolved manganese exceeded the WQO of 1.9 mg/L at several sites on Meandu Creek adjacent to the mine and at site CP3 between 2014 and 2017. Concentrations of dissolved manganese were often highest at compliance point CP3; however, concentrations of dissolved manganese at site CP1 on Meandu Creek Dam were much lower than those recorded at CP3, and were below the WQO.

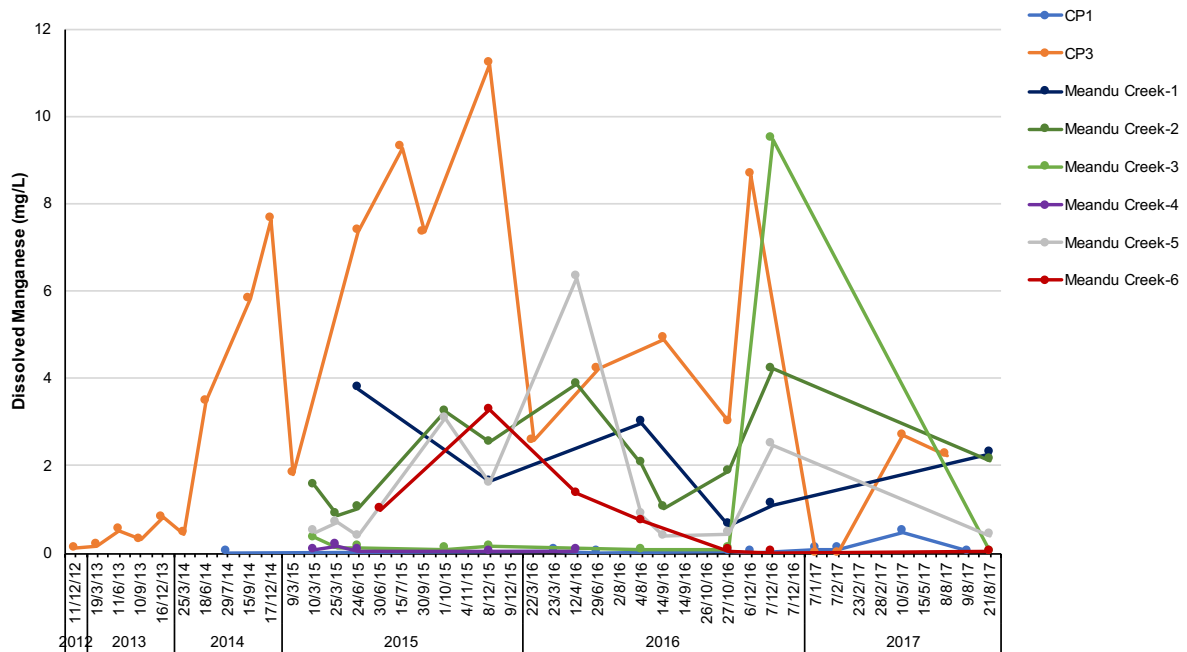


Figure 4.9 Dissolved manganese concentrations in water at sites on Meandu Creek from 2012 to 2017



Dissolved Cobalt, Nickel and Zinc

Concentrations of dissolved cobalt, nickel and zinc were much higher at site CP3 than all other sites, including site CP1 on Meandu Creek Dam, and variable over time (Figure 4.10, Figure 4.11 and Figure 4.12). However, while not directly applicable, concentrations of dissolved cobalt, nickel and zinc at site CP3 were mostly below the WQOs (modified for hardness as required).

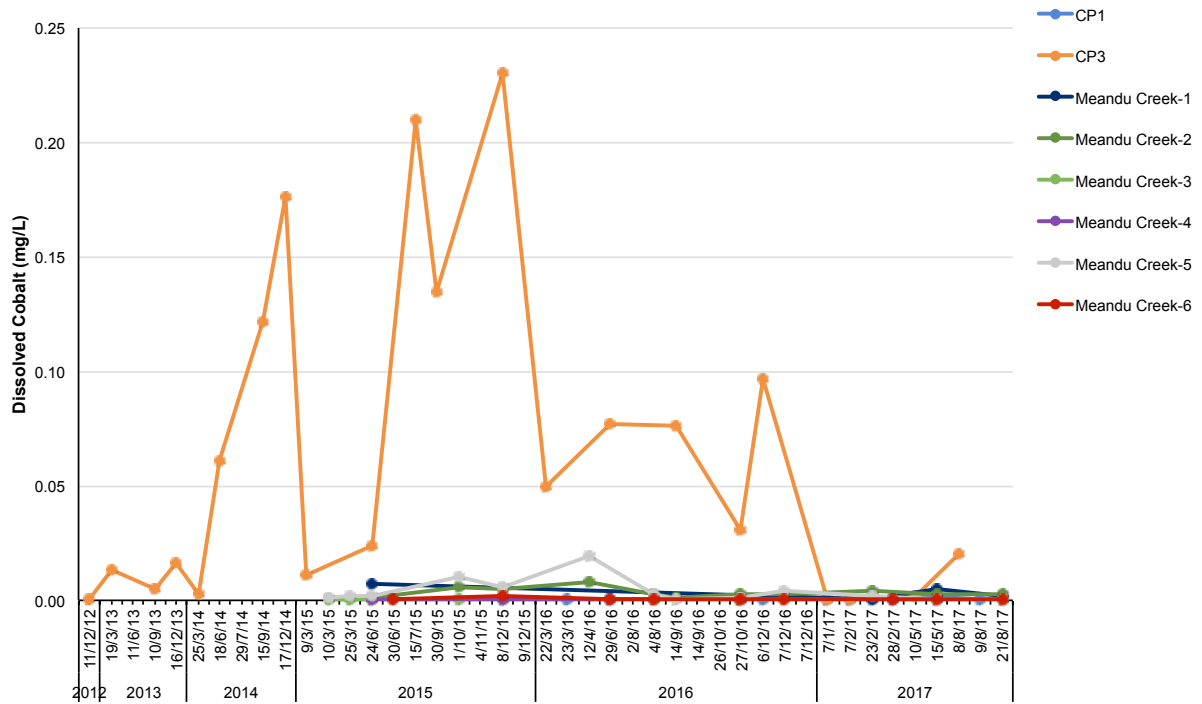


Figure 4.10 Dissolved cobalt concentrations in water at sites on Meandu Creek from 2012 to 2017

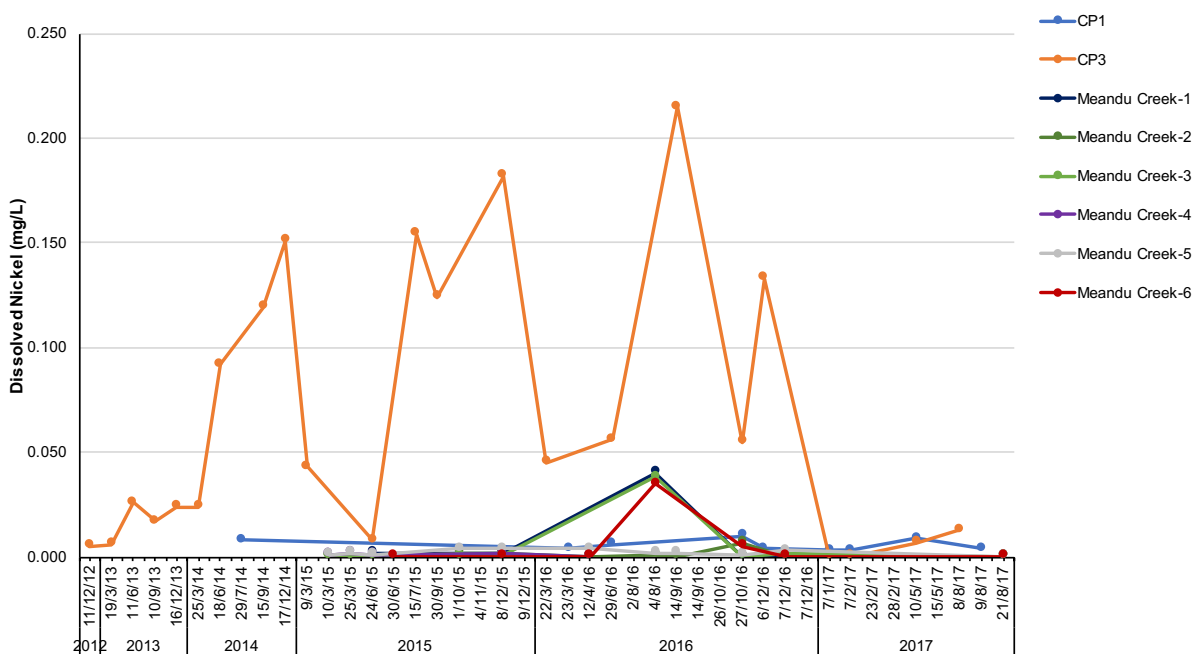


Figure 4.11 Dissolved nickel concentrations in water at sites on Meandu Creek from 2012 to 2017

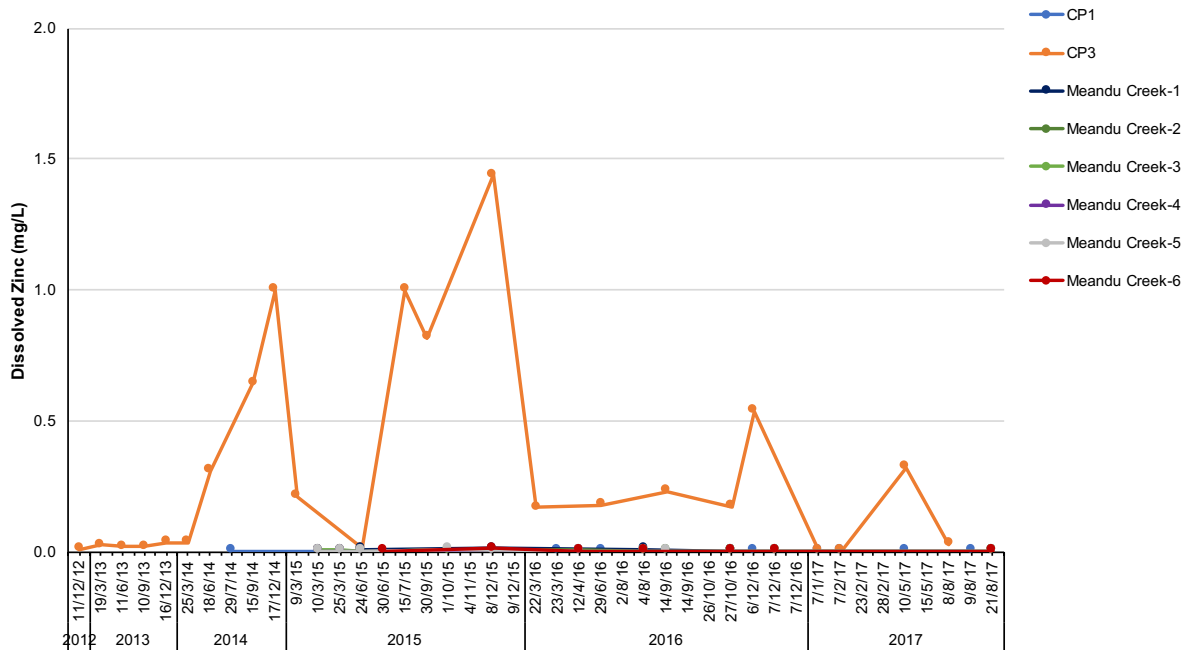


Figure 4.12 Dissolved zinc concentrations in water at compliance sites and sites on Meandu Creek from 2012 to 2017

4.2.1.5 Nitrate

The concentration of nitrate was only routinely monitored at five sites on Meandu Creek upstream of Meandu Creek Dam. Concentrations of nitrate were consistently high at sites CP3 and Meandu Creek 4 from 2007 to 2017 (Figure 4.13); particularly at site CP3 from 2009 to early 2014. Although not directly applicable to the reaches of Meandu Creek upstream of Meandu Creek Dam, the median concentration of oxides of nitrogen from 2013 to 2017 exceeded the WQO (0.015 mg/L), primarily due to the high levels of nitrate at these sites (concentrations of nitrite were generally below LOR).

Concentrations of nitrate were low at other sites on Meandu Creek upstream of the dam (i.e. Meandu Creek 2, 3 and 5); however, few data points are available for these sites (<10 data points available for each site). Nitrate was not monitored at site CP1 in Meandu Creek Dam.



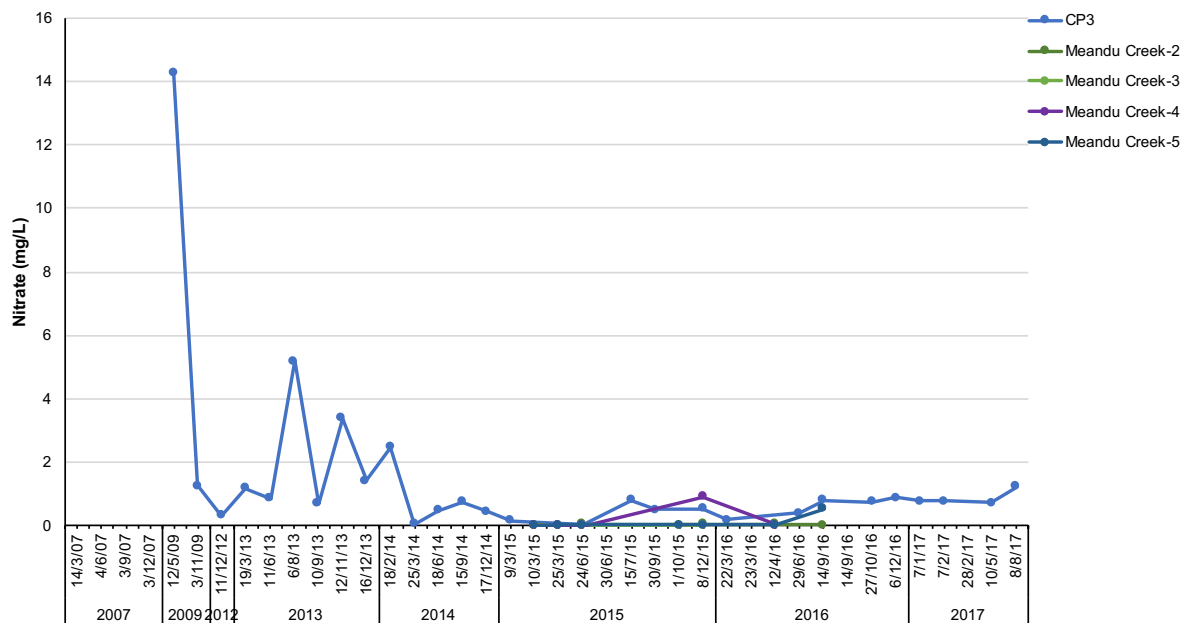


Figure 4.13 Nitrate concentrations in water at compliance sites and sites on Meandu Creek from 2007 to 2017

4.2.2 Meandu Creek Dam

Summaries of long-term and more recent (past 4 years) water quality at Meandu Creek Dam are presented in Table 4.3. Graphs for all parameters investigated are provided in Attachment C.

While not directly applicable to the waters of Meandu Creek Dam, the summary statistics mostly complied with the WQOs (applicable to Meandu Creek downstream of Meandu Creek Dam), with the following exceptions:

- The 95th percentile value for electrical conductivity for the entire monitoring period. Electrical conductivity levels in Meandu Creek Dam are related to rainfall and dilution, with higher electrical conductivity during low rainfall periods / drought and lower electrical conductivity during and after significant wet seasons (JBT Consulting 2017). For example, electrical conductivity was higher than the WQO during the 2007/2008 drought period and lower during the 2010/2011 and 2012/2013 floods (Figure 4.14).
- The 95th percentile for turbidity during the entire monitoring period and the 80th and 95th percentiles for the past four years. High turbidity is linked with high rainfall (and subsequent runoff of sediment-laden water to the dam).
- The median, 20th percentile, 80th percentile and 95th percentile concentration of nitrate during the entire monitoring period and the past four years.
- The 95th percentile for dissolved aluminium during the entire monitoring period and the past four years. Median concentrations were below the WQO.
- The 95th percentile for dissolved arsenic and iron during the entire monitoring period (but not the past four years). Median concentrations were below the WQO.



Over the past four years, the following was noted when compared with the entire dataset Table 4.3:

- similar median electrical conductivity levels and ion concentrations between the two time periods, but a reduction in maximum electrical conductivity levels and the maximum concentration of major ions
- an increase in the median concentration of nitrate
- a reduction in the concentrations of dissolved arsenic, boron and molybdenum, and
- a slight increase in the concentrations of cobalt and nickel; as well as an apparent increase in the concentrations of selenium and vanadium, although this was influenced by an increase in the laboratory limit of reporting in recent years.

The results of the one-off December 2016 survey (which involved sampling of bottom waters in Meandu Creek Dam) were within the range of water quality values recorded during the historical monitoring. While not directly applicable to the waters of the dam, all results were within the relevant water quality objectives (WQOs). Electrical conductivity was relatively high in December 2016, and similar to the 95th percentile value for the past 4 years (2014–2017). This was related to the low dam levels at the time of survey, due to a lack of recent rainfall and inflows to the dam (ESP 2016).

4.2.3 Meandu Creek Downstream of Meandu Creek Dam

Summaries of long-term water quality (all available data) at the two monitoring sites in Meandu Creek downstream of Meandu Creek Dam are presented in Table 4.4, with summaries for recent years (past 4 years) presented in Table 4.5. Graphs for parameters investigated are presented in Attachment C.

The summary statistics mostly complied with the WQOs, including all median values; except for median concentrations of nitrate, which exceeded the WQO for oxides of nitrogen (Attachment C, Figure C.10). In some cases, the 95th percentile value exceeded the WQO, as described below:

- Electrical conductivity for the entire monitoring period at both sites, and at site SW16 (20 km downstream of Meandu Creek Dam) only in the past four years.
- The 95th percentile for turbidity during the entire monitoring period. High turbidity is linked with high rainfall (and subsequent runoff of sediment-laden water to the dam).
- The 95th percentile for pH for the entire monitoring period at site SW16 only, but not the past four years.
- The 95th percentile for dissolved aluminium during the entire monitoring period (but not the past four years), due to occasional spikes in dissolved aluminium concentrations (Attachment C, Figure C.11). Median concentrations were below the WQO.
- The 95th percentile for dissolved arsenic and iron during the entire monitoring period (but not the past four years, due to a trend of decreasing concentrations; Attachment C Figure C.12 and Figure C.16). Median concentrations were below the WQO.



As site SW16 is located 20 km downstream of Meandu Creek Dam, surrounding land uses as well as releases from Meandu Creek Dam influence water quality at this location.

Water quality in Meandu Creek downstream of Meandu Creek Dam has been routinely monitoring by operators of the Tarong and Tarong North power stations (Stanwell / Tarong Energy) in accordance with the Meandu Creek Monitoring Protocol (Stanwell 2016), recently updated to the Meandu Creek REMP (ESP 2018). Detailed assessments of the data occur every three years. The most recent three-yearly assessment concluded that concentrations of some parameters (notably electrical conductivity / major ions and arsenic, chromium and copper) are higher in Meandu Creek downstream of Meandu Creek Dam compared to concentrations in the waterways of the region (ESP 2017). This is related to the higher concentrations of these parameters in the cooling water blowdown (related to operation of the Tarong power stations and the presence of CCA-treated timber in the stations) that is usually discharged to Meandu Creek Dam, and subsequently released to Meandu Creek downstream of Meandu Creek Dam (ESP 2017). However, concentrations in Meandu Creek downstream of Meandu Creek Dam were below the relevant WQOs, and other land uses also influence water quality.



Table 4.3 Summary of surface water quality results for the Meandu Creek Dam release point (W3) from 1983 to June 2017 and from June 2013 to June 2017)

Parameter	Units	WQO^	All Available Data (1983–2017)							Past 4 Years (June 2013–June 2017)						
			Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile
Physico-chemical																
pH	–	6.5–9.0	994	6.0	8.9	7.7	7.4	8.0	8.2	92	6.7	8.3	7.7	7.5	7.8	8.0
Specific EC	µS/cm	2037	991	213	3250	1690	1300	1880	2590	92	1090	1973	1670	1374	1760	1878
DO	% sat.	70 – 110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Turbidity	NTU	25	757	1	1300	9	4	19	72	90	1	53	15	10	31	47
TDS	mg/L	2000	847	113	1830	910	721	1010	1477	53	614	1030	865	711	976	1003
Major Ions																
Calcium	mg/L	1000	532	5	136	56	48	65	76	50	31	65	59	52	61	64
Magnesium	mg/L	NA	532	6	114	55	43	62	74	50	33	73	59	53	66	71
Sodium	mg/L	NA	464	24	320	190	160	210	259	50	120	225	180	160	196	207
Potassium	mg/L	NA	463	5	41	14	11	19	24	50	14	24	20	18	21	23
Chloride	mg/L	NA	465	33	740	404	324	462	572	51	192	479	387	342	423	455
Sulfate	mg/L	1000	465	23	398	104	70	171	234	51	150	241	184	175	201	206
Fluoride	mg/L	2	457	0.1	2.1	0.7	0.4	0.9	1.1	51	0.2	0.7	0.5	0.5	0.6	0.7
Total Hardness	mg/L CaCO ₃	NA	531	38	817	379	297	416	497	49	216	450	390	365	408	441
Nutrients																
Nitrate	mg/L	0.015 [#]	300	<LOR	28	0.8	0.2	1.2	2.9	24	0.1	28	1.45	0.36	4.2	14.7



Parameter	Units	WQO^	All Available Data (1983–2017)							Past 4 Years (June 2013–June 2017)						
			Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile
Dissolved metals and metalloids																
Aluminium	µg/L	55	116	<LOR	780	<LOR	<LOR	40	200	48	<LOR	230	<LOR	<LOR	17.2	63
Arsenic	µg/L	13	658	<LOR	39.5	8.4	4.2	12.8	18.2	91	<LOR	15	5	2.8	7.5	11.4
Boron	µg/L	370	323	3	350	144	117	258	313	73	25	200	120	108	140	164
Cadmium	µg/L	2*	288	<LOR	1.5	0.5	<LOR	0.5	0.5	64	<LOR	0.5	<LOR	<LOR	0.5	0.5
Chromium	µg/L	6	658	<LOR	21	1.2	<LOR	1.5	3	89	<LOR	21	1.5	1	2	2
Cobalt	µg/L	90	301	<LOR	6.5	<LOR	<LOR	1.5	3	65	<LOR	5.8	2	1.5	2	4
Copper	µg/L	12.7 *	657	<LOR	29	6.1	3.3	8.8	12	89	<LOR	12	6	2	9	10
Iron	µg/L	300	246	<LOR	2810	43	20	204	531	40	4	180	28	20	80	131
Lead	µg/L	91.2 *	102	<LOR	4	0.5	0.5	2	2	49	<LOR	2	1	0.5	2	2
Molybdenum	µg/L	34	319	<LOR	35	5	3	6.8	10	72	<LOR	16	3	2	4	6
Nickel	µg/L	99.5*	287	<LOR	17	3.4	1.9	7	9	72	<LOR	17	5.5	2.5	8	12
Selenium	µg/L	18	119	<LOR	10	0.6	0.5	<LOR	<LOR	49	<LOR	10	5	0.6	<LOR	<LOR
Vanadium	µg/L	10	320	<LOR	13	2.4	1.1	<LOR	<LOR	73	<LOR	10	5	1.5	<LOR	<LOR
Zinc	µg/L	72.3 *	119	<LOR	64	7	<LOR	13	25	48	<LOR	64	5	<LOR	9	30

NA – not applicable (e.g. no relevant comparison criteria, no data available, insufficient samples collected to complete calculation)

< LOR – Result is less than the laboratory limit of reporting

[^] WQO not directly applicable to Meandu Creek Dam, but is presented for comparison; shaded cells indicate exceedance of the WQO to assist in interpretation only

WQO for oxides of nitrogen presented as a guide

* Hardness modified trigger value based on a hardness of 400 mgCaCO₃/L (extremely hard)



Table 4.4 Summary of all available surface water quality results for Meandu Creek 5 km downstream of Meandu Creek Dam (W2; 1984–2017) and 20 km downstream of Meandu Creek Dam (SW16; 1998–2017)

Parameter	Units	WQO	W2 (5 km downstream from Meandu Creek Dam)							SW16 (20 km downstream from Meandu Creek Dam)						
			Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile
Physico-chemical																
pH	–	6.5–9.0	975	6.3	8.7	7.5	7.2	7.8	8.0	95	5.2	9.7	7.7	7.2	8.6	9.1
Specific EC	µS/cm	2037	876	254	4100	1720	1260	1950	3353	95	572	2990	1830	1594	2013	2674
DO	% sat.	70 – 110	529	14	112	84	72	90	98	NA	NA	NA	NA	NA	NA	NA
Turbidity	NTU	25	879	1	1300	10	4	26	78	75	0.5	970	15	5	33	143
TDS	mg/L	2000	107	209	2180	943	709	1440	1944	52	314	1630	1019	749	1264	1513
Major Ions																
Calcium	mg/L	1000	410	6	132	53	35	64	94	57	22	120	68	52	84	101
Magnesium	mg/L	NA	409	7	190	53	34	65	94	57	19	100	59	43	77	96
Sodium	mg/L	NA	382	28	420	180	140	210	290	57	24	310	190	150	228	292
Potassium	mg/L	NA	383	2	41	12	8	19	23	57	2	42	19	14	27	36
Chloride	mg/L	NA	384	57	1070	377	268	471	708	57	32	702	408	286	497	628
Sulfate	mg/L	1000	384	2	379	108	64	181	234	57	40	389	185	148	240	289
Fluoride	mg/L	2	323	0.1	2.5	0.7	0.4	0.9	1.3	53	0.1	1.4	0.7	0.4	0.9	1
Total Hardness	mg/L CaCO ₃	NA	409	43	1095	362	228	423	592	59	132	717	396	302	487	635
Nutrients																



Parameter	Units	WQO	W2 (5 km downstream from Meandu Creek Dam)							SW16 (20 km downstream from Meandu Creek Dam)						
			Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile
Nitrate	mg/L	0.015 [#]	201	<LOR	8	1	0.6	2	3.82	50	<LOR	17	<LOR	<LOR	0.82	2.13
Dissolved metals and metalloids																
Aluminium	µg/L	55	164	3	24400	8	<10	40	119	6	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Arsenic	µg/L	13	331	<LOR	31.4	3.3	0.8	7.5	14.9	38	<LOR	5	2	1	2	3.2
Boron	µg/L	370	349	21	400	143	100	200	300	36	50	320	140	100	100	273
Cadmium	µg/L	2*	238	<LOR	3	<LOR	<LOR	<1	<1	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Chromium	µg/L	6	320	<LOR	15	<LOR	<LOR	1.72	5	38	<LOR	5	<LOR	<LOR	<LOR	1.3
Cobalt	µg/L	90	249	<LOR	3	<LOR	<LOR	1	1.4	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Copper	µg/L	12.7 *	322	<LOR	29	4.8	2	8	11	38	<LOR	8	2	1	3	4.2
Iron	µg/L	300	190	<LOR	3800	69	34	255	532	15	<LOR	130	60	25	70	109
Lead	µg/L	91.2 *	143	<LOR	7	<1	<LOR	2	2	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Molybdenum	µg/L	34	227	<LOR	14	5	3	7	10	36	<LOR	20	6.5	3	8	11.2
Nickel	µg/L	99.5*	274	<LOR	12.7	4	1	5.6	7.3	6	2	5	3	2	5	5
Selenium	µg/L	18	140	<LOR	10	2.5	0.4	5	5	36	<LOR	0.6	<LOR	<LOR	<LOR	<LOR
Vanadium	µg/L	10	228	<LOR	18	3.9	<LOR	5	5	36	<LOR	4	<LOR	<LOR	<LOR	<LOR
Zinc	µg/L	72.3 *	165	<LOR	50	5	<LOR	11	24	6	<LOR	2	<LOR	<LOR	<LOR	<LOR

NA – not applicable (e.g. no relevant WQO, no data available, insufficient samples collected to complete calculation)

Shading indicates values that exceed the WQO

< LOR – Result is less than the laboratory limit of reporting

[#] WQO for oxides of nitrogen presented as a guide

* Hardness modified trigger value based on a hardness of 400 mgCaCO₃/L (extremely hard)



Table 4.5 Summary of surface water quality results for Meandu Creek 5 km downstream of Meandu Creek Dam (W2) and 20 km downstream of Meandu Creek Dam (SW16) for the past four years (June 2013–June 2017)

Parameter	Units	WQO	W2 (5 km downstream from Meandu Creek Dam)							SW16 (20 km downstream from Meandu Creek Dam)						
			Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile
Physico-chemical																
pH	–	6.5 – 9.0	91	6.7	8.0	7.6	7.4	7.8	7.9	16	5.2	8.9	7.38	7.4	8.2	8.7
Specific EC	µS/cm	2037	91	1110	2010	1720	1370	1805	1918	16	1320	2145	1879	1778	2009	2122
DO	% sat.	70 – 110	80	73	109	90	86	96	98	NA	NA	NA	NA	NA	NA	NA
Turbidity	NTU	25	89	1	19	7	4	11	14	1	25	25	NA	NA	NA	NA
TDS	mg/L	2000	12	623	1020	859	710	961	1009	3	738	1310	1140	899	1242	1293
Major Ions																
Calcium	mg/L	1000	50	32	66	60	54	62	64	8	44	90	59	55	68	82
Magnesium	mg/L	NA	50	34	76	60	55	68	74	8	42	79	66	60	69	76
Sodium	mg/L	NA	50	120	235	180	170	201	217	8	140	242	200	179	209	232
Potassium	mg/L	NA	50	13	23	19	18	21	22	8	2	23	21	16	22	23
Chloride	mg/L	NA	51	205	491	408	357	440	467	8	255	497	435	407	280	496
Sulfate	mg/L	1000	51	143	212	194	172	198	208	8	107	194	186	166	189	193
Fluoride	mg/L	2	50	0.2	0.7	0.5	0.4	0.6	0.6	4	0.3	0.6	0.6	0.4	0.6	0.6
Total Hardness	mg/L CaCO ₃	NA	49	156	470	400	360	420	456	3	286	475	421	340	453	470
Nutrients																
Nitrate	mg/L	0.015 [#]	24	<LOR	6.9	1.4	0.6	2.9	5	1	0.3	0.3	NA	NA	NA	NA



Parameter	Units	WQO	W2 (5 km downstream from Meandu Creek Dam)							SW16 (20 km downstream from Meandu Creek Dam)						
			Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile	Count	Min.	Max.	Median	20th %ile	80th %ile	95%ile
Dissolved metals and metalloids																
Aluminium	µg/L	55	49	<LOR	80	5	5	10	20	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Arsenic	µg/L	13	49	<LOR	14	3	2	5	7.5	8	<LOR	2	2	1	2	2
Boron	µg/L	370	48	<LOR	170	120	104	150	170	8	<LOR	160	120	120	140	153
Cadmium	µg/L	2*	39	<LOR	0.2	<LOR	<LOR	<LOR	<LOR	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Chromium	µg/L	6	48	<LOR	1.5	<LOR	<LOR	<LOR	1.5	8	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Cobalt	µg/L	90	39	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Copper	µg/L	12.7 *	48	<LOR	10	2	<LOR	5.8	9	8	<LOR	2	<LOR	<LOR	1.4	2.0
Iron	µg/L	300	15	<LOR	130	60	<LOR	70	109	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Lead	µg/L	91.2 *	49	<LOR	2.5	<LOR	<LOR	<LOR	<LOR	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Molybdenum	µg/L	34	49	<LOR	9	3	2	4	5	8	<LOR	8	3.5	2	4.6	7
Nickel	µg/L	99.5*	49	<LOR	8	5	3	6	7.6	3	2	3	2	2	2.6	2.9
Selenium	µg/L	18	45	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	8	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Vanadium	µg/L	10	49	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	8	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Zinc	µg/L	72.3 *	49	<LOR	35	<LOR	<LOR	6	11.6	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR

NA – not applicable (e.g. no relevant WQO, no data available, insufficient samples collected to complete calculation)

Shading indicates values that exceed the WQO

< LOR – Result is less than the laboratory limit of reporting

WQO for oxides of nitrogen presented as a guide

* Hardness modified trigger value based on a hardness of 400 mgCaCO₃/L (extremely hard)



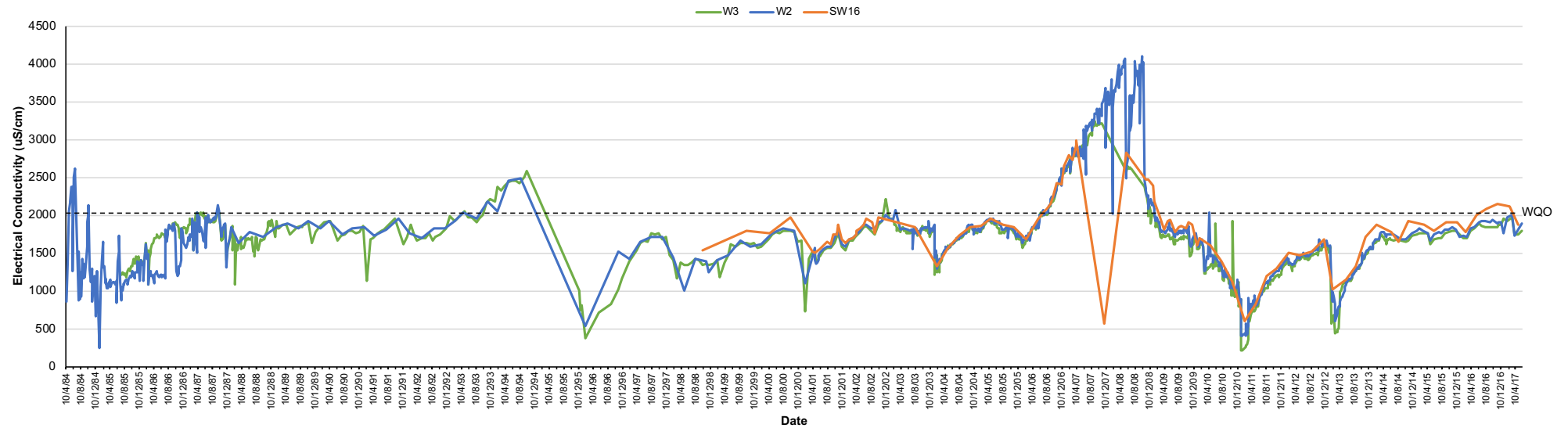


Figure 4.14 Electrical conductivity in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017



4.3 March 2017 Survey

4.3.1 Overview of Results

Concentrations of the following parameters were equal to or below the LORs in all samples, and are therefore not discussed further in this section (Attachment A):

- Dissolved aluminium – while concentrations of dissolved aluminium have occasionally exceeded the WQO at sites upstream of, within and downstream of Meandu Creek Dam; it is possible those higher concentrations are linked with high rainfall and runoff events in the catchment, and that the result from the March 2017 survey reflects the lack of rainfall and runoff prior to the survey.
- Total and dissolved chromium and copper – concentrations of chromium and copper have historically been high (compared to background concentrations in the waterways of the region) in the blowdown water from the Tarong power stations, due to the use of CCA-treated timber in the cooling towers. This can affect (increase) the concentration of chromium, copper and arsenic in Meandu Creek Dam, though concentrations of these metals have decreased over the past three years (2014–2017) relative to historical concentrations (ESP 2017).
- Dissolved cadmium; and total and dissolved lead, selenium and vanadium – this is consistent with the results of historical surveys, when concentrations of these metals in the surface waters of Meandu Creek Dam and Meandu Creek downstream of Meandu Creek Dam have been low or below the laboratory LOR.
- Total and dissolved mercury – mercury is not a contaminant of concern for Meandu Mine or the Tarong power stations, and is not routinely monitored in surface waters.

Concentrations of the following parameters were below the applicable WQOs at all sites, and / or did not differ consistently between sites and locations, and are therefore not discussed in detail in this section (Table 4.6):

- pH – this is consistent with the results of historical surveys, when pH has generally been within the WQO range at sites upstream of, within and downstream of Meandu Creek Dam.
- Dissolved oxygen – dissolved oxygen levels in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) were variable, but within the range recorded at the intermittent comparative sites. Dissolved oxygen levels in Meandu Creek downstream of Meandu Creek Dam were generally close to or within the WQO range, which is consistent with the findings of historical monitoring (Section 4.2.3).
- Turbidity – turbidity levels were below the WQO at all sites in the May 2017 survey, which was after a period of below average rainfall. Historically, turbidity has been below the WQO except during high flow events, when sediment-laden runoff enters Meandu Creek and other waterways within the Barker Creek catchment (JBT Consulting 2014).



- Calcium – concentrations of calcium at all sites were similar to the long-term median concentrations in Meandu Creek upstream and downstream of Meandu Creek Dam (Section 4.2).
- Total nitrogen and total phosphorus – concentrations did not differ substantially between sites.
- Total and dissolved cobalt – in the March 2017 survey, cobalt was only detected (i.e. at concentrations above the laboratory LOR) at sites on Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine), but the concentrations were well-below the WQO. This is consistent with the results of historical surveys in Meandu Creek Dam and Meandu Creek downstream of the dam, where concentrations of cobalt have been low (e.g. well below the WQO), and below the laboratory LOR in recent years.
- Total and dissolved zinc. While higher concentrations of dissolved zinc have historically been recorded at Meandu Mine compliance site CP3 upstream of Meandu Creek Dam (Section 4.2.1.4) and at site CM2 (inlet to Meandu Creek Dam from Meandu Mine) in the March 2017 survey (Table 4.6), concentrations were well below the hardness-modified trigger value.



Table 4.6 Water quality parameters measured at sites holding water during the 2017 field survey compared with the relevant WQOs as assigned in Section 3.3

Parameter	Unit	WQO ^A	Comparative			Meandu Creek upstream of Meandu Creek Dam (adjacent to mine)				Black Creek		Meandu Creek downstream of Meandu Creek Dam						
			C1	C1B	SW36	MCA1/ MC6	MCA2/ MC1	MCA3/ MC5	CM2	BC1	BC2	MCD-OUT	MC-500	MC2	MC5/W2	MC15	MC20/ SW16	MC25
Physicochemical																		
Temperature	°C	16–34	27.0	25.0	25.6	24.3	22.4	20.9	24.9	25.1	24.4	25.5	25.5	24.3	24.6	26.2	24.8	25.5
DO	% sat.	70 – 110	201	46	14	162	36	46	72	85	97	69	83	77	92	134	104	85
pH	pH units	6.5 – 9.0	8.7	7.3	7.4	8.1	7.3	7.5	7.5	8.7	8.1	7.7	7.8	7.5	7.8	8.4	7.9	7.8
EC	µS/cm	2037	987	892	905	3115	3445	3670	1474	4423	331	1602	1605	1605	1626	1589	1628	1620
Turbidity	NTU	25	7.5	8	1	10	12	18	18	10	21	17	8	3	7	12	3	6
TDS	mg/L	2000	801	708	717	2180	2420	2520	1090	3230	278	1230	1260	1240	1260	1210	1240	1220
Total hardness	mg/L	NA	372	346	268	461	538	656	383	865	68	459	463	459	469	459	456	471
Fluoride	mg/L	2	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.5	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Major Anions																		
Chloride	mg/L	NA	315	260	289	937	1060	1040	405	1460	117	482	482	473	489	483	492	493
Sulfate	mg/L	1000	4	2	22	255	180	272	271	84	9	176	177	176	172	169	168	168
Alkalinity	mg/L	NA	177	208	129	290	354	284	59	267	28	99	96	95	100	99	108	107
Major Cations																		
Calcium	mg/L	1000	60	66	38	56	62	65	48	48	6	60	60	60	61	60	59	60
Magnesium	mg/L	NA	54	44	42	78	93	120	64	181	13	75	76	75	77	75	75	78
Sodium	mg/L	NA	100	88	111	709	761	697	250	834	57	225	225	228	229	230	226	234
Potassium	mg/L	NA	4	6	10	13	10	13	16	28	4	20	20	20	20	19	19	20
Nutrients																		
Oxides of nitrogen	mg/L	0.015	<0.01	<0.01	0.06	0.01	0.14	0.06	0.26	<0.01	0.01	0.07	0.16	0.26	0.24	0.09	0.03	0.02
Total nitrogen	mg/L	0.25	0.6	0.7	0.8	0.3	0.4	0.5	0.7	2.8	0.2	0.9	1.0	0.9	0.8	0.7	1.0	0.7
Total phosphorus	mg/L	0.03	0.06	0.3	0.12	0.02	0.06	<0.01	0.02	0.1	0.01	0.04	<0.01	0.09	0.11	0.02	0.1	0.06
Dissolved Metals and Metalloids																		
Arsenic	µg/L	13	<1	<1	2	<1	<1	<1	<1	3	1	7	6	6	4	3	2	2
Boron	µg/L	370	<50	<50	<50	160	140	90	70	250	<50	100	100	100	100	100	100	100
Cobalt	µg/L	90	<1	<1	<1	<1	3	1	6	1	<1	<1	<1	<1	<1	<1	<1	<1
Iron	µg/L	300	<50	<50	<50	<50	360	<50	<50	50	<50	<50	<50	<50	<50	<50	<50	<50
Manganese	µg/L	1900	4	569	514	268	2360	991	763	641	17	575	370	53	114	24	8	27



Parameter	Unit	WQO ^A	Comparative			Meandu Creek upstream of Meandu Creek Dam (adjacent to mine)				Black Creek		Meandu Creek downstream of Meandu Creek Dam						
			C1	C1B	SW36	MCA1/ MC6	MCA2/ MC1	MCA3/ MC5	CM2	BC1	BC2	MCD-OUT	MC-500	MC2	MC5/W2	MC15	MC20/ SW16	MC25
Molybdenum	µg/L	34	<1	<1	<1	<1	<1	<1	1	<1	<1	2	2	2	2	2	2	2
Nickel ^B	µg/L	11	<1	<1	<1	<1	<1	<1	11	1	<1	2	2	2	1	<1	<1	<1
Zinc ^B	µg/L	8	<5	<5	<5	<5	<5	<5	8 ^C	<5	<5	<5	<5	<5	<5	<5	<5	<5
Total Metals and Metalloids																		
Aluminium	µg/L	NA	190	90	<10	50	20	20	400	150	530	120	120	50	100	340	70	70
Arsenic	µg/L	NA	<1	<1	2	<1	<1	<1	<1	3	2	7	7	6	5	3	2	2
Boron	µg/L	NA	<50	<50	70	200	190	120	90	300	<50	140	130	140	140	130	130	140
Cadmium	µg/L	NA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2 ^C	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	µg/L	NA	<1	<1	<1	<1	3	1	29	2	<1	<1	<1	<1	<1	<1	<1	<1
Iron	µg/L	NA	380	740	80	150	1420	1480	1480	1250	450	100	150	90	390	430	130	150
Manganese	µg/L	NA	34	759	553	324	2620	1240	2010	922	55	733	566	152	255	50	10	30
Molybdenum	µg/L	NA	<1	<1	<1	<1	<1	<1	2	<1	<1	2	2	2	2	2	2	2
Nickel	µg/L	NA	<1	<1	<1	<1	<1	<1	22	3	<1	4	4	3	3	2	2	1
Zinc	µg/L	NA	<5	<5	<5	<5	<5	<5	93	5	<5	<5	<5	<5	<5	<5	<5	<5

blue shading denotes values that are below the relevant WQO range

grey shading denotes values that are above the relevant WQO range / WQO

NA no WQO exists for this parameter

^A WQO derived for moderately disturbed waters as per Table 3.2, applied to comparative sites and receiving environment sites downstream of Meandu Creek Dam; shading applied to other sites to assist with interpretation only

^B HMTV applies for this parameter

^C concentration does not exceed the relevant HMTV



Concentrations of the following parameters were high at one or more site/s on Meandu Creek upstream of Meandu Creek Dam and/or Black Creek sites, as well as higher at sites downstream of Meandu Creek Dam compared to comparative sites (Table 4.6). However, the concentrations of these parameters in Meandu Creek downstream of Meandu Creek Dam were not above the relevant WQOs:

- Total and dissolved arsenic (Figure 4.15; Figure 4.16) – concentrations of arsenic were below the laboratory LOR at sites on Meandu Creek upstream of Meandu Creek Dam; the results are likely to reflect influences from the use of CCA-treated timber at the Tarong power stations. This is consistent with the findings of historical surveys, which indicated that concentrations of arsenic in Meandu Creek downstream of Meandu Creek Dam were influenced by power station operation but were unlikely to be toxic to aquatic biota (Section 4.2.3).
- Total and dissolved boron (Figure 4.17; Figure 4.18) – this is consistent with the findings of historical surveys, where concentrations of boron have been below the WQO both upstream and downstream of Meandu Creek Dam (Section 4.2).
- Sulfate (Figure 4.19) – while concentrations were higher in Meandu Creek (upstream and downstream of Meandu Creek Dam) than at the comparative sites, they were below the WQO (which is based on protection of the stock watering EV, there is no WQO available for the protection of aquatic ecosystems). Note that the concentration of sulfate in Meandu Creek downstream of Meandu Creek Dam was also below the Fitzroy Basin Model Mining Condition of 250 mg/L (Table 3.2), which is derived from the Australian drinking water guidelines. This is consistent with the results of historical surveys (Section 4.2.3).



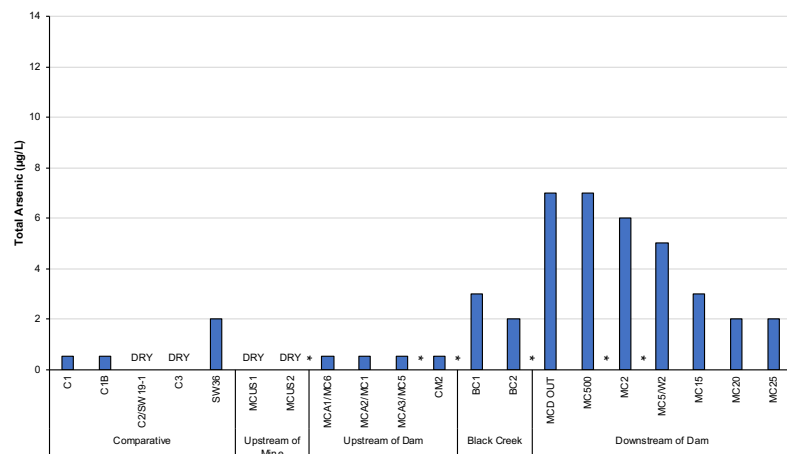


Figure 4.15 Total arsenic concentrations in water in the March 2017 survey⁵

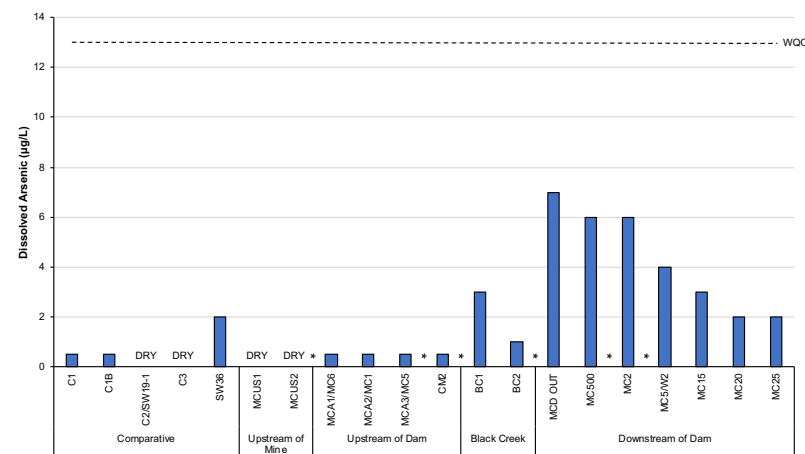


Figure 4.16 Dissolved arsenic concentrations in water in the March 2017 survey⁵

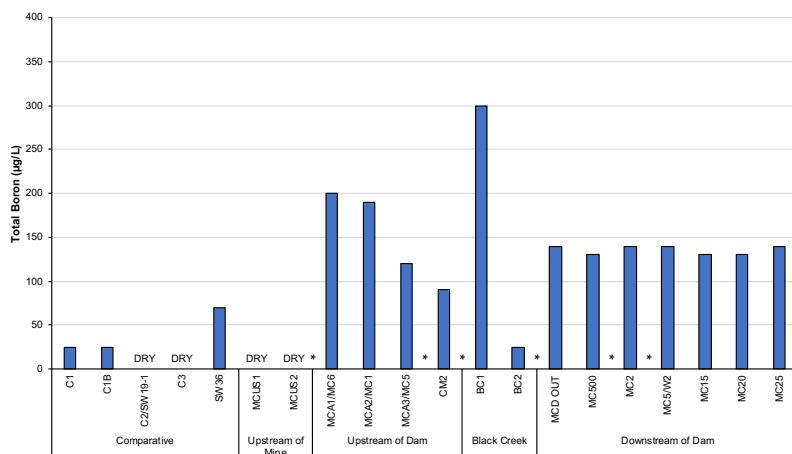


Figure 4.17 Total boron concentrations in water in the March 2017 survey⁵

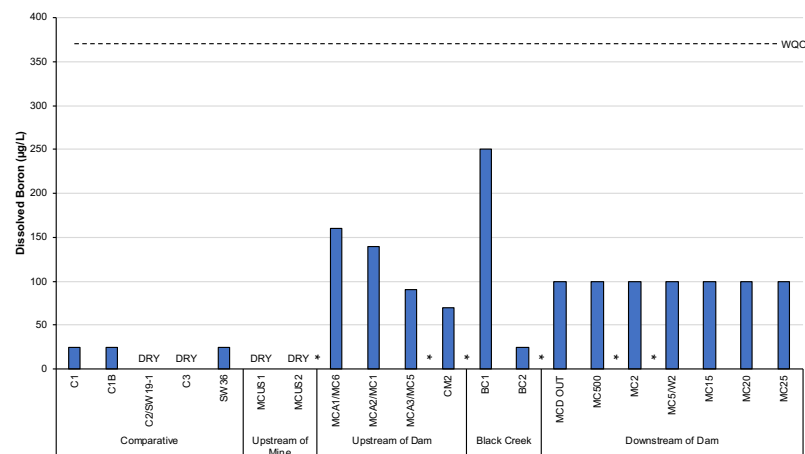


Figure 4.18 Dissolved boron concentrations in water in the March 2017 survey⁵

⁵ WQOs for slightly-moderately disturbed ecosystems are shown; * on graphs indicates where external inputs enter the waterways from discharge locations



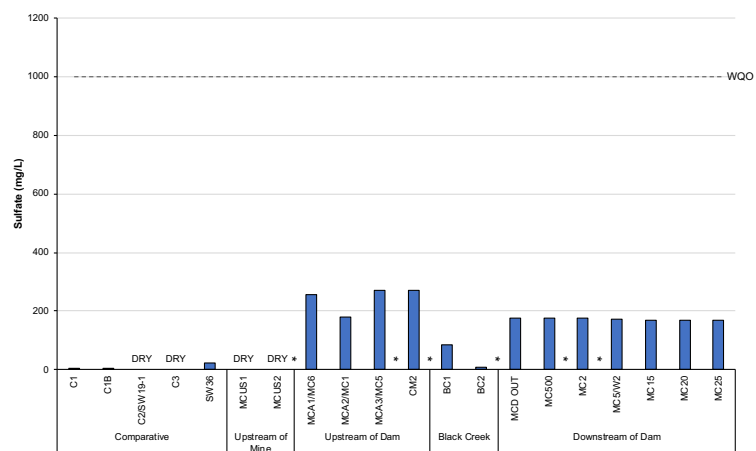


Figure 4.19 Sulfate concentrations in water in the March 2017 survey ⁶

⁶ * on graphs indicates where external inputs enter the waterways from discharge locations



Concentrations of the remaining parameters were high at one or more site/s on Meandu Creek upstream of Meandu Creek Dam, and/or Black Creek site/s, as well as higher downstream of Meandu Creek Dam compared to comparative sites. The concentrations of some of these parameters were also above the relevant WQOs at one or more sites (where applicable) (Table 4.6):

- electrical conductivity
- total dissolved solids
- total hardness
- chloride ⁷
- sodium ⁷
- magnesium ⁷
- potassium ⁷
- nitrate and nitrite
- total aluminium
- total iron
- total and dissolved manganese, and
- total and dissolved nickel.

These parameters are discussed in further detail in the following sections.

⁷ no WQO available; however the concentrations were high at sites on Meandu Creek upstream of Meandu Creek Dam and concentrations at all sites on Meandu Creek downstream of Meandu Creek Dam were higher than the range at comparative sites



4.3.2 Electrical Conductivity and Major Ions

4.3.2.1 Electrical Conductivity

Electrical conductivity was below the WQO at all sites on Meandu Creek downstream of Meandu Creek Dam (where it ranged between 1589 $\mu\text{S}/\text{cm}$ and 1628 $\mu\text{S}/\text{cm}$) and at all comparative sites (where it ranged from 892 $\mu\text{S}/\text{cm}$ and 987 $\mu\text{S}/\text{cm}$) (Figure 4.20).

In contrast, electrical conductivity was high at sites on Black Creek and Meandu Creek upstream of Meandu Creek Dam. Although the WQO of 2037 $\mu\text{S}/\text{cm}$ does not strictly apply to sites on Meandu Creek and Black Creek and upstream of Meandu Creek Dam (for which the designated EV is industrial use), electrical conductivity at most sites upstream of Meandu Creek Dam exceeded the WQO in these reaches except site CM2 (on Meandu Creek near Meandu Creek Dam inlet) and BC2 (on Black Creek). This is consistent with the results of historical surveys, which indicated that electrical conductivity was generally high at sites on Meandu Creek adjacent to Meandu Mine, but lower at the inflow to Meandu Creek Dam (e.g. Meandu Mine compliance site CP3) (Section 4.2.1.1).

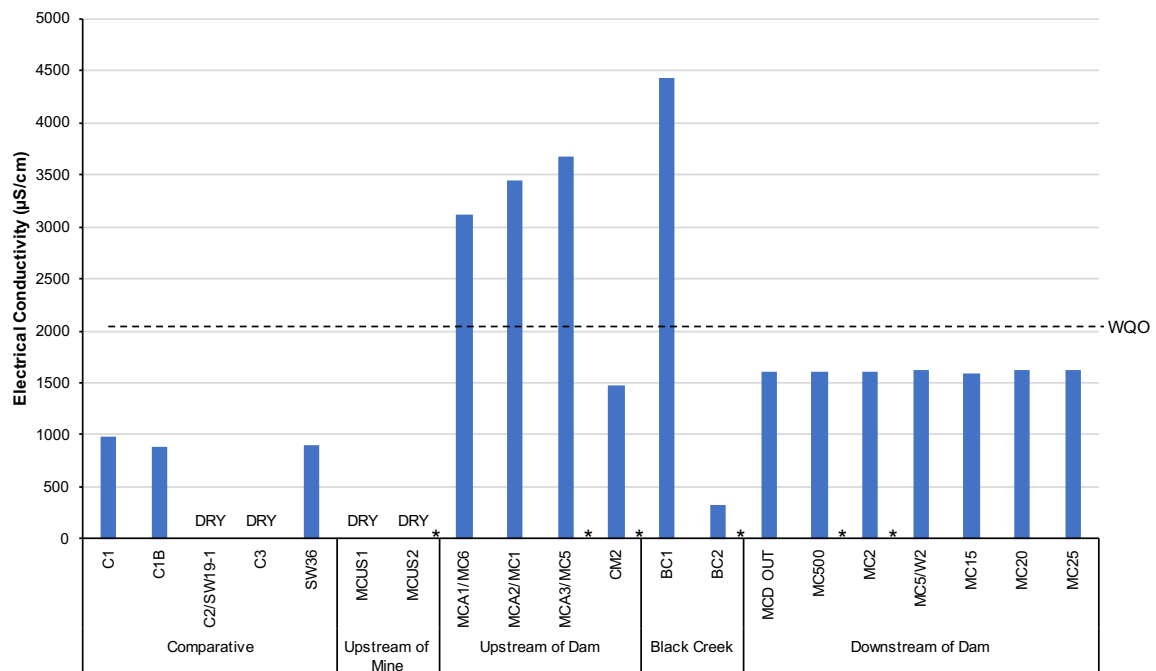


Figure 4.20 Electrical conductivity of water in the March 2017 survey⁸

⁸ * on graph indicates where external inputs enter the waterways from discharge locations



4.3.2.2 Total Dissolved Solids

The concentration of total dissolved solids was high at most sites on Meandu Creek upstream of Meandu Creek Dam (except site CM2) and Black Creek site BC1. Although it exceeded the WQO at these sites, it should be noted that this WQO does not apply to sites within these reaches (for which the designated EV is industrial use). Concentrations of total dissolved solids in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) were within the upper range (e.g. 80th percentile) of concentrations recorded during historical monitoring (Section 4.2.1). The concentration of total dissolved solids at sites on Meandu Creek downstream of Meandu Creek Dam and comparative sites were below the WQO. However, the concentration of total dissolved solids at the sites downstream of Meandu Creek Dam ranged between 1210 mg/L and 1260 mg/L, which was higher than the range at comparative sites (between 708 mg/L and 801 mg/L; Figure 4.21). Concentrations in Meandu Creek downstream of Meandu Creek Dam were consistent with the upper range (80th percentile) concentrations recorded during historical surveys (Section 4.2.3).

Similar to electrical conductivity, total dissolved solids are a measure of ions in water, but include inorganic and organic compounds. There is no WQO for the protection of aquatic ecosystems, as electrical conductivity is used as a more appropriate measure for aquatic animals (Volume 4 of ANZECC & ARMCANZ 2000a); the WQO used in this case applies to agricultural use (specifically livestock drinking water). Given the concentrations in Meandu Creek downstream of Meandu Creek Dam are below the WQO, it is unlikely that the concentrations of total dissolved solids are at a level that would cause acute or chronic effects to livestock exposed to the water.

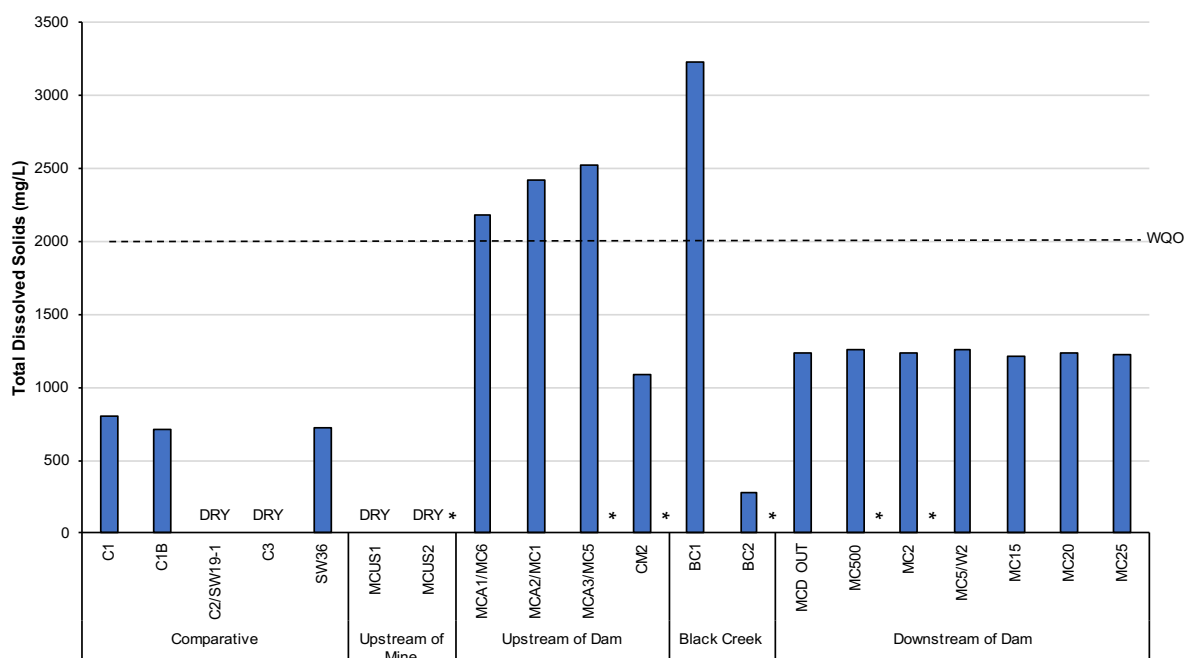


Figure 4.21 Total dissolved solids in water in the March 2017 survey⁹

⁹ * on graph indicates where external inputs enter the waterways from discharge locations



4.3.2.3 Total Hardness

Total hardness was high at all sites across all locations (including comparative sites), indicating that water hardness is naturally high in the study area. Concentrations were highest at Black Creek site BC1 followed by sites on Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine). Overall, total hardness was higher at sites on Meandu Creek than at comparative sites (Figure 4.22).

Hardness is a measure of the dissolved calcium and/or magnesium salts in water and is used as a measure of the corrosion potential of waters on metal surfaces. As this relates predominantly to agricultural uses of water, there is no WQO for the protection of aquatic ecosystems. Soft water has a tendency to be more corrosive than hard water, and it is recommended that waters are above 60 mg/L for farm use (Volume 4 of ANZECC & ARMCANZ 2000a). Furthermore, the uptake and toxicity of several metals in freshwater animals is significantly reduced with higher water hardness (Volume 2 of ANZECC and ARMCANZ 2000a). In this regard, the high water hardness in the study area is likely to have a protective effect on the aquatic ecosystem, and reduces the risk of impacts to the aquatic ecosystem from high concentrations of some metals.

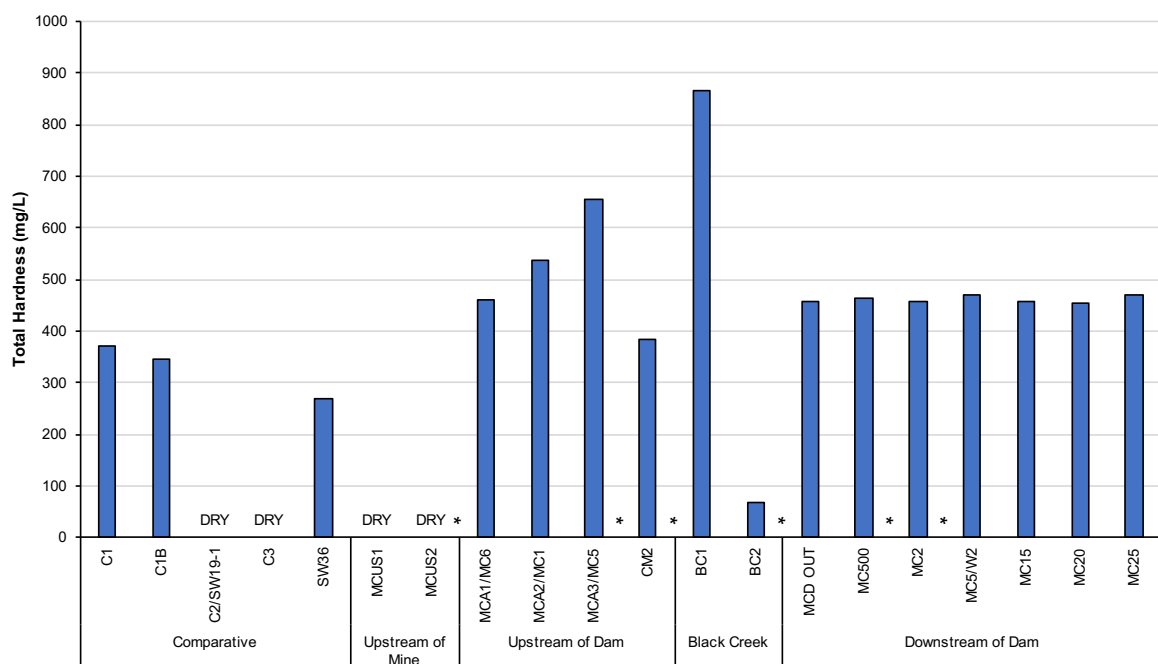


Figure 4.22 Total hardness of water in the March 2017 survey



4.3.2.4 Chloride

There is no applicable WQO for chloride. Concentrations of chloride were highest at Black Creek site BC1 (1460 mg/L). The concentration of chloride in Meandu Creek ranged between 405 mg/L and 493 mg/L, which was higher than the range at comparative sites (between 260 mg/L and 315 mg/L) (Figure 4.23). Concentrations of chloride in March 2017 were similar to the long-term medians recorded in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) (Section 4.2.1) and downstream of Meandu Creek Dam (Section 4.2.3).

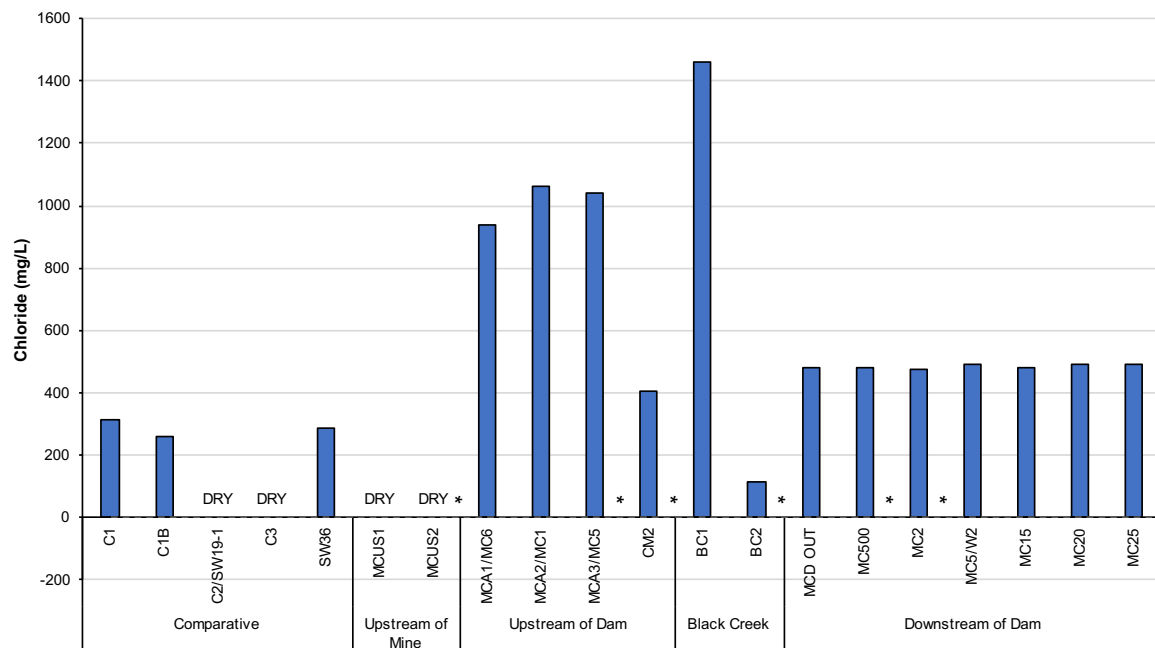


Figure 4.23 Chloride concentrations in water in the March 2017 survey ¹⁰

4.3.2.5 Sodium

There is no applicable WQO for sodium. Concentrations of sodium were highest at Black Creek site BC1 (834 mg/L), and high at most sites on Meandu Creek upstream of Meandu Creek Dam (consistent with the 80th percentile value from long-term monitoring of Meandu Creek adjacent to the mine; Section 4.2.1). The concentration of sodium in Meandu Creek downstream of Meandu Creek Dam ranged between 225 mg/L and 234 mg/L, which was higher than the range at comparative sites (between 88 mg/L and 111 mg/L) (Figure 4.24) but within the upper range (80th percentile) of historical results for Meandu Creek downstream of Meandu Creek Dam.

¹⁰ * on graph indicates where external inputs enter the waterways from discharge locations



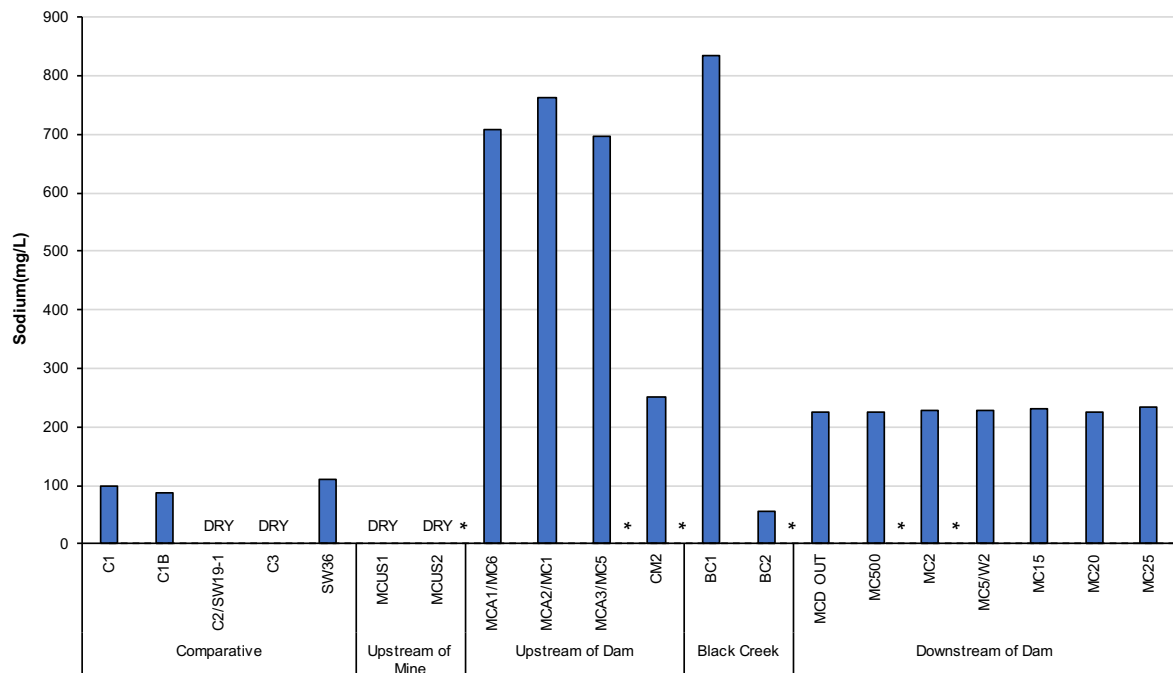


Figure 4.24 Sodium concentrations in water in the March 2017 survey ¹¹

4.3.2.6 Magnesium

There is no applicable WQO for magnesium. Concentrations of magnesium were highest at Black Creek site BC1 (181 mg/L). The concentration of magnesium in Meandu Creek ranged between 75 mg/L and 120 mg/L, which was higher than the range at comparative sites (between 42 mg/L and 54 mg/L) (Figure 4.25). Concentrations in March 2017 were similar to the upper range of values (80th percentile) recorded historically for Meandu Creek upstream and downstream of Meandu Creek Dam (Section 4.2).

¹¹ * on graph indicates where external inputs enter the waterways from discharge locations



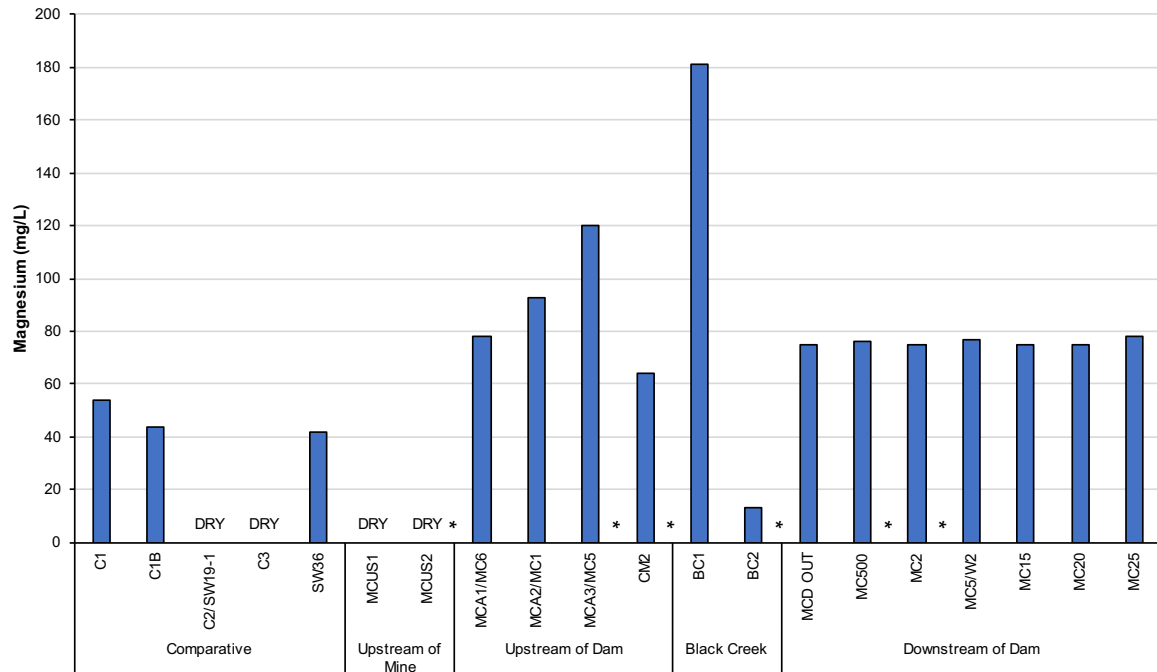


Figure 4.25 Magnesium concentrations in water in the March 2017 survey ¹²

4.3.2.7 Potassium

There is no WQO for potassium. Concentrations were highest at Black Creek site BC1 (28 mg/L), and in Meandu Creek downstream of Meandu Creek Dam. Concentrations in Meandu Creek ranged between 10 mg/L and 20 mg/L and were above the range at comparative sites (between 4 mg/L and 10 mg/L) (Figure 4.26). Concentrations of potassium in Meandu Creek upstream and downstream of Meandu Creek Dam were consistent with the long-term median or 80th percentile values recorded during historical monitoring (Section 4.2).

¹² * on graph indicates where external inputs enter the waterways from discharge locations



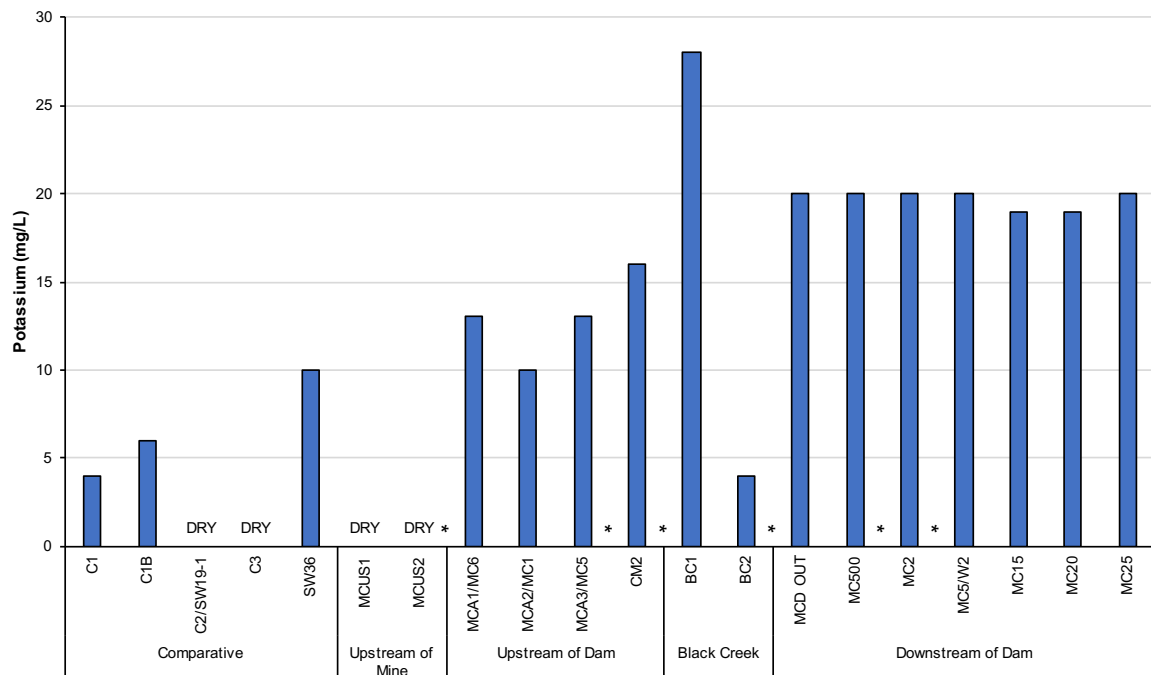


Figure 4.26 Potassium concentrations in water in the March 2017 survey.¹³

4.3.3 Nutrients

4.3.3.1 Nitrate and Nitrite

The concentrations of nitrate and nitrite (oxides of nitrogen) ranged between 0.01 mg/L and 0.26 mg/L and were above the WQO at most sites where they were detected, including comparative site SW36 (noting that this WQO is derived from the QWQG for slightly to moderately disturbed aquatic ecosystems in the central coast region and does not directly apply to sites on Meandu Creek upstream of Meandu Creek Dam and on Black Creek, and is to be used as a guide only) (Figure 4.27). The concentration of oxides of nitrogen was also below the LOR at the Barker Creek comparative sites. Concentrations at sites on Meandu Creek within the first 20 km of the Meandu Creek Dam (i.e. at all sites downstream of the Meandu Creek Dam outlet up to site MC20) were above the concentration at comparative site SW36 (0.06 mg/L). As concentrations increased with distance downstream of the Meandu Creek Dam outlet (MCDOUT), it is likely that there are catchment sources of nitrate and nitrite influencing concentrations in Meandu Creek.

¹³ * on graph indicates where external inputs enter the waterways from discharge locations



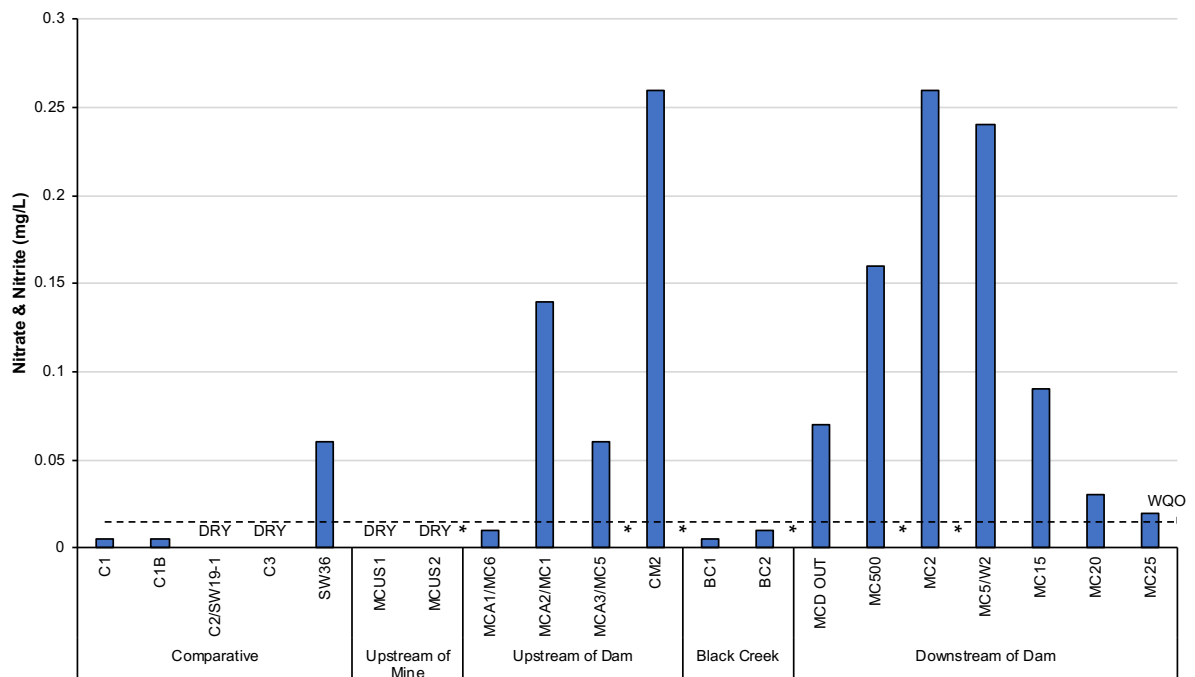


Figure 4.27 Nitrate and nitrite concentrations in water in the March 2017 survey ¹⁴

4.3.4 Metals and Metalloids

4.3.4.1 Aluminium

The concentration of total aluminium was high at sites CM2 on Meandu Creek upstream of Meandu Creek Dam and at site BC2 on Black Creek compared to all other sites (Figure 4.28). Overall, the concentrations at sites downstream of Meandu Creek Dam ranged between 50 µg/L and 340 µg/L and most were within or below the range of comparative sites (between 90 µg/L and 190 µg/L), except at site MC15 where the concentration was highest.

Aluminium is common naturally occurring element (ANZECC & ARMCANZ 2000a). The relatively high concentrations at comparative sites indicate that total aluminium concentrations are likely to be naturally high in the study area. The high concentration at MC15 is also likely to be from a localised source; given that this was an isolated spike in the results, and concentrations at sites upstream and downstream of MC15 were within the range of the comparative sites.

The concentration of dissolved aluminium at all sites was below the LOR and WQO (i.e. the bioavailable concentrations of aluminium were negligible) at all sites.

¹⁴ * on graph indicates where external inputs enter the waterways from discharge locations



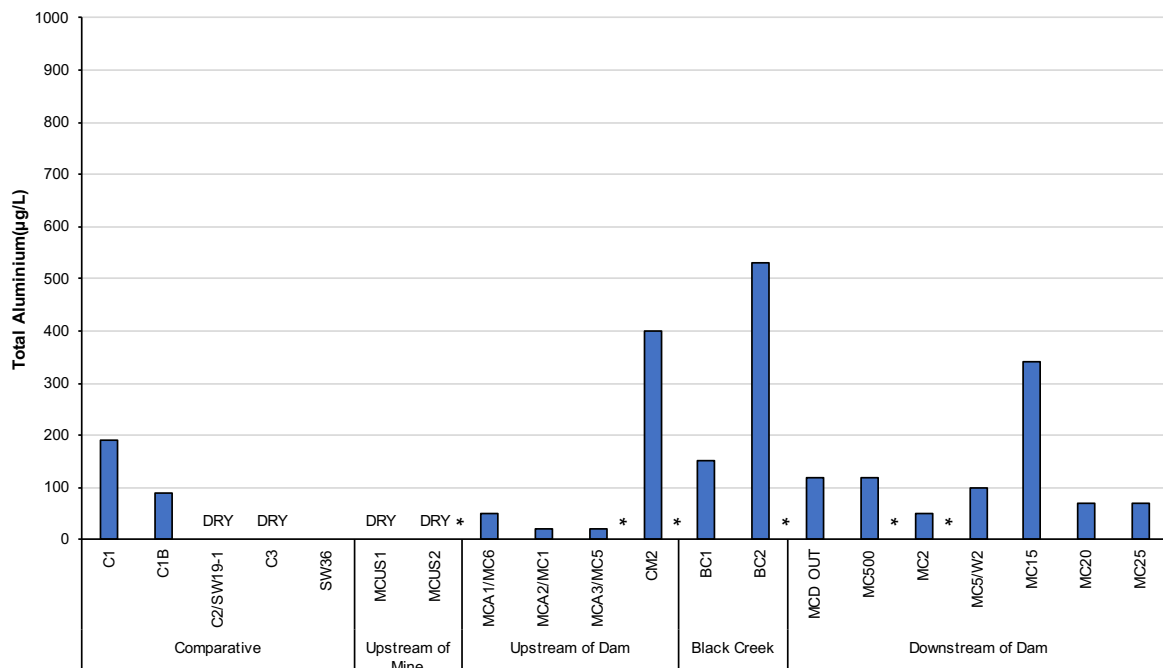


Figure 4.28 Total aluminium concentrations in water in the March 2017 survey ¹⁵

4.3.4.2 Iron

The concentration of total iron was high at both comparative sites on Barker Creek (C1 and C1B), at all sites on Meandu Creek upstream of Meandu Creek Dam (except at site MCA1/MC6), both sites on Black Creek, and at two sites on Meandu Creek downstream of Meandu Creek Dam (MC5/W2 and MC15). Overall, the concentrations of total iron ranged between 150 µg/L and 1480 µg/L at sites on Meandu Creek upstream of Meandu Creek Dam and ranged between 90 µg/L and 430 µg/L at sites downstream of the dam.

The concentrations at sites on Meandu Creek upstream of Meandu Creek Dam (excluding MCA1/MC6) and Black Creek site BC1 were above the range at the comparative sites (between 80 µg/L and 740 µg/L), and the concentrations at sites on Meandu Creek downstream of Meandu Creek Dam were within or below the range of comparative sites (Figure 4.29).

The concentrations of dissolved iron were below the LOR at all sites except at site MCA2/MC1 on Meandu Creek upstream of Meandu Creek Dam, where it was higher than the WQO at 360 µg/L; and at Black Creek site BC1 where it was detected but below the WQO at 50 µg/L (noting that this WQO is to be used as a guide only, and is not directly applicable to the reaches of Meandu Creek and Black Creek upstream of Meandu Creek Dam, for which the designated EV is industrial use) (Figure 4.30).

¹⁵ * on graph indicates where external inputs enter the waterways from discharge locations



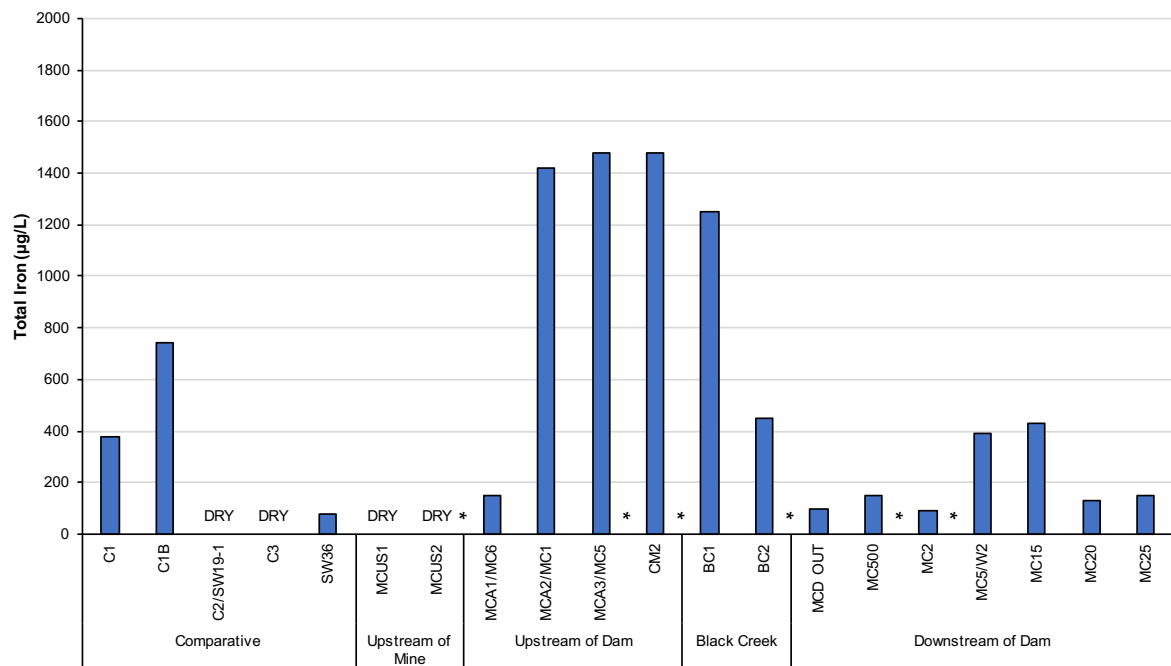


Figure 4.29 Total iron concentrations in water in the March 2017 survey ¹⁶

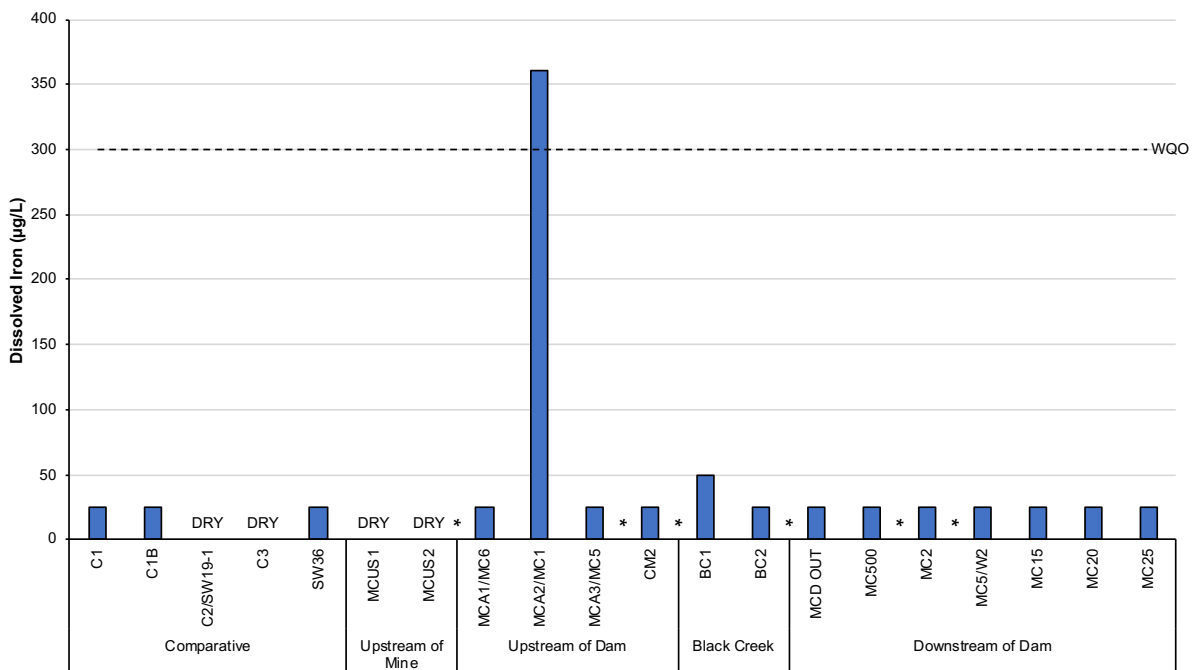


Figure 4.30 Dissolved iron concentrations in water in the March 2017 survey ¹⁷

¹⁶ * on graph indicates where external inputs enter the waterways from discharge locations



4.3.4.3 Manganese

The concentrations of total manganese were high at sites MCA2/MC1 and CM2 on Meandu Creek upstream of Meandu Creek Dam compared to all other sites. The concentrations of total manganese at sites on Meandu Creek upstream of Meandu Creek Dam ranged between 324 µg/L and 2620 µg/L and ranged between 10 µg/L and 733 µg/L at sites on Meandu Creek downstream of Meandu Creek Dam. The concentrations at sites on Meandu Creek upstream of Meandu Creek Dam (excluding MCA1/MC6) and Black Creek site BC1 were above the range at comparative sites (between 36 µg/L and 749 µg/L) and the concentrations at sites downstream of the Meandu Creek Dam were within or below the range of comparative sites (Figure 4.31).

The concentrations of dissolved manganese were above the WQO at site MCA2/MC1 on Meandu Creek upstream of Meandu Creek Dam (noting that this WQO is to be used as a guide only, and is not directly applicable to the industrial use EV upstream of Meandu Creek Dam) and were below the WQO at all other sites. Similar to total manganese, the concentrations of dissolved manganese at sites on Meandu Creek upstream of Meandu Creek Dam (excluding MCA1/MC6) and Black Creek site BC1 were above the range at comparative sites, and the concentrations at sites on Meandu Creek downstream of Meandu Creek Dam were below the WQO and within or below the range of comparative sites (Figure 4.32). Concentrations of dissolved manganese at sites on Meandu Creek upstream of Meandu Creek Dam were within the range previously recorded during historical monitoring (Section 4.2.1.4). Manganese is not routinely monitored in Meandu Creek downstream of Meandu Creek Dam.

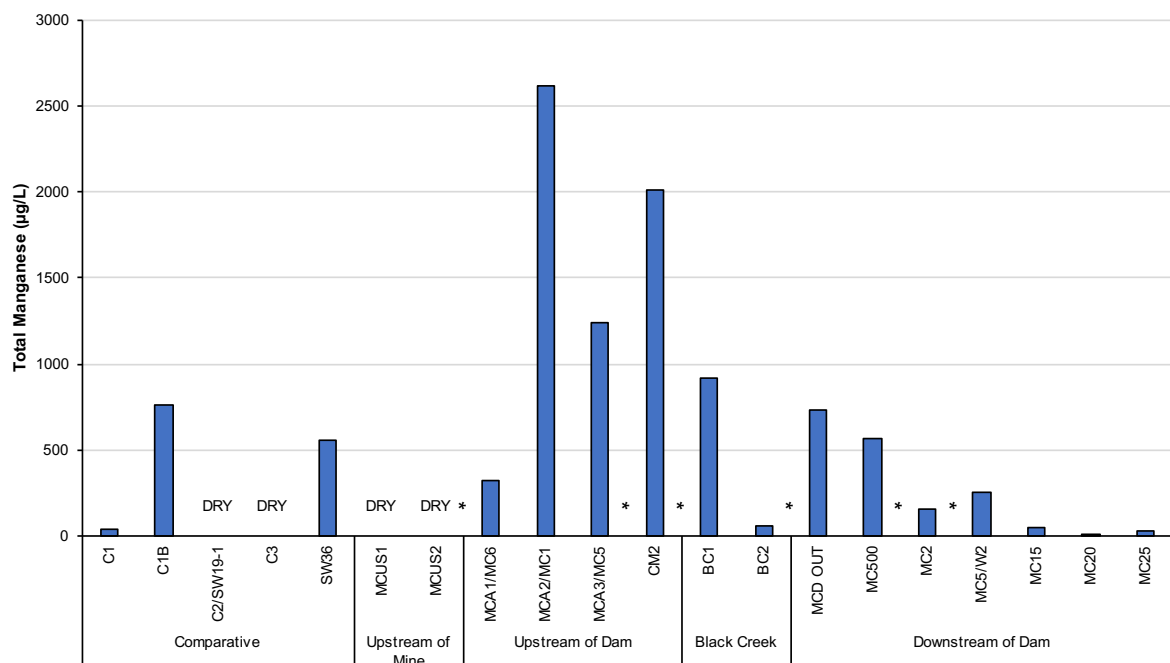


Figure 4.31 Total manganese concentrations in water in the March 2017 survey¹⁷

¹⁷ * on graph indicates where external inputs enter the waterways from discharge locations



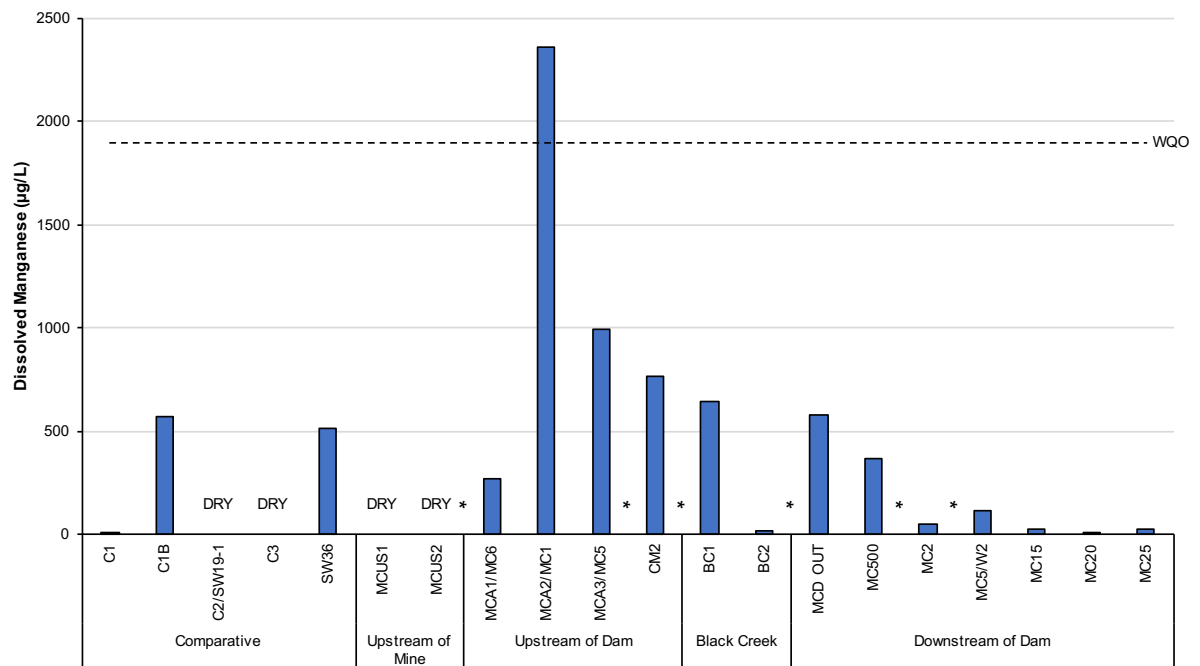


Figure 4.32 Dissolved manganese concentrations in water in the March 2017 survey ¹⁸

4.3.4.4 Nickel

The concentration of total nickel was high at site CM2 on Meandu Creek upstream of Meandu Creek Dam, which is consistent with the high concentrations historically recorded at Meandu Mine compliance site CP3 (Section 4.2.1.4). However, the concentration of dissolved nickel was below the WQO at this site. Total and dissolved nickel was also detected (but below the WQO) at Black Creek site BC1 (although the WQO is for moderately disturbed aquatic ecosystems is not directly applicable to the industrial use waters of Black Creek).

Total and dissolved nickel was detected at all sites on Meandu Creek downstream of Meandu Creek Dam but at concentrations below the WQO. The concentrations of total and dissolved nickel were below the LOR at all comparative sites (Figure 4.33; Figure 4.34).

¹⁸ * on graph indicates where external inputs enter the waterways from discharge locations



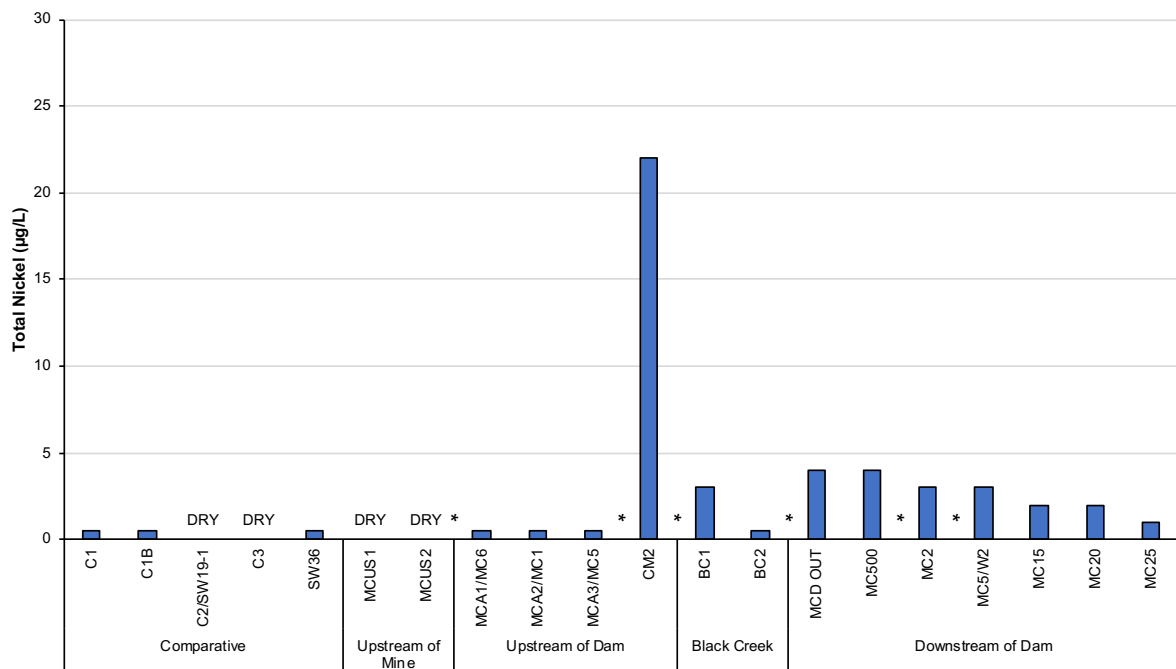


Figure 4.33 Total nickel concentrations in water in the March 2017 survey ¹⁹

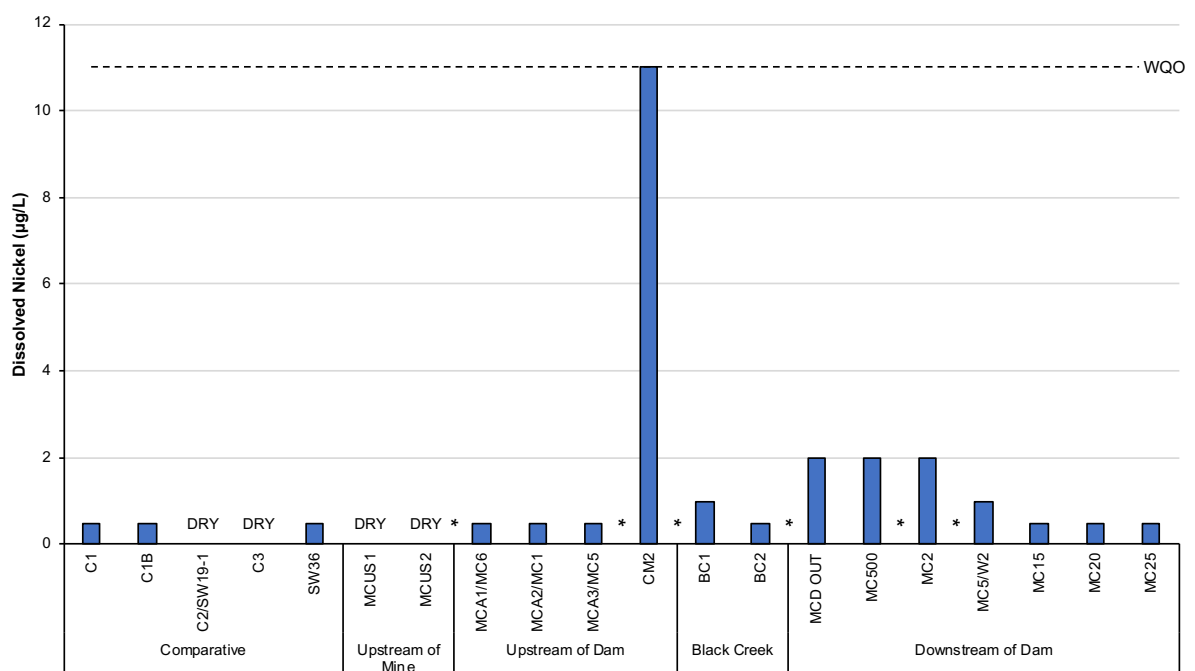


Figure 4.34 Dissolved nickel concentrations in water in the March 2017 survey ²⁰

¹⁹ * on graph indicates where external inputs enter the waterways from discharge locations



4.3.5 Quality Assurance and Quality Control

There was no substantial difference between the sample and field duplicate for most parameters ($RPD < 20\%$ where results were > 10 times LOR). The exception was total alkalinity ($RPD = 39.5\%$). However, the magnitude of difference between the sample and field duplicate for this parameter was small, and only exceeded the recommended RPD threshold by approximately 4%. In addition, internal QAQC procedures undertaken by the laboratory were within acceptable limits. Therefore, the results for this parameter were considered acceptable.

Concentrations of all parameters were below the LOR in the blank sample, indicating that there were no potential sources of sample contamination during field sampling.

The laboratory results for water quality were considered to be accurate.



5 Sediment Quality

5.1 Historical Sediment Quality

Sediment has historically been sampled at sites within Meandu Creek and Meandu Creek Dam, with routine monitoring of sediment quality commencing in 2014. Sediment sampling is conducted by Stanwell every three years at two sites on Meandu Creek (at the Meandu Creek Dam discharge point into Meandu Creek and 5 km downstream of the discharge point) and at nine sites on Meandu Creek Dam, in accordance with the Meandu Creek REMP (ESP 2018).

Concentrations of the following total metals were recorded in high concentrations in the sediment at sites in Meandu Creek Dam in 2014 (JBT Consulting 2014; Footprints 2014):

- copper
- chromium
- arsenic
- mercury
- nickel, and
- zinc.

While concentrations of these parameters exceeded the sediment quality guideline value (SQGV) in Meandu Creek Dam, the SQGV does not necessarily indicate concentrations that are toxic to biota; rather it is a trigger for further investigation of background levels and bioavailability. The concentrations of these metals at sites on Meandu Creek downstream of Meandu Creek Dam did not exceed the SQGVs (except for nickel), indicating that there was no impact on sediments in Meandu Creek downstream of Meandu Creek Dam (JBT Consulting 2014; Footprints 2014). The concentration of nickel at sites on Meandu Creek upstream of the mine also exceeded the SQGVs, indicating that the background concentrations within the catchment were already high, and that an alternative source of nickel (which may be natural) may exist (JBT Consulting 2014; Footprints 2014).

Depth profiles revealed a trend that indicated contaminants have been accumulating in the sediments of Meandu Creek Dam (i.e. it is acting as a sink) (Footprints 2014). This trend was evident with arsenic, chromium, copper, mercury, and nickel. Under normal operating conditions, the presence of these contaminants were not of great concern, however, should there be an event that results in the sediments being disturbed, oxidised and subsequently mobilised and released downstream to Meandu Creek, there may be potential impacts to aquatic health of the downstream system (Footprints 2014a).

5.2 March 2017 Survey

Concentrations of the following parameters were below or equal to the laboratory limits of reporting (LORs) and SQGVs in all sediment samples, and are therefore not discussed further (Attachment B):



- boron
- cadmium, and
- mercury.

Concentrations of the following parameters were below the SQGV at all sites, and / or did not differ between sites and locations, and are therefore not discussed further (Table 5.1):

- Aluminium: the concentration of aluminium in sediment was highest at site MCUS1 on Meandu Creek upstream of the mine, indicating that concentrations are naturally high in the sediment of the study area (there are no SQGVs for aluminium).
- Chromium: the concentration of chromium in sediment was highest (and exceeded the SQGV, but not the sediment quality guideline-high (SQG-high)) at site MCUS1 on Meandu Creek upstream of the mine, indicating that concentrations are naturally high in the sediment of the study area. The concentrations at all other sites were below the SQGV.
- Iron: the concentration of iron in sediment was highest at site MCUS1 on Meandu Creek upstream of the mine, indicating that concentrations are naturally high in the sediment of the study area (there are no SQGVs for iron).
- Selenium: the concentration of selenium in sediment was highest at comparative site C1, indicating that concentrations are naturally high in the sediment of the study area (there are no SQGVs for selenium).
- Vanadium: the concentration of vanadium in sediment was highest at site MCUS1 on Meandu Creek upstream of the mine, indicating that concentrations are naturally high in the sediment of the study area (there are no SQGVs for vanadium).

The concentrations of the following parameters were above the SQGVs at one or more sites and are discussed in more detail below:

- arsenic (Section 5.2.2)
- copper (Section 5.2.3)
- lead (Section 5.2.4)
- nickel (Section 5.2.5), and
- zinc (Section 5.2.6).



Table 5.1 Sediment quality parameters measured at sites during the March 2017 field survey and relevant SQGVs

Parameter	Unit	SQG-High	SQGV	Comparative					Meandu Creek Upstream of Mine		Meandu Creek Upstream of Meandu Creek Dam				Black Creek		Meandu Creek Dam MC Dam ^a	Meandu Creek Downstream of Meandu Creek Dam						
				C1	C1B	C2/SW19	C3	SW36	MCUS1	MCUS2	MCA1 / MC6	MCA2 / MC1	MCA3 / MC5	CM2	BC1	BC2		MCD-OUT	MC500	MC2	MC5/W2	MC15	MC20 / SW16	MC25
Moisture Content	%			66.1	37.6	2.9	2.1	36	28	12.5	23.9	68.4	47.1	58.3	38.1	17.3	51.7	24.4	67.6	18.8	53.1	31.4	37.5	19.2
Metals and Metalloids																								
Aluminium	mg/kg	NA	NA	18700	6040	2650	5200	5140	29000	14600	4890	12700	9980	8180	6090	5150	9740	2680	11500	1110	14000	8280	26000	1840
Arsenic	mg/kg	70	20	<5	<5	<5	<5	5	<5	<5	<5	8	8	9	5	10	10	11	33	<5	14	12	6	<5
Chromium	mg/kg	370	80	30	10	6	9	32	104	73	21	26	16	20	36	5	33	7	64	4	26	54	33	12
Cobalt	mg/kg	NA	NA	23	11	6	12	10	50	14	6	23	42	615	11	8	13	17	86	<2	25	21	27	8
Copper	mg/kg	270	65	21	7	<5	6	9	33	15	6	22	20	31	18	<5	59	6	75	<5	82	12	24	<5
Iron	mg/kg	NA	NA	50300	18300	11900	22000	24100	154000	52500	19600	34300	25600	50800	20000	14400	20000	7940	27400	2530	27100	45200	64600	7740
Lead	mg/kg	220	50	9	<5	<5	<5	8	10	8	55	17	19	24	11	10	22	<5	23	<5	16	11	10	<5
Manganese	mg/kg	NA	NA	345	144	147	211	410	3300	690	199	823	2280	19500	141	194	199	3750	11400	831	2220	777	383	49
Molybdenum	mg/kg	NA	NA	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	4	<2	2	<2	<2	<2	<2	<2	<2	<2	<2
Nickel	mg/kg	52	21	25	10	6	14	12	44	18	6	20	37	261	18	5	26	16	71	4	22	14	29	5
Selenium	mg/kg	NA	NA	16	6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	8	<5	<5	<5	10	<5
Vanadium	mg/kg	NA	NA	83	30	16	25	43	148	82	37	44	35	35	39	13	45	17	74	7	70	72	91	14
Zinc	mg/kg	410	200	112	38	15	30	30	81	36	48	75	154	1780	90	55	105	55	319	7	122	21	106	11

blue shading denotes values that are above the SQG-high

grey shading denotes values that are above the SQGV

^a median for all sites in Meandu Creek Dam is presented

NA no SQGV exists for this parameter



5.2.1 General Trends

5.2.1.1 Meandu Creek Upstream of Meandu Creek Dam

The concentrations of several parameters were much higher at site CM2 on Meandu Creek upstream of Meandu Creek Dam than at all other sites (Table 5.1; Attachment B), including:

- cobalt
- manganese
- molybdenum
- nickel, and
- zinc.

Site CM2 was located at the Meandu Mine inlet to Meandu Creek Dam. This site is located on a section of Meandu Creek that is downstream from the mine, and receives discharges from RD7 and RD8 via compliance point CP3. The site was characterised as a narrow pool with substrate dominated by silt. Cumbungi (bulrush) was present and significantly dense along the banks and within the waterway of the site. Cumbungi is known to have significant sediment-trapping abilities by slowing water flow and trapping suspended sediment in their root systems (Stephens & Dowling 2002). It is likely that the presence of Cumbungi at site CM2 is causing a build-up of fine sediments that are potentially impacted by mining activities. The high concentrations of metals in sediment at site CM2 are likely to be a result of the settlement of fine sediments, which adsorb organic and heavy metal contaminants to a high degree (Volume 2, ANZECC & ARMCANZ 2000a).

5.2.1.2 Meandu Creek Dam

Median concentrations of metals in the sediment of the dam were below the SQGV, except for nickel (Table 5.1). Concentrations of arsenic, chromium and copper exceeded the SQGV at up to three sites in the dam (sites MCD3, 4 and 5; Table 5.2), although the median concentrations for all sites in the dam were below the SQGV (Table 5.1). Sites MCDS3, 4 and 5 are located around the margins of the dam, with sites MCDS3 and MCDS5 located near inputs from the Tarong power stations. Concentrations of nickel and zinc were also highest at these locations. The presence of arsenic, chromium and copper in the sediments of the dam may be related to the use of CCA-treated timber at the Tarong power stations. Sediment depth profiles completed in Meandu Creek Dam in 2014 also indicated that the accumulation of copper in sediments in the dam had been occurring over a long timeframe, and is most likely a result of historical leaching associated with the aluminium/brass alloy piping that was used in the cooling water condensers prior to the replacement of these tubes with titanium tubes (Footprints 2014a).

Sites MCDS1 and MCDS2 are located in Meandu Creek Dam near the inflow from Meandu Creek (which receives discharges from Meandu Mine). Nickel was the only metal detected in concentrations higher than the SQGV at these sites (Table 5.2).



Table 5.2 Sediment quality parameters measured at sites within Meandu Creek Dam during the March 2017 field survey

Parameter	SQ-GV	Meandu Creek Dam								
		MCDS 1	MCDS 2	MCDS 3	MCDS 4	MCDS 5	MCDS 6	MCDS 7	MCDS 8	MCDS 9
Metals and Metalloids (mg/kg)										
Aluminium	NA	9740	9430	17400	11800	14800	11400	1870	5020	8680
Arsenic	20	9	10	49	21	43	9	<5	17	<5
Chromium	80	32	28	145	74	109	33	6	36	13
Cobalt	NA	19	11	13	22	31	27	6	11	11
Copper	65	30	28	243	153	142	36	16	90	59
Iron	NA	22800	20000	29400	25800	23100	16700	2990	8620	10800
Lead	50	22	22	19	22	33	25	<5	8	11
Mang-anese	NA	199	174	429	181	370	521	58	200	160
Molyb-denum	NA	<2	<2	2	4	<2	<2	<2	<2	<2
Nickel	21	28	22	26	58	45	29	6	15	14
Selenium	NA	<5	<5	7	7	6	<5	<5	<5	<5
Vanadium	NA	47	42	76	49	64	45	7	24	20
Zinc	200	108	77	242	247	250	105	34	91	102

blue shading denotes values that are above the SQGV trigger value

NA no comparison criteria for this parameter

5.2.1.3 Meandu Creek Downstream of Meandu Creek Dam

Concentrations of cobalt, manganese and zinc were higher at MC500 compared to other sites downstream of Meandu Creek Dam and comparative sites (Table 5.1; Attachment B). Concentrations were between the SQGV and SQG-high for zinc. At site MC500 the channel morphology was characterised by riffles, pools, bars, bends and sloping banks where sediments are more likely to aggregate (i.e. suspended sediments are more likely to settle at these sites).



In general, the concentrations of metals at site MC2 were significantly lower than concentrations at sites upstream and downstream of it. This is likely to be due to the channel morphology characteristics of the site. Site MC2 was a fast flowing pool in a well-defined section of Meandu Creek with no features (e.g. bars, sloping banks or bends) for sediment to aggregate at (i.e. the majority of suspended sediments would mostly be carried downstream). In contrast, at sites MC500 and MC5/W2 (both downstream of Meandu Creek Dam) the channel morphology was characterised by riffles, pools, bars, bends and sloping banks where sediments aggregate (i.e. suspended sediments are more likely to settle at these sites).

5.2.2 Arsenic

The concentration of arsenic was highest, and above the SQGV (but below the SQG-high), at site MC500 (33 mg/kg) on Meandu Creek downstream of Meandu Creek Dam (Figure 5.1). The concentration of arsenic at sites on Meandu Creek downstream of Meandu Creek Dam (where it was detected) ranged between 6 mg/kg and 33 mg/kg, and was above the concentration at comparative site SW36 (5 mg/kg) (concentrations were below the LOR at all other comparative sites and sites on Meandu Creek upstream of the mine). Arsenic was detected in sediment at sites on Meandu Creek upstream of Meandu Creek Dam, Black Creek sites and in Meandu Creek Dam; concentrations ranged between 5 mg/kg and 10 mg/kg.

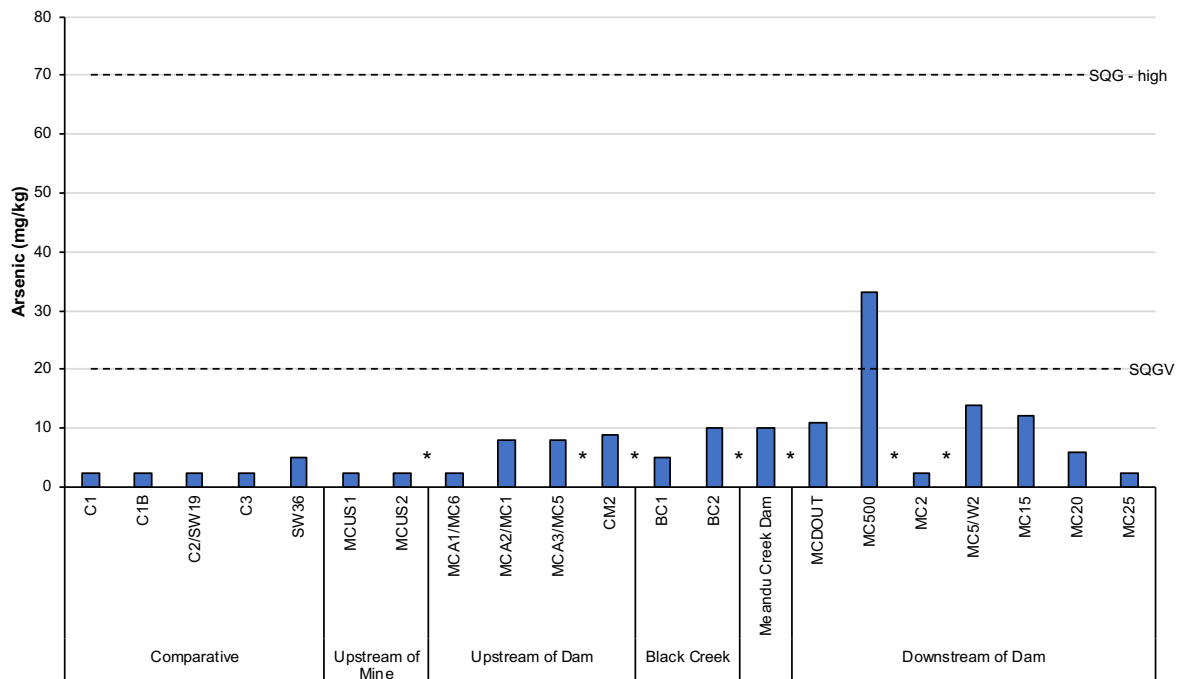


Figure 5.1 Total arsenic concentration in sediment in the March 2017 survey²⁰

²⁰ * on graph indicates where external inputs enter the waterways from discharge locations



5.2.3 Copper

The concentration of copper was highest, and above the SQGV, at site MC5/W2 (82 mg/kg) on Meandu Creek downstream of Meandu Creek Dam followed by site MC500 (75 mg/kg) in this same reach; however, concentrations remained below the SQG-high (Figure 5.2).

Overall, the concentration of copper in sediment at sites on Meandu Creek downstream of Meandu Creek Dam (where it was detected) ranged between 6 mg/kg and 82 mg/kg and was either within or higher than the range at comparative or sites on Meandu Creek upstream of the mine (between 6 mg/kg and 33 mg/kg). While copper was detected in sediment at all sites on Meandu Creek upstream of Meandu Creek Dam, Black Creek site BC1 and in Meandu Creek Dam; copper was below the LOR in the water at all sites.

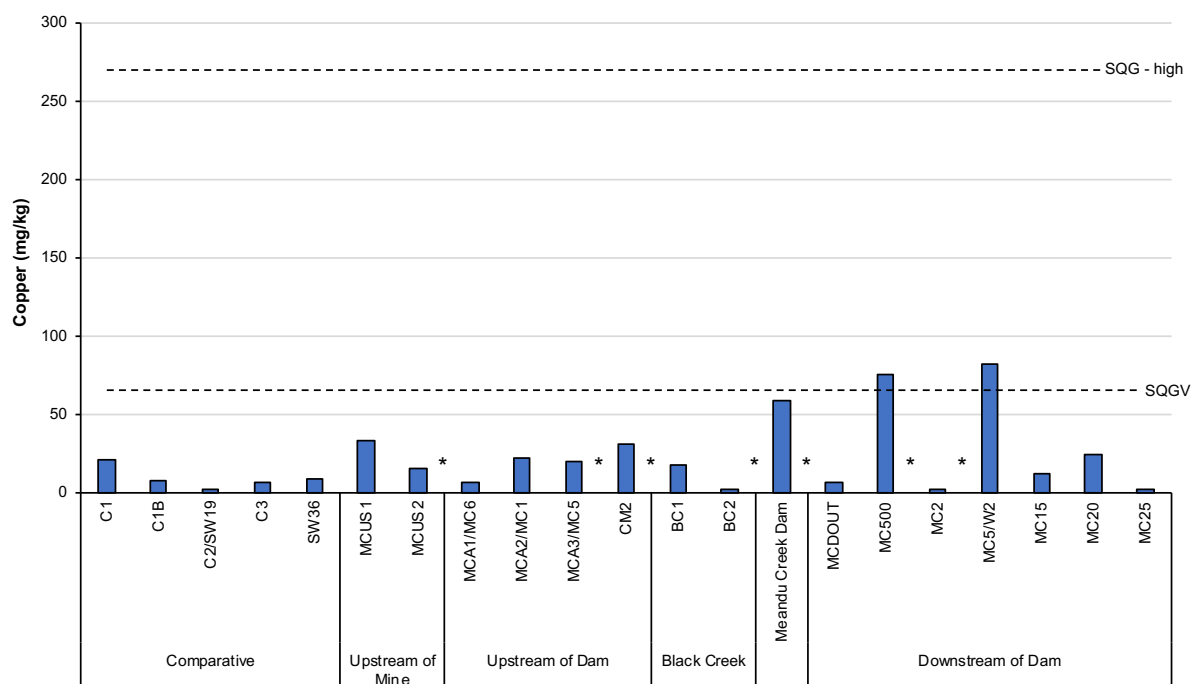


Figure 5.2 Total copper concentration in sediment in the March 2017 survey ²¹

5.2.4 Lead

The concentration of lead was highest, and above the SQGV, at site MCA1/MC6 (55 mg/kg) on Meandu Creek upstream of Meandu Creek Dam but did not exceed the SQG-high (Figure 5.3).

Overall, the concentrations of lead at sites on Meandu Creek downstream of Meandu Creek Dam (where it was detected) ranged between 10 mg/kg and 23 mg/kg and were above or equal to the range of comparative and sites on Meandu Creek upstream of the mine (between 8 and 10 mg/kg) (but well below the SQGV). Concentrations of lead at sites on Meandu Creek upstream of Meandu Creek Dam (except at site MCA1/MC6), Black Creek

²¹ * on graph indicates where external inputs enter the waterways from discharge locations



sites and in Meandu Creek Dam ranged between 10 mg/kg and 22 mg/kg and were above or equal to the range of comparative sites and sites on Meandu Creek upstream of the mine. Lead was below the LOR in the water at all sites. Sediment depth profiles completed in Meandu Creek Dam in 2014 indicated that lead concentrations in sediment were increasing over time, although at the time of the survey they were not considered a contaminant of concern because concentrations were below SQGV at all sites surveyed (Footprints 2014a). The source of lead has not been identified.

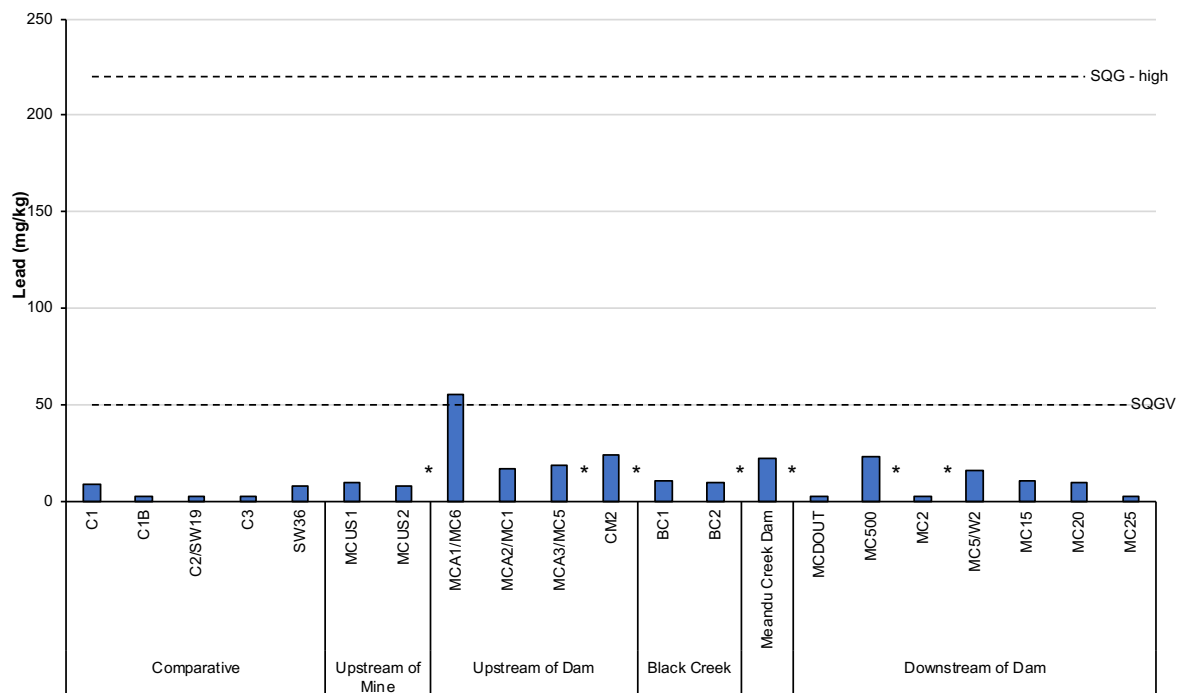


Figure 5.3 Total lead concentration in sediment in the March 2017 survey ²²

5.2.5 Nickel

The concentration of nickel was highest, and above the SQG-high, at site CM2 (261 mg/kg) on Meandu Creek upstream of Meandu Creek Dam and site MC500 (71 mg/kg) on Meandu Creek downstream of Meandu Creek Dam (Figure 5.4). Nickel concentrations have historically exceeded the SQGV at a number of locations, with potential sources including local geology, metal leaching from condensers at Tarong Power Station (prior to their replacement with titanium) and mine-affected water, as well as the cycling of raw water from Boondooma Dam.

²² * on graph indicates where external inputs enter the waterways from discharge locations



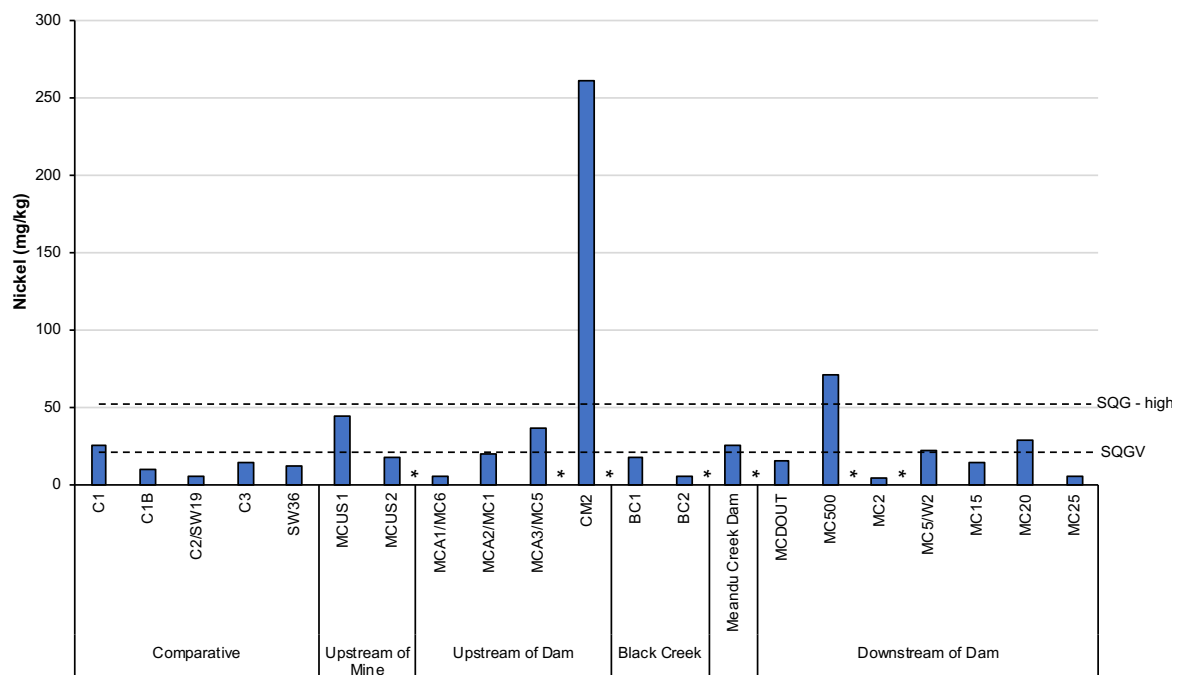


Figure 5.4 Total nickel concentration in sediment in the March 2017 survey ²³

5.2.6 Zinc

The concentration of zinc was highest at site CM2 on Meandu Creek upstream of Meandu Creek Dam (1780 mg/kg, above the SQG-high), and site MC500 on Meandu Creek downstream of Meandu Creek Dam (319 mg/kg, above the SQGV). Zinc was detected at all other sites in concentrations below the SQGV (Figure 5.4). However, for the most part (with the exception of site MC500), concentrations of zinc downstream of Meandu Creek Dam were within the range recorded at the comparative and upstream sites.

²³ * on graph indicates where external inputs enter the waterways from discharge locations



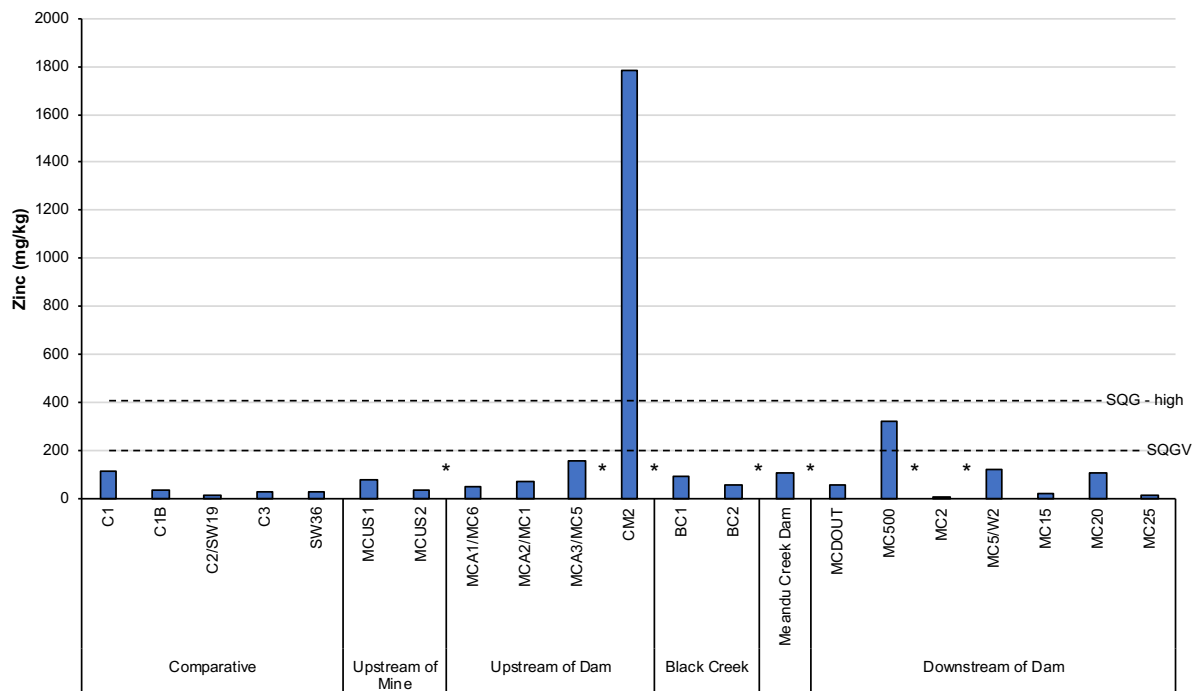


Figure 5.5 Total zinc concentration in sediment in the March 2017 survey²⁴

5.2.7 Quality Assurance / Quality Control

There was no substantial difference between the sample and field replicate for most parameters (RPD < 50%). The exception was cadmium (RPD = 66.6%). However, the magnitude of difference between the sample and the field replicate was very small (1 mg/kg difference; exceeded the recommended RPD by approximately 17%). Cadmium was below the LOR in all samples except the field replicate, and in the field replicate the concentration was only 1 mg/kg above the LOR. In addition, QA/QC procedures undertaken by the laboratory were within acceptable limits. Therefore, the results for this parameter were not considered to be of concern.

The laboratory results for sediment quality for March 2017 were considered to be accurate.

5.3 April 2018 Survey

In April 2018, results for total metals and metalloids were generally similar to those from the March 2017 survey. In April 2018, 95th percentile concentrations of the following total metals and metalloids were below or equal to the LORs in all sediment samples, and are therefore not discussed further (Attachment B):

- boron
- cadmium, and

²⁴ * on graph indicates where external inputs enter the waterways from discharge locations



- selenium.

The 95th percentile concentrations of the following total metals and metalloids were below SQGV at all sites, and / or did not differ between sites and locations, and are therefore not discussed further (Table 5.3):

- Aluminium: the total concentration of aluminium in sediment was highest at site MCUS1 on Meandu Creek upstream of the mine and at sites BPD1 and BPD2 on Bjelke-Peterson Dam, indicating that concentrations are naturally high in the sediment of the study area (there is no SQGV for aluminium).
- Chromium: the total concentration of chromium in sediment was high (and exceeded the SQGV, but not the SQG-high) at sites MCDS3 and MCDS5 on Meandu Creek Dam but also at MCUS1 on Meandu Creek upstream of the mine, indicating that concentrations are naturally high in the sediment of the study area. Concentrations at sites MCDS3 and MCDS5 on Meandu Creek Dam were relative similar to MCUS1 on Meandu Creek upstream of the mine.
- Iron: the total concentration of iron in sediment was highest at site MCUS1 on Meandu Creek upstream of the mine, indicating that concentrations are naturally high in the sediment of the study area (there is no SQGV for iron).
- Mercury: the total concentration of mercury in sediment was equal to or below the LOR at all sites except comparative site C1 (where it was also above the SQGV), indicating that concentrations are not of concern in the study area or surrounds.
- Vanadium: the total concentration of vanadium in sediment was high at comparative sites MCUS1 and MCUS2 on Meandu Creek upstream of the mine, as well as BPD1 and BPD2 on Bjelke-Peterson Dam, indicating that concentrations are naturally high in the sediment of the study area (there is no SQGV for vanadium).

The total concentrations of the following parameters were above the SQGV at one or more sites and / or showed a trend between locations (see graphs in Attachment D):

- Arsenic: the 95th percentile concentration of total arsenic was above the SQGV at most sites on Meandu Creek Dam (except MCDS2) and at site MC500 downstream of Meandu Creek Dam. The 95th percentile concentrations remained below the SQG-high. The 95th percentile arsenic concentrations were equal to or below the LOR at all comparative sites and sites on Meandu Creek upstream of the mine, and all sites downstream of MC500 (i.e. from 5 km downstream). Arsenic is sparingly soluble in acid and thus total concentrations rather than dilute acid extractable concentrations were compared to guidelines.
- Copper: the 95th percentile concentration of total copper was above the SQGV (but below the SQG-high) at half of the sites on Meandu Creek Dam (i.e. MCDS4 and MCDS5). It was below the SQGV at all other sites but was slightly higher than the range at comparative sites and sites upstream of the mine at sites MCDOUT and MC500 downstream of Meandu Creek Dam. The 95th percentile concentration of dilute acid extractable copper (considered to be the potential bioavailable concentration) was also above the SQGV at site MCDS4.



- Lead: the 95th percentile concentration of total lead was slightly higher at most sites upstream of, within, and immediately downstream of Meandu Creek Dam than at comparative sites and sites upstream of the mine. Regardless of these differences, it was below the SQGV at all sites.
- Nickel: the 95th percentile concentration of total nickel was highest at site CM2 upstream of Meandu Creek Dam (where it was above the SQG-high). It also exceeded the SQGV at site MCUS1 upstream of the mine, site MCA3/MC5 upstream of Meandu Creek Dam, most sites on Meandu Creek Dam, and sites MCD-OUT, MC500 and MC20/SW16 in Meandu Creek downstream of Meandu Creek Dam. The 95th percentile concentration of dilute acid extractable nickel (considered to be the potential bioavailable concentration) was also above the SQGV at sites CM2 upstream of the dam, MCDS2 and MCDS4 on Meandu Creek Dam and MC500 in Meandu Creek downstream of Meandu Creek Dam.
- Zinc: the 95th percentile concentration of total zinc was highest at site CM2 upstream of Meandu Creek Dam and MCDS2 on Meandu Creek Dam (where it exceeded the SQG-high). It also exceeded the SQGV at sites MCDS4 and MCDS5 on Meandu Creek Dam. The 95th percentile concentration of dilute acid extractable zinc (considered to be the potential bioavailable concentration) was also above the SQG-high at site CM2 and the SQGV at sites MCDS2 and MCDS5.

Of these metals, nickel and zinc are indicators of AMD at Meandu Mine and are discussed further in Sections 5.3.2 and 5.3.3. As discussed above, the presence of arsenic, lead and copper in the sediments of the dam may be related to other sources not related to AMD, such as the use of CCA-treated timber at the Tarong power stations (arsenic and copper only).



Table 5.3 The 95th percentile concentrations of sediment quality parameters measured at sites during the April 2018 field survey and relevant SQGVs

Parameter	Unit	SQG-High	SQGV	Comparative		Meandu Creek Upstream of Mine		Meandu Creek Upstream of Meandu Creek Dam				Meandu Creek Dam					Meandu Creek Downstream of Meandu Creek Dam				Bjelke-Peterson Dam	
				C1	SW36	MCUS1	MCUS2	MCA1 / MC6	MCA2 / MC1	MCA3 / MC5	CM2	MCDS2	MCDS3	MCDS4	MCDS5	MCD-OUT	MC500	MC5/W2	MC20 / SW16	BPD1	BPD2	
Moisture Content	%	NA	NA	38.66	18.38	14.06	10.12	47.92	56.37	63.77	61.20	54.31	47.88	71.10	67.29	48.88	67.61	19.44	34.07	65.36	63.46	
Total Metals																						
Aluminium	mg/kg	NA	NA	8167	3740	24400	14230	13240	6168	7119	6721	5604	4082	6843	7942	7229	6404	1898	21300	19350	14980	
Arsenic	mg/kg	70	20	2.50	2.50	2.50	2.50	6.90	2.50	11.40	6.80	12.80	52.40	31.20	40.70	19.90	37.80	2.50	2.50	4.75	4.75	
Chromium	mg/kg	370	80	13.80	21.90	86.90	64.00	31.00	14.80	14.70	18.70	24.00	127.40	62.80	94.20	25.40	34.10	9.00	28.90	24.00	21.00	
Cobalt	mg/kg	NA	NA	10.80	6.90	27.60	14.80	20.30	9.80	75.60	304.20	68.50	7.60	22.80	30.60	50.30	56.90	3.00	24.80	19.90	21.90	
Copper	mg/kg	270	65	9.00	6.90	29.60	16.60	16.80	16.90	13.90	25.60	33.00	54.00	152.60	110.40	39.80	38.00	2.50	20.00	22.90	24.00	
Iron	mg/kg	NA	NA	27600	19630	107980	45690	35780	14810	49580	23330	15980	13899	17480	16350	18140	24550	6036	55680	39940	34690	
Lead	mg/kg	220	50	2.50	5.65	9.80	7.90	16.60	11.90	13.80	17.80	18.00	6.55	14.00	17.90	11.90	13.50	2.50	9.60	8.90	10.00	
Manganese	mg/kg	NA	NA	208	248	1623	760	4630	1030	10020	8776	643	320	152	893	5776	25120	333	998	2300	1196	
Molybdenum	mg/kg	NA	NA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.90	1.00	1.00	2.90	1.00	4.80	1.00	1.00	1.00	1.00	1.00	
Nickel	mg/kg	52	21	11.80	8.90	32.60	17.60	19.20	12.70	25.90	128.50	58.00	13.10	48.00	33.00	37.40	39.90	5.80	27.80	19.00	19.00	
Vanadium	mg/kg	NA	NA	42.10	43.40	123.30	80.90	59.10	24.80	27.80	30.60	32.90	28.60	49.70	40.90	52.30	52.30	17.90	83.90	70.00	56.90	
Zinc	mg/kg	410	200	48.70	19.90	75.20	40.60	97.60	51.30	97.20	687.50	508.00	72.60	214.50	262.00	121.30	134.30	11.80	107.90	55.90	58.90	
Mercury	mg/kg	1	0.15	0.19	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.05	0.10	0.05	0.10	0.05	0.05	0.05	0.05	
Acid Dilute Extractable Metals																						
Aluminium	mg/kg	NA	NA	2090	539	2725	1989	1561	1457	1035	1133	867	580	729	1039	829	799	237	2993	2938	2115	
Arsenic	mg/kg	70	20	0.50	0.50	0.50	0.50	1.40	1.37	5.42	2.37	5.67	22.60	9.53	14.90	5.85	19.31	0.50	1.18	1.86	1.29	
Cadmium	mg/kg	10	1.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.40	0.40	0.50	0.47	0.20	0.50	0.50	0.50	0.50	0.50	0.50	
Cobalt	mg/kg	NA	NA	6.69	3.46	7.36	5.02	10.69	7.31	51.14	250.40	26.48	3.47	5.98	10.63	19.21	37.99	1.25	9.41	10.97	10.92	
Chromium	mg/kg	370	80	1.58	2.52	1.79	1.40	2.32	2.99	0.50	1.84	5.93	45.25	8.01	24.51	6.36	11.87	0.50	1.89	3.29	3.09	
Copper	mg/kg	270	65	4.66	2.29	10.40	7.37	8.22	10.94	8.66	14.38	24.90	29.42	65.12	60.89	19.02	19.31	1.83	8.00	12.07	12.04	



Parameter	Unit	SQG-High	SQGV	Comparative		Meandu Creek Upstream of Mine		Meandu Creek Upstream of Meandu Creek Dam				Meandu Creek Dam				Meandu Creek Downstream of Meandu Creek Dam				Bjelke-Peterson Dam	
				C1	SW36	MCUS1	MCUS2	MCA1 / MC6	MCA2 / MC1	MCA3 / MC5	CM2	MCDS2	MCDS3	MCDS4	MCDS5	MCD-OUT	MC500	MC5/W2	MC20 / SW16	BPD1	BPD2
Iron	mg/kg	NA	NA	5515	2506	6380	4183	18024	8474	49111	14360	4659	7982	4598	5096	5990	17420	959	5704	11360	9570
Lead	mg/kg	220	50	1.65	2.29	3.59	4.23	9.07	10.50	7.74	12.11	11.28	3.53	8.06	11.85	6.83	7.26	0.50	3.05	5.60	7.15
Manganese	mg/kg	NA	NA	135	187	550	231	4674	1321	10631	9893	444	263	80	534	4824	22440	188	428	1847	820
Nickel	mg/kg	52	21	4.34	2.14	5.44	2.93	8.19	8.31	18.63	109.66	30.18	8.20	22.27	17.12	17.61	28.76	2.58	6.47	6.28	6.57
Vanadium	mg/kg	NA	NA	12.79	7.10	24.16	12.87	15.13	13.28	8.17	11.61	17.81	20.18	30.27	27.66	28.37	37.66	4.67	24.80	35.44	28.79
Zinc	mg/kg	410	200	13.48	5.78	10.73	7.43	33.13	42.69	65.35	741.80	392.30	50.02	143.80	214.70	83.52	113.96	5.57	18.29	17.68	22.85
Molybdenum	mg/kg	NA	NA	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Total Organic Carbon	%	NA	NA	8.10	1.17	4.01	5.00	2.49	6.07	7.99	5.26	3.12	3.23	5.02	4.94	3.06	4.25	0.56	1.18	3.86	4.52
Particle Grain Size																					
Fines (< 75 µm)	%	NA	NA	25.50	15.20	90.40	62.40	85.60	91.90	73.90	95.00	95.90	13.10	72.80	90.40	72.20	53.00	5.00	88.90	77.70	82.00
Sand (> 75 µm)	%	NA	NA	61.10	77.20	16.80	46.30	30.40	13.20	43.50	5.80	4.90	91.70	43.10	10.90	49.10	54.40	80.60	11.70	17.70	9.70
Gravel (> 2 mm)	%	NA	NA	30.00	47.20	1.85	12.90	2.90	3.00	5.80	1.00	1.90	24.90	19.20	15.80	4.80	14.30	36.00	3.80	28.60	13.90
Cobbles (>6 cm)	%	NA	NA	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
SEM:AVS		NA	NA	0.10	0.15	0.94	0.20	0.12	0.03	0.16	1.33 ^a	0.42	0.18	0.22	0.24	0.20	0.12	0.04	0.32	0.14	0.05

blue shading denotes values that are above the SQG-high trigger value

grey shading denotes values that are above the SQG-low trigger value

NA no SQGV exists for this parameter

^a shaded value indicates that sediments contain a molar excess of simultaneously extracted cadmium, copper, nickel, lead and zinc over acid volatile sulfides at this site (i.e. SEM:AVS ratio > 1)



5.3.1 General Trends

5.3.1.1 Meandu Creek Upstream of Meandu Creek Dam

Overall, general trends in the concentrations of total metals and metalloids were similar in March 2017 and April 2018 (see graphs in Attachment D). The concentrations of several total metals and metalloids were higher at site CM2 on Meandu Creek upstream of Meandu Creek Dam than at all other sites (Table 5.3), including:

- cobalt
- manganese (also high at site MCA3/MC5)
- molybdenum
- nickel, and
- zinc.

Potential bioavailable concentrations (i.e. acid dilute extractable concentrations) of nickel and zinc exceeded the SQG-high (as discussed further in Sections 5.3.2 and 5.3.3 below). Sediments at this site did not contain a molar excess of acid volatile sulfides compared to simultaneously extracted metals, therefore these metals may be bioavailable to aquatic organisms at this site (Simpson & Batley 2016).

Site CM2 was located at the Meandu Mine inlet to Meandu Creek Dam. As discussed in Section 5.2.1.1, this site is located on a section of Meandu Creek that is downstream from the mine, and receives discharges from RD7 and RD8 via compliance point CP3. The site was characterised as a narrow pool with substrate dominated by silt. Cumbungi (bulrush) was present and significantly dense along the banks and within the waterway of the site. It is likely that the presence of Cumbungi at site CM2 and the slowing of water as it enters the dam are causing a build-up of fine sediments that are potentially impacted by mining activities.

Bioavailable concentrations of all other metals and metalloids (as indicated by acid dilute extractable metals) and were below the SQGV (where available) at all other sites upstream of Meandu Creek Dam.

5.3.1.2 Meandu Creek Dam

Concentrations of total arsenic, chromium, copper, nickel and zinc exceeded the SQGV at up to three sites in the dam (Table 5.3). Sites MCDS3, MCDS4 and MCDS5 are located around the margins of the dam, with sites MCDS3 and MCDS5 also located near inputs from the Tarong power stations. The presence of arsenic, chromium and copper in the sediments of the dam at sites MCDS3, MCDS4 and/or MCDS5 may be related to the use of CCA-treated timber at the Tarong power stations. Sediment depth profiles completed in Meandu Creek Dam in 2014 also indicated that the accumulation of copper in sediments in the dam had been occurring over a long timeframe, and is most likely a result of historical leaching



associated with the aluminium/brass alloy piping that was used in the cooling water condensers (Footprints 2014a).

Site MCDS2 is located in Meandu Creek Dam near the inflow from Meandu Creek (which receives discharges from Meandu Mine). Nickel and zinc, which are potential key indicators of AMD, were the only metals detected in concentrations higher than the SQGV at this site; the potential bioavailable concentrations (i.e. acid dilute extractable concentrations) of these metals also exceeded the SQGV. The acid dilute extractable concentration of nickel was also above the SQGV at site MCDS4 and the acid dilute extractable concentration of zinc was also above the SQGV at MCDS5. However, sediment at these sites contained a molar excess of acid volatile sulfides compared to simultaneously extracted metals, therefore it is considered that metals were not bioavailable (via porewater) to aquatic organisms (Simpson & Batley 2016). These metals were also high in sediments at site CM2 in Meandu Creek upstream of the dam, as discussed in Section 5.3.1.1 (Table 5.3).

Concentrations of all metals and metalloids in sediment were not considered bioavailable at sites in Meandu Creek Dam in April 2018.

5.3.1.3 Meandu Creek Downstream of Meandu Creek Dam

Concentrations of total arsenic, cobalt, copper, manganese, nickel and zinc were higher at MC500 compared to other sites downstream of Meandu Creek Dam and comparative sites; of these parameters, cobalt, manganese and zinc are considered key potential indicators of AMD (Table 5.3). Although total concentrations of these metals were high at this site, and in some cases exceeded the SQGV where available (e.g. arsenic, nickel), the maximum bioavailable concentrations (i.e. dilute acid extractable concentrations) were generally low. The exception was nickel, with the maximum bioavailable concentration exceeding the SQGV. However, there was molar excess of acid volatile sulfides compared to simultaneously extracted metals at this site, therefore it is considered that metals were not dissolved (i.e. bioavailable) and are of low risk to aquatic organisms (Simpson & Batley 2016). At site MC500 the channel morphology was characterised by riffles, pools, bars, bends and sloping banks where sediments are more likely to aggregate (i.e. suspended sediments are more likely to settle at these sites).

5.3.2 Nickel

In April 2018, concentrations of nickel were generally higher at sites upstream of, within, and immediately downstream (within 500m) of Meandu Creek Dam than at sites upstream of the mine and comparative sites. The potential bioavailable concentration of nickel (i.e. dilute acid extractable nickel) was highest, and above the SQG-high, at site CM2 (mean of 70.5 mg/kg) on Meandu Creek upstream of Meandu Creek Dam (Figure 5.6). It also exceeded the SQGV at site MCDS2 (mean of 26.3 mg/kg) and MCDS4 (mean of 13.4 mg/kg) on Meandu Creek Dam and site MC500 (mean of 27.6 mg/kg) downstream of Meandu Creek Dam. Potential sources of nickel include local geology (total nickel was also high and above the SQGV at upstream site MCUS1), metal leaching from condensers at Tarong Power Station (prior to their replacement with titanium) and mine-affected water, as well as cycling of raw water from Boondooma Dam.



Regardless of these occasionally high concentrations of nickel, there was molar excess of acid volatile sulfides over simultaneously extracted metals at all sites downstream of the Meandu Creek Dam, within Meandu Creek Dam, and most sites upstream of the dam (except for CM2). Therefore, it is considered that metals were not bioavailable to aquatic organisms at all sites downstream of Meandu Creek Dam, and most other sites except site CM2 (Simpson & Batley 2016).

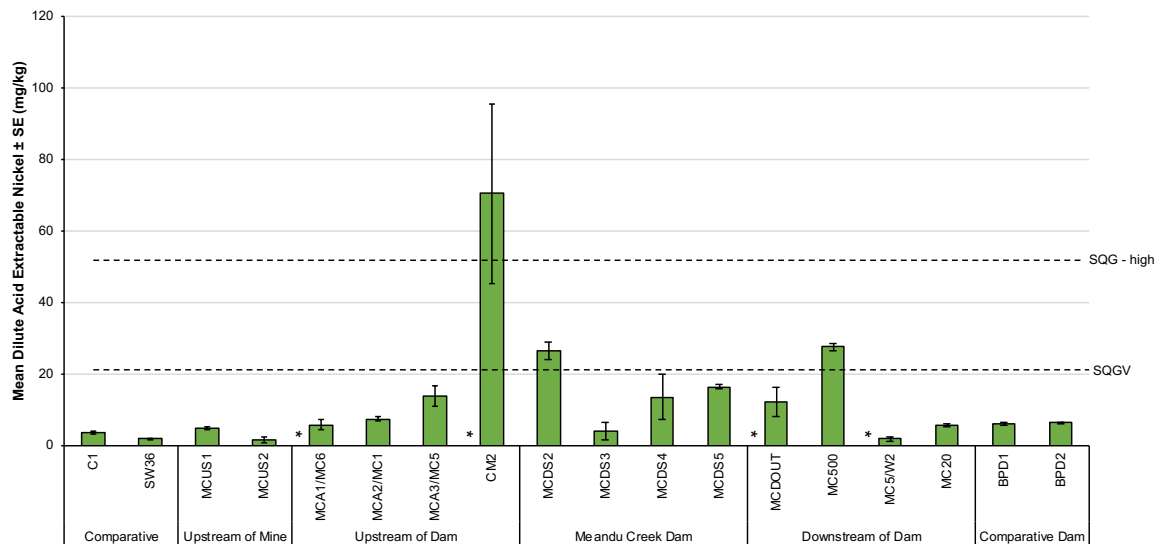


Figure 5.6 Mean ($\pm$ SE) concentration of acid dilute extractable nickel in sediment in the April 2018 survey²⁵

5.3.3 Zinc

In April 2018, concentrations of zinc generally followed a similar pattern to nickel described above, with concentrations higher at sites upstream of, within, and immediately downstream (within 500 m) of Meandu Creek Dam than at sites upstream of the mine and comparative sites. The potential bioavailable concentration of zinc (i.e. dilute acid extractable zinc) was highest, and above the SQG-high, at site CM2 (mean of 529.0 mg/kg) on Meandu Creek upstream of Meandu Creek Dam (Figure 5.7). It also exceeded the SQGV at site MCDS2 (mean of 338.0 mg/kg) and MCDS5 (mean of 189.0 mg/kg) on Meandu Creek Dam.

Bioavailable (dilute acid extractable) concentrations of zinc were below the SQGV at all sites downstream of the Meandu Creek Dam (Figure 5.7). There was also molar excess of acid volatile sulfides compared to simultaneously extracted metals at all sites downstream of Meandu Creek Dam, within Meandu Creek Dam, and most sites upstream of the dam (except for CM2). This indicates that metals are likely to be bound in sulfide complexes and have limited bioavailability to aquatic flora and fauna at all sites except site CM2.

²⁵

* on graphs indicates where external inputs enter the waterways from discharge locations



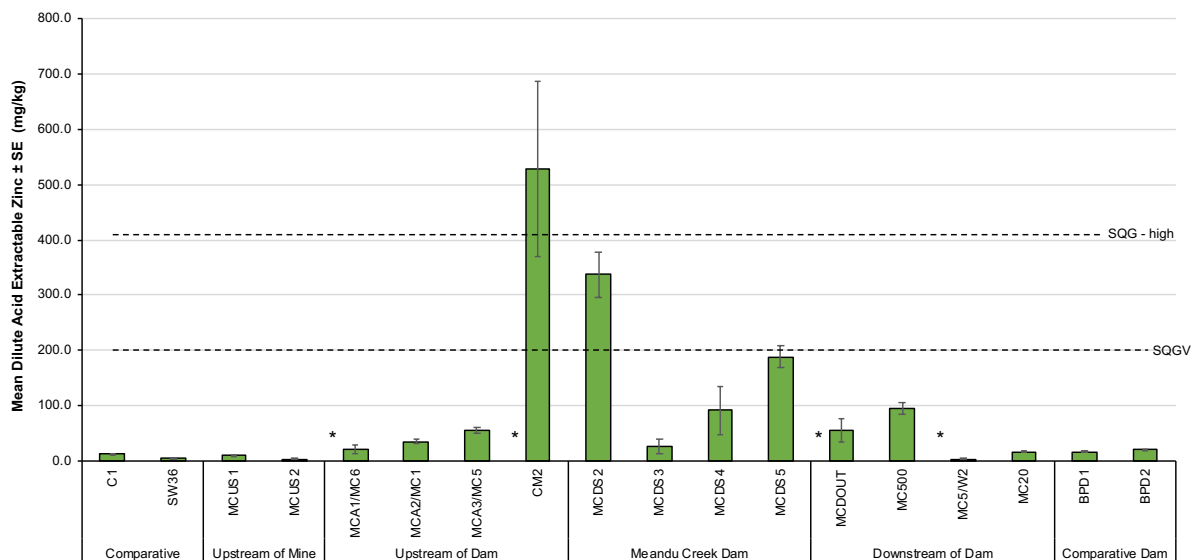


Figure 5.7 Mean ($\pm$ SE) concentration of acid dilute extractable zinc in sediment in the April 2018 survey²⁶

5.3.4 Quality Assurance / Quality Control

ALS Environmental reported high sample heterogeneity in several sediment samples, resulting in poor quality assurance / quality control results for some parameters (confirmed by re-analysis of duplicate samples; see laboratory certificates of analysis in Attachment B). High sample heterogeneity, along with high background concentrations of some parameters, also contributed to poor spike recovery for some parameters.

The relative standard deviation between replicate sediment samples exceeded the recommended guidelines (> 50% where results were > 10 times the limit of reporting) for some parameters at some sites in April 2018. Given the high level of heterogeneity deduced from the laboratory, this result is not unsurprising. Given three replicate samples were collected at each site, the heterogeneity between samples has been captured and assessed in the calculations standard errors at each site. Further, the 95th percentile concentration (representing the upper concentration limits at each site) has been used for comparisons to guidelines. Thus, the laboratory results for sediment quality for April 2018 were considered to be accurate.

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* on graphs indicates where external inputs enter the waterways from discharge locations



6 Aquatic Habitat

The study area is located within the Burnett Basin in the Barker and Barambah creeks Sub-basin. Waterways within this region are generally impacted by one of more of the following: industrial land use; agricultural land use; hydrological change; riparian degradation; and weed infestation (BMRG 2015).

A summary of the aquatic habitat within each location surveyed is presented below, and specific habitat observations recorded at each of the sites surveyed is presented in Attachment E.

6.1 Comparative Sites

In general, comparative sites on Barker Creek were characterised as isolated pools disconnected from waterways upstream and downstream (Figure 6.1), or dry creek beds. The riparian vegetation was significantly impacted by vegetation clearing associated with the adjacent land uses (cropping and grazing). In-stream habitats had a number of features providing structure and shelter for aquatic fauna (including bank vegetation, a variety of in-stream vegetation and woody debris) but they lacked a variety of flow regimes (riffles, runs and glides), depth profiles and channel sinuosity (bends, bars and straight sections). External impacts were moderate and mostly associated with the adjacent land clearing that had reduced the presence and continuity of riparian vegetation. Other apparent impacts included stock access and poor connectivity to other waterways.

The comparative site on Barambah Creek (site SW36) was characterised as a flowing pool located approximately 5 km downstream from Bjelke-Petersen Dam. Flows are released from the dam for downstream uses (including drinking water), resulting in a perennial flow regime. The riparian vegetation was impacted by vegetation clearing associated with the adjacent land uses (cropping and grazing) and a road corridor and road bridge that crossed above the site. In-stream habitats had a significant number of features providing excellent structure and shelter for aquatic fauna (including bank vegetation, a variety of in-stream vegetation including submerged aquatic plants, woody debris as well as a variety of flow regimes (including pool, glide, run, and riffle), depth profiles and channel sinuosity (Figure 6.2). External impacts were moderate and mostly associated with adjacent land clearing that has reduced the presence and continuity of riparian vegetation. Some human impact from recreational fishing and camping was also apparent.





Figure 6.1 Isolated pool at comparative site C1B on Barker Creek



Figure 6.2 A wide variety of connected aquatic habitat types at comparative site SW36 on Barambah Creek

6.2 Meandu Creek Upstream of Mine

Upstream sites on Meandu Creek were characterised as ephemeral drainage channels (Figure 6.3). The riparian vegetation was in good condition due to minimal impacts from the surrounding land use (sites were within the Yarraman State Forest). In-stream habitat was not assessed in the dry conditions, and it is unlikely that the waterways would hold water for long periods even after rain. External impacts were low given the surrounding area was intact native forest; the most apparent impact was humans accessing the State Forest for recreational activities.





Figure 6.3 Ephemeral drainage channel with good riparian cover at site MCUS2 on Meandu Creek upstream of the mine

6.3 Meandu Creek Upstream of Meandu Creek Dam

The sites located on Meandu Creek upstream of Meandu Creek Dam were characterised as isolated pools disconnected from waterways upstream and downstream. The riparian vegetation was impacted by vegetation clearing associated with the adjacent land use (mining activities) (Figure 6.4). In-stream habitats had a number of features providing some structure and shelter for aquatic fauna, but sites were typically dominated by one or two main habitat features (predominantly in-stream vegetation) and they lacked the variety of habitat associated with different flow regimes and channel sinuosity. External impacts were high and mostly associated with the adjacent land use (Meandu Mine); channel modifications have changed the natural flow and function of the waterway and the natural source of water feeding the sites. It is understood that in 2016 and 2017 seepage into the reaches adjacent to the mine was managed by pumping out the pools regularly into RD7 (though currently pumping is very infrequent, and is expected to remain rare in 2019).



Figure 6.4 Poor riparian cover due to vegetation clearing at site CM2



6.4 Black Creek

The sites on Black Creek were both characterised as large pools significantly altered from their natural states and not connected to waterways further upstream and downstream. The riparian vegetation was impacted by vegetation clearing associated with the adjacent land uses (Tarong and Tarong North power stations) and the construction of the Black Creek diversion channel (Figure 6.5). While Black Creek Dam provides some habitat for aquatic flora and fauna, in the constructed channel downstream of the dam the habitat is entirely engineered.



Figure 6.5 Highly modified diversion channel at Black Creek site BC2

6.5 Meandu Creek Dam

Meandu Creek Dam was characterised as a constructed waterbody connected to waterways further upstream and downstream via various inlets, outlets and waterway channels. The riparian vegetation condition varied around the perimeter of the dam and consisted of some cleared areas and some well-vegetated areas of intact native forest. The in-stream habitat had a number of features providing structure and shelter for aquatic fauna, including extensive in-stream vegetation and large woody debris. External impacts were high and mostly associated with the adjacent land use (the Tarong power stations) and the various water sources that feed the dam including Meandu Mine. The water level in the dam was relatively low during the field survey (Figure 6.6). As a result, the location of site SW11 was moved slightly into the wetted channel, as the original sampling location was dry. Macroinvertebrate samples were collected from the wetted margins of the dam, but the sampling locations lacked the typical 'edge' habitat (e.g. trailing or aquatic vegetation) that is likely to characterise edge habitat when water levels are higher. In addition, sediment sampling site MCDS4 was dry at the time of survey.





Figure 6.6 Low water level at Meandu Creek Dam

6.6 Meandu Creek Downstream of Meandu Creek Dam

The sites located within Meandu Creek downstream of Meandu Creek Dam and Barker Creek were characterised as flowing pools that were well-connected to waterways further upstream and downstream. The riparian vegetation condition varied and was typically impacted by vegetation clearing associated with the adjacent land uses (cropping and grazing) and/or road corridors and road crossings located at some sites (Figure 6.7). In-stream habitats had a significant number of features providing good structure and shelter for aquatic fauna; including bank vegetation, a variety of in-stream vegetation, woody debris as well as a variety of flow regimes, depth profiles and channel sinuosity. External impacts were moderate to high and mostly associated with the upstream mining and power station activities: continual discharges from Meandu Creek Dam have changed the natural flows and functions of the waterway. Additionally, land clearing associated with surrounding land uses have reduced the presence and continuity of riparian vegetation to varying degrees at sites.



Figure 6.7 A representative site (MC5 / W2), with a well-connected channel and a variety of aquatic habitat types but some impacts from vegetation clearing and a road bridge



7 Aquatic Plants

7.1 Community Composition

A total of 28 plant species comprising of 20 families were recorded across all sites and locations (Table 7.1). Twenty one of these species are listed as wetland indicator species (all native species) (EHP 2017b) (Table 7.1). Four other native plant species that are not listed wetland species were recorded across the survey area on the banks or within the channel and were supporting the aquatic ecosystem by providing habitat (Table 7.1).

Three exotic species were recorded across the survey area (Table 7.1). However, no weeds of national significance were recorded and no plant species listed as prohibited or restricted invasive plants under the *Biosecurity Act 2014* were recorded.

Water pepper was the most widespread and abundant emergent species commonly growing along the edges and on the banks. Hornwort, common duckweed and curly pondweed were the most widespread floating / submerged species; water fern and hydrilla were the most abundant floating / submerged species (Table 7.1).

The majority of the plant species identified during the survey are common and widespread around Queensland. Many are tolerant of waters that are higher in salinity (i.e. occur in coastal areas brackish regions as well as freshwater areas) (Stephens & Dowling 2002). In general, the plant species were providing bank stability and suitable edge habitat and in-stream habitat for aquatic fauna.



Table 7.1 Average percent cover of each aquatic plant species at each site during the March 2017 field survey

Family <i>Species Name</i>	Common Name	Form ^B	Comparative			Meandu Creek upstream of Meandu Creek Dam		Meandu Creek downstream of Meandu Creek Dam				
			C1	C1B	SW36	MCA1/ MC6	MCA3/ MC5	MC500	MC5/ W2	MC15	MC20/ SW16	MC25
Amaranthaceae												
<i>Alternanthera denticulata</i>	Lesser joyweed	E		0.3	0.1			0.2	0.1			
Asteraceae												
<i>Xanthium occidentale</i> *	Noogoora burr	E	1.6	7.5	0.3	0.3			0.7			0.1
Araceae												
<i>Spirodela oligorrhiza</i>	Common duck weed	F		5.7	3.1			0.5	0.3		0.9	0.3
Azollaceae												
<i>Azolla pinnata</i> ^A	Water fern	F	4.5	18.7						5.8	13.7	
Ceratophyllaceae												
<i>Ceratophyllum demersum</i> ^A	Hornwort	S	13	0.8	3.3	1					10.7	3.7
Commelinaceae												
<i>Commelina diffusa</i>	Wandering jew	E	2		0.2			0.5	4.8			0.4
Cyperaceae												
<i>Cyperus javanicus</i>	Javanese flat sedge	E			0.1							
<i>Cyperus polystachyos</i> ^A	Bunchy sedge	E		0.2	0.6				0.1		0.2	
<i>Cyperus rotundus</i> *	Nutgrass	E			1.3							
<i>Schoenoplectus tabernaemontani</i> ^A	River clubrush	E				5.4	1.9	0.2				
Haloragaceae												
<i>Myriophyllum gracile</i> ^A	Milfoil	E										0.5



Family <i>Species Name</i>	Common Name	Form ^B	Comparative			Meandu Creek upstream of Meandu Creek Dam		Meandu Creek downstream of Meandu Creek Dam				
			C1	C1B	SW36	MCA1/ MC6	MCA3/ MC5	MC500	MC5/ W2	MC15	MC20/ SW16	MC25
Hydrocharitaceae												
<i>Hydrilla verticillata</i> ^A	Hydrilla	S	16.5								22	2.3
<i>Vallisneria nana</i> ^A	Ribbonweed	S			10.3							
Juncaceae												
<i>Juncus usitatus</i> ^A	Rush	E	1		0.4				1.3	4.1	2	1.2
Juncaginaceae												
<i>Triglochin multifructa</i>	Water ribbons	E								0.1		0.2
Laxmanniaceae												
<i>Lomandra longifolia</i>	Spiny-headed mat-rush	E				10		4.6				0.1
Lentibulariaceae												
<i>Utricularia aurea</i> ^A	Bladderwort	S										3.5
Menyanthaceae												
<i>Nymphoides geminata</i> ^A	Entire marshwort	F								0.4		
Onagraceae												
<i>Ludwigia peploides</i> ^A	Water primrose	E		1.2	0.1							0.7
Poaceae												
<i>Leptochloa digitata</i> ^A	Umbrella canegrass	E								0.1		6
Polygonaceae												
<i>Persicaria attenuata</i> ^A	Water pepper	E		1.5	3.4	0.2		1	0.1	0.1		16
<i>Persicaria decipiens</i> ^A	Slender knotweed	E		1.4								
<i>Rumex crispus</i> [*]	Curled dock	E										0.5



Family <i>Species Name</i>	Common Name	Form ^B	Comparative			Meandu Creek upstream of Meandu Creek Dam		Meandu Creek downstream of Meandu Creek Dam				
			C1	C1B	SW36	MCA1/ MC6	MCA3/ MC5	MC500	MC5/ W2	MC15	MC20/ SW16	MC25
Potamogetonaceae												
<i>Potamogeton crispus</i> ^A	Curly pondweed	S			7.9			10.2	0.1	4.3	3.1	0.7
<i>Potamogeton tricarinatus</i> ^A	Floating pondweed	F									7.4	6.3
<i>Stuckenia pectinata</i> ^A	Fennel pondweed	S						0.2	14.5	20.5		
Ranunculaceae												
<i>Ranunculus inundatus</i> ^A	River buttercup	E							1			
Typhaceae												
<i>Typha domingensis</i> ^A	Cumbungi	E				15.5	5.8	3		3		
Total average cover at each site (%)			38.6	37.3	31.1	32.4	7.7	20.4	23	38.4	60	42.5

A Denotes Wetland Indicator Species

B Plant growth form: E = Emergent; S = Submerged; F = Floating

* Denotes exotic species



7.2 Taxonomic Richness

Taxonomic richness was lowest at site MCA3/MC5 on Meandu Creek upstream of Meandu Creek Dam, where only two species were recorded (Figure 7.1). Taxonomic richness was highest at site MC25 on Meandu Creek downstream of Meandu Creek Dam and taxonomic richness at all other sites in this reach was within the range of comparative sites. Similar species were found at sites across all locations, and there were no obvious signs of poor health on plants at sites on Meandu Creek upstream or downstream of Meandu Creek Dam.

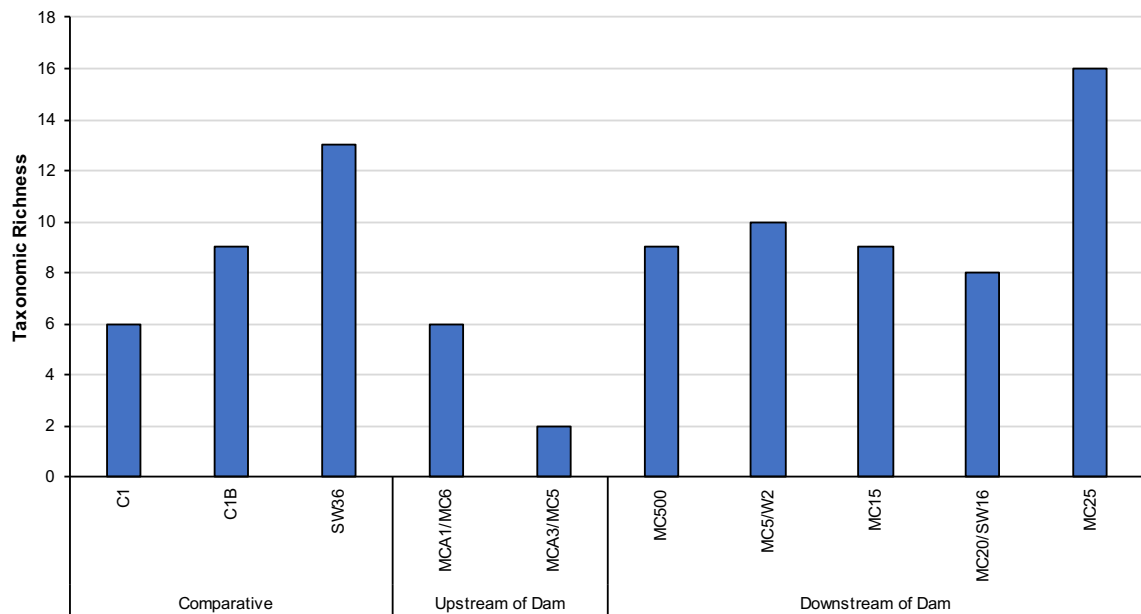


Figure 7.1 Taxonomic richness recorded at sites during the March 2017 field survey



7.3 Percent Cover

Percent cover of aquatic plants was lowest at site MCA3/MC5 on Meandu Creek upstream of Meandu Creek Dam, where percent cover was less than 10% (Figure 7.2). Percent cover at all comparative sites was above 30%, while percent cover and at sites on Meandu Creek downstream of Meandu Creek Dam ranged between 20% and 60%. Percent cover at sites MC500 and MC5/W2 (downstream of Meandu Creek Dam, and closest to the dam outlet) was lower than the range of comparative sites. The lower cover of aquatic plants at sites MCA3/MC5, MC500 and MC5/W2 is likely to be related to the habitat characteristics of these sites (such as fast flowing water at sites MC500 and MC5/W2, and surrounding land uses and subsequent condition of aquatic habitat at site MCA3/MC5).

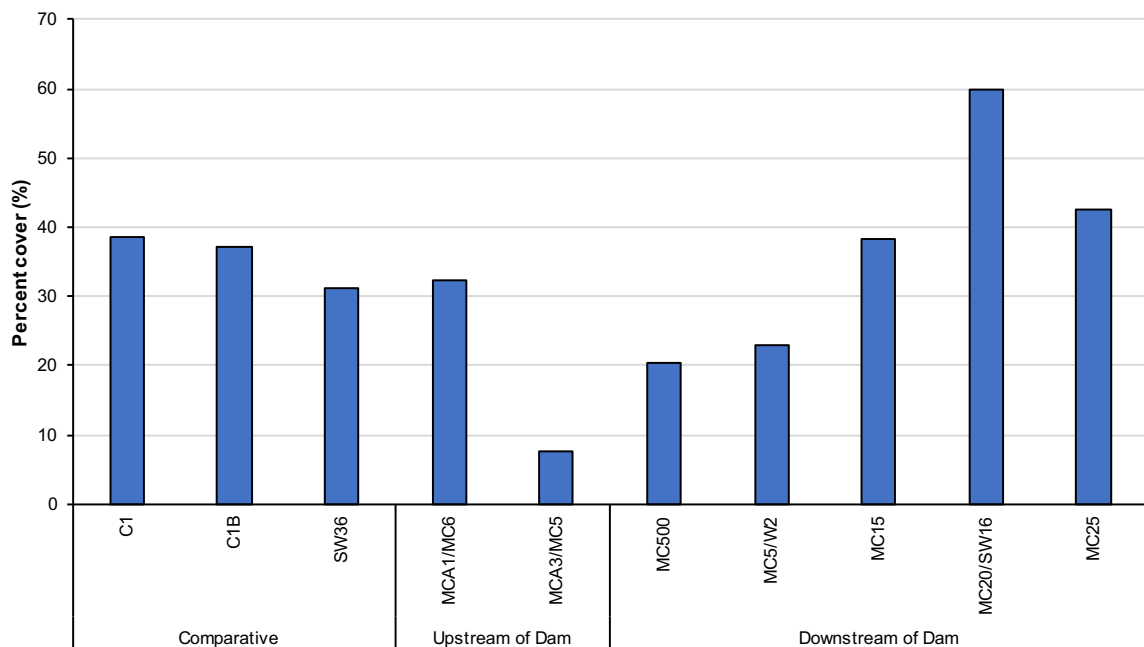


Figure 7.2 Percent cover of aquatic plants recorded at sites during the March 2017 field survey



7.4 Growth Forms

Submerged and floating vegetation were the most abundant growth forms of aquatic plants across the survey area, and made up over 50% of the total coverage at comparative sites and sites on Meandu Creek downstream of Meandu Creek Dam (Figure 7.3). Sites on Meandu Creek upstream of Meandu Creek Dam were the exception to this; at both site MCA1/MC6 and site MCA3/MC5 emergent plant species dominated. At both of these sites, cumbungi was growing excessively around the channel. Cumbungi is a native species and can grow in varying water quality conditions. When present in high densities, cumbungi can become a weed and cause problems to waterways mainly by obstructing water-flow, increasing sedimentation and reducing water quality.

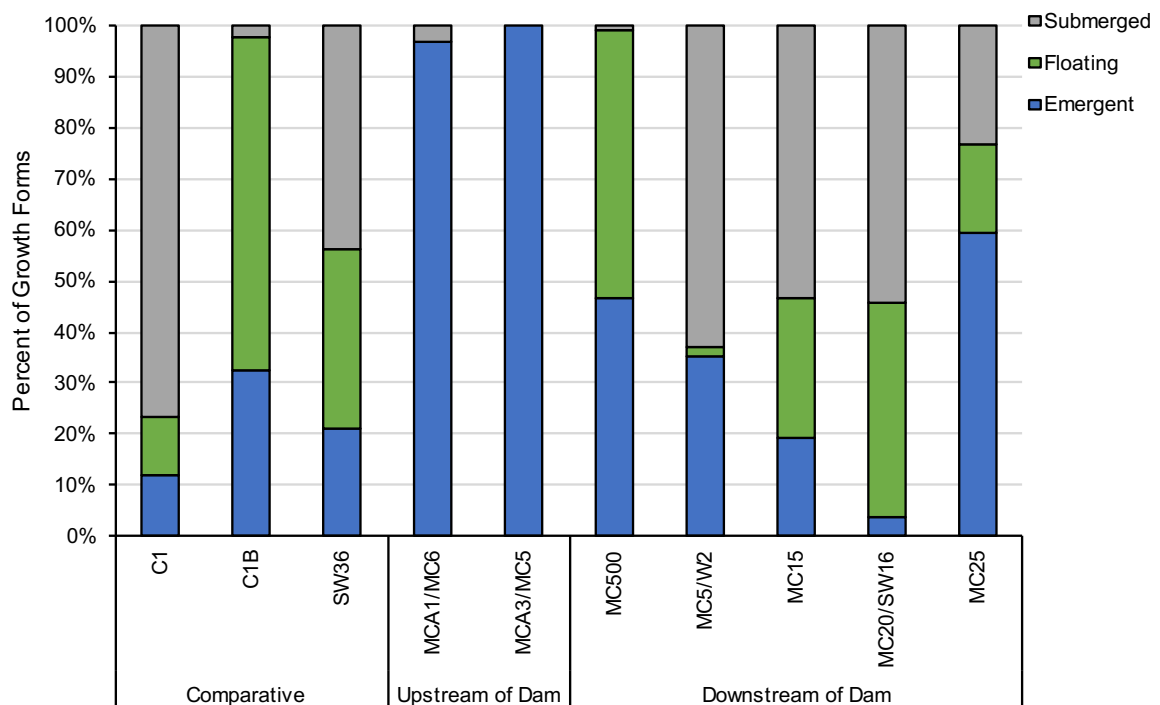


Figure 7.3 Relative composition of aquatic plant growth forms recorded at sites during the March 2017 field survey



8 Macroinvertebrates

8.1 Results of Historical Surveys

Macroinvertebrates have historically been surveyed at sites within Meandu Creek Dam (including at the Meandu Mine Inlet), Meandu Creek downstream of Meandu Creek Dam and at several comparative sites on Barkers Creek. Routine monitoring has been completed since 1999.

Results from the two most recent surveys (2014 and the current 2017 survey) indicated that macroinvertebrate richness and diversity has increased compared with previous surveys (Table 8.1). The greater number of taxa recorded in the current March 2017 survey may be related to the inclusion of additional sites, seasonal effects, differences in sampling technique and/or an improvement in overall waterway condition.

In general, taxonomic richness has been lowest at sites in Meandu Creek Dam, which is to be expected due to the lower habitat diversity compared with creek sites. Richness at sites on Meandu Creek downstream of Meandu Creek Dam is generally within or greater than the range at the comparative sites. The results from the historical monitoring events have indicated that under normal operating conditions, discharges from Meandu Creek Dam are not adversely impacting the macroinvertebrate communities in Meandu Creek downstream of Meandu Creek Dam (IMEMS 2013, Footprints 2014b).

Table 8.1 Number of taxa (richness) at riverine sites in Meandu and Barker Creek from 2000 to 2017 inclusive

Year	Number of Taxa ^A	Year	Number of Taxa ¹
2000	46	March 2007	48
2001	53	May 2008	38
2002	42	July 2008	44
2003	36	May 2009	48
2004	47	June 2011	37
2005	47	June 2012	40
March 2006	47	June 2014	72 (65 Meandu Creek, 48 Barker Creek)
August 2006	52	March 2017	98 (86 Meandu Creek; 71 Barker/Barambah Creek)

^A Number of taxa for 2000 to 2014 sourced from Footprints 2014b



8.2 Indices

8.2.1 Abundance

In edge habitat, abundance did not significantly differ between locations²⁷; however there was spatial variability in abundance within and between sites (Figure 8.1 and Figure 8.2, noting the large standard error bars for some sites), with abundance being highest at site MC5/W2 on Meandu Creek downstream of Meandu Creek Dam followed by MC500, and was lowest at dam site SWI1. Abundance at (Figure 8.1 and Figure 8.2):

- sites on Meandu Creek downstream of Meandu Creek Dam was within or above the range recorded at the comparative sites
- sites on Meandu Creek upstream of Meandu Creek Dam was within or above the range recorded at the comparative sites, except at site MCA3/MC5, where abundance was lower than comparative sites, and
- dam sites MCD1 and SWI2 was within the range recorded at the comparative sites, while abundance at MCD2 and SWI1 was lower than comparative sites.

Similarly in bed habitat, abundance did not differ significantly between locations²⁸. There was variation in abundance within and between sites, with abundance being highest at site MC500 on Meandu Creek downstream of Meandu Creek Dam and was lowest at dam site SWI1 (Figure 8.3 and Figure 8.4). Abundance at:

- site MC2 on Meandu Creek downstream of Meandu Creek Dam was lower than the range recorded at the comparative sites, but all other sites were within or above the range of comparative sites
- sites MCA3/MC5 and CM2 on Meandu Creek upstream of Meandu Creek Dam were lower than the range recorded at the comparative sites, but all other sites were within the range of comparative sites, and
- dam site SWI1 was lower than the range recorded at the comparative sites.

Given the lack of statistically significant difference in abundance between locations (comparative, Meandu Creek upstream of Meandu Creek Dam, dam and Meandu Creek downstream of the dam), and the large range of 'natural' abundances recorded at comparative sites, no negative impacts to macroinvertebrate abundance were noted. Moreover, the high abundance at sites downstream of Meandu Creek Dam indicates that releases from the dam are having a positive influence on macroinvertebrate abundance in Meandu Creek downstream of Meandu Creek Dam, which is most likely due to the flow and stable, perennial and diverse habitat created by the constant releases. Lower abundances at the dam sites may be related to the low water levels at the time of survey, resulting in bare

²⁷ PERMANOVA edge location effect Pseudo- $F_{3,14} = 1.90$, $p = 0.2$; Site (location) effect Pseudo- $F_{14,72} = 6.32$, $p = 0.001$

²⁸ PERMANOVA bed location effect Pseudo- $F_{3,11} = 0.83$, $p = 0.5$; Site (location) effect Pseudo- $F_{11,60} = 2.73$, $p = 0.002$



substrate being sampled (as opposed to edge habitat with overhanging, trailing or aquatic vegetation when water levels are higher).



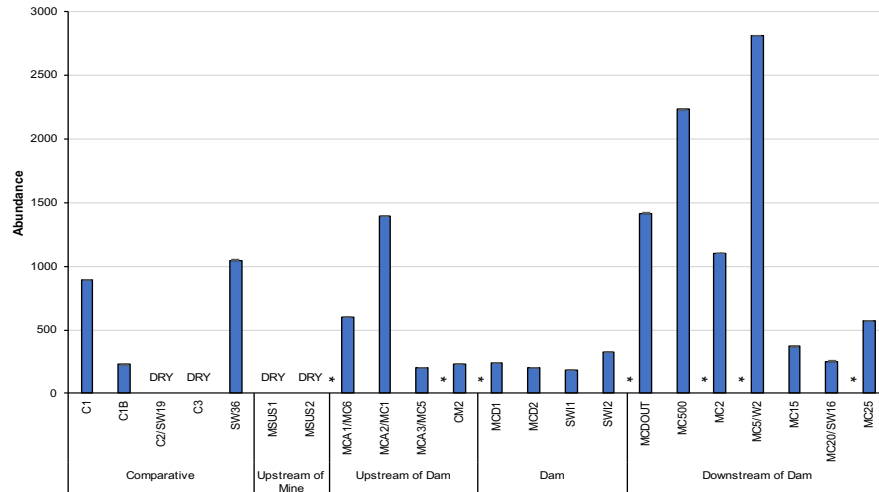


Figure 8.1 Total abundance in edge habitat in the March 2017 survey

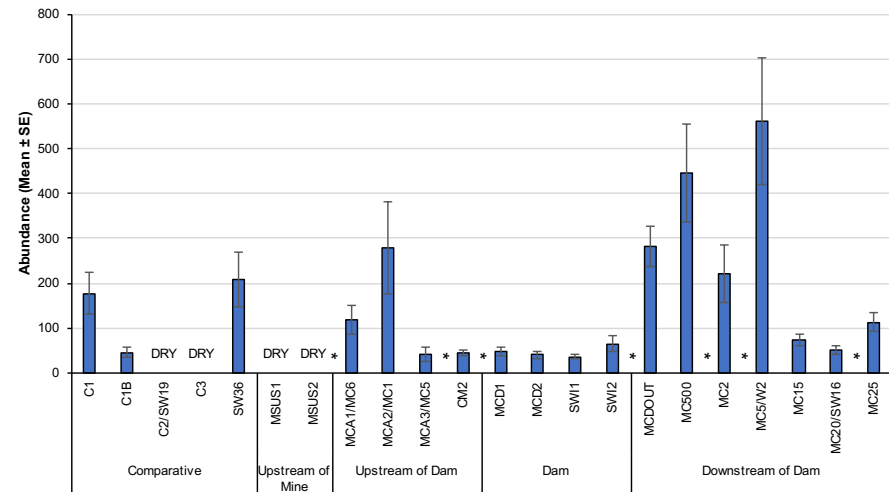


Figure 8.2 Mean abundance (± standard error) in edge habitat in the March 2017 survey

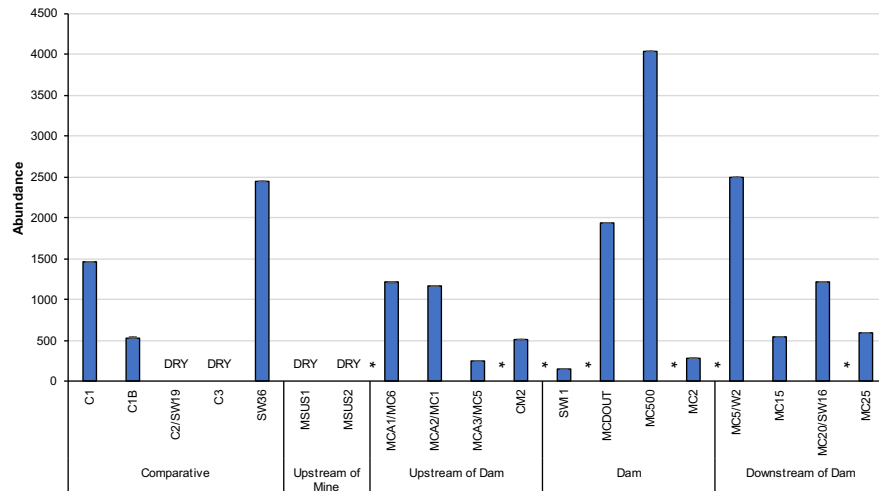


Figure 8.3 Total abundance in bed habitat in the March 2017 survey

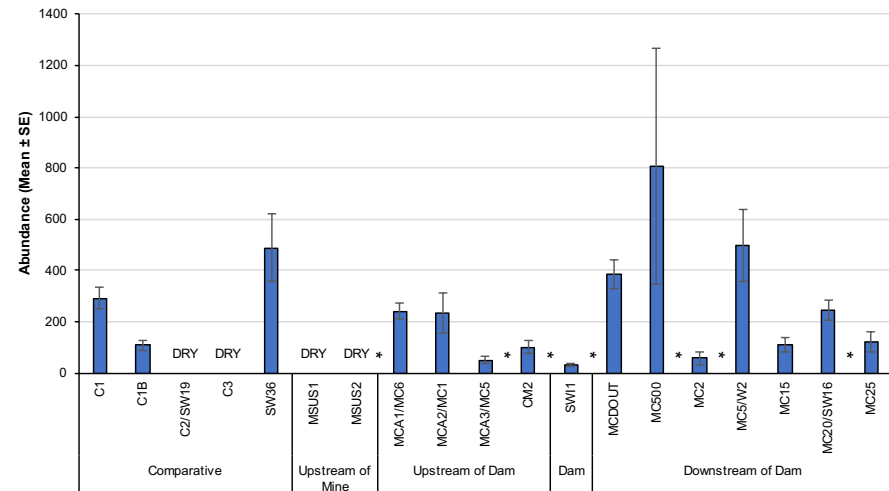


Figure 8.4 Mean abundance (± standard error) in bed habitat in the March 2017 survey



8.2.2 Taxonomic Richness

A total of 101 taxonomic groups were identified in the March 2017 survey within Meandu Creek Dam and Meandu Creek downstream of Meandu Creek Dam, which is significantly greater than the number of taxa identified in surveys of these reaches completed from 2000 to 2014 (where between 36 and 72 taxa were recorded per survey) (Footprints 2014b). The greater number of taxa recorded in the current survey may be related to the inclusion of additional sites, the different sampling technique used and/or an improvement in overall waterway condition. The most abundant groups were non-biting midges (Chironomidae) and seed shrimps (Ostracoda), while the most widespread groups included segmented worms (Oligochaeta), seed shrimps (Ostracoda), biting midges (Ceratopogonidae) and non-biting midges.

Total taxonomic richness (i.e. pooled for all samples collected at each site) was within or above the biological WQO range for edge and bed habitat (i.e. WQO range from central coast region biological guidelines from the QWQG, based on the 20th – 80th percentile range recorded at reference sites as outlined in Section 2.2.7.5; DEHP 2013), indicating that macroinvertebrate richness was within or above the range expected at reference sites throughout the central coast region of Queensland (Figure 8.5 and Figure 8.7). The exceptions were at site CM2 for edge habitat and most of the dam sites; which is likely due to the poor quality of edge habitat at site CM2 and the low water levels in the dam at the time of survey. Total richness in riffle habitat at sites MCDOUT and MC5/W2 on Meandu Creek downstream of Meandu Creek Dam was 32 and 30 taxa respectively, which exceeds the biological WQO for composite bed habitat. In general, richness at each site was similar to or higher than that recorded in previous surveys (Footprints 2014b).

In edge habitat, taxonomic richness was highest at site MC5/W2 on Meandu Creek downstream of Meandu Creek Dam and was lowest at dam site MCD2 (Figure 8.5 and Figure 8.6). Taxonomic richness at:

- sites on Meandu Creek downstream of Meandu Creek Dam was within or above the range recorded at the comparative sites
- sites on Meandu Creek upstream of Meandu Creek Dam was within the range recorded at the comparative sites, except at site CM2 which was lower than the range at the comparative sites, and
- dam sites were below the range of comparative sites except at site SWI2 which was within the range of comparative sites (Figure 8.5; Figure 8.6).

Richness in edge habitat at sites on Meandu Creek upstream and downstream of Meandu Creek Dam was not significantly different to richness at the comparative sites²⁹. Richness was significantly lower at the dam sites compared with the comparative sites and sites downstream of Meandu Creek Dam, which is likely to reflect the low water levels (and the resulting lack of edge habitat) at the time of the survey, as well as low habitat diversity (which is typical of impoundments).

²⁹ PERMANOVA edge location effect Pseudo- $F_{3,14} = 5.05$, $p = 0.021$; Site (location) effect Pseudo- $F_{14,72} = 5.38$, $p = 0.001$; Significant location pairwise comparisons $p < 0.05$: Downstream of Dam > Dam; Comparative > Dam.



In bed habitat, taxonomic richness was significantly higher in Meandu Creek downstream of Meandu Creek Dam compared with the sites on Meandu Creek upstream of Meandu Creek Dam and dam sites, but richness at each location did not differ significantly from that at the comparative sites³⁰. Richness in bed habitat was highest at comparative site SW36 and was lowest at comparative site C1B (i.e. taxonomic richness at all sites on Meandu Creek upstream and downstream of Meandu Creek Dam, and dam sites was within the range recorded at the comparative sites) (Figure 8.7; Figure 8.8).

³⁰ PERMANOVA bed location effect Pseudo- $F_{3,11} = 3.58$, $p = 0.04$; Site (location) effect Pseudo- $F_{11,60} = 3.69$, $p = 0.001$; Significant location pairwise comparisons $p < 0.05$: Downstream of Dam > Dam; Downstream of Dam > Upstream of Dam.



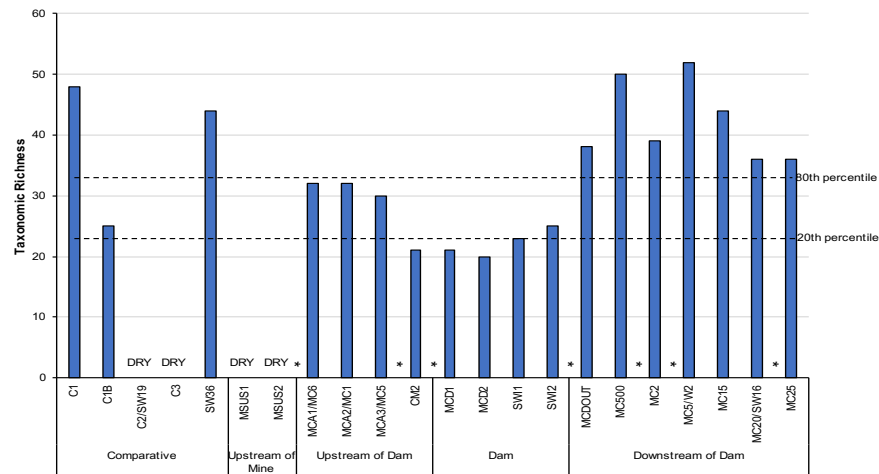


Figure 8.5 Total taxonomic richness in edge habitat in the March 2017 survey

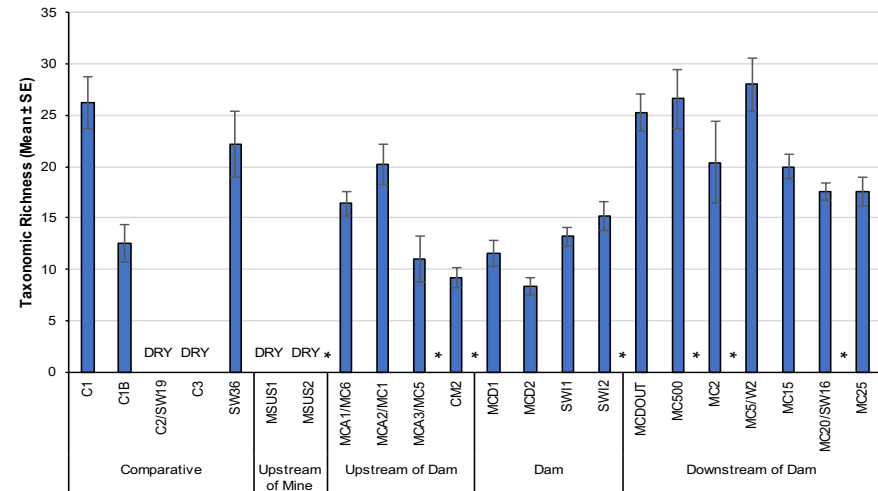


Figure 8.6 Mean taxonomic richness in edge in the March 2017 survey

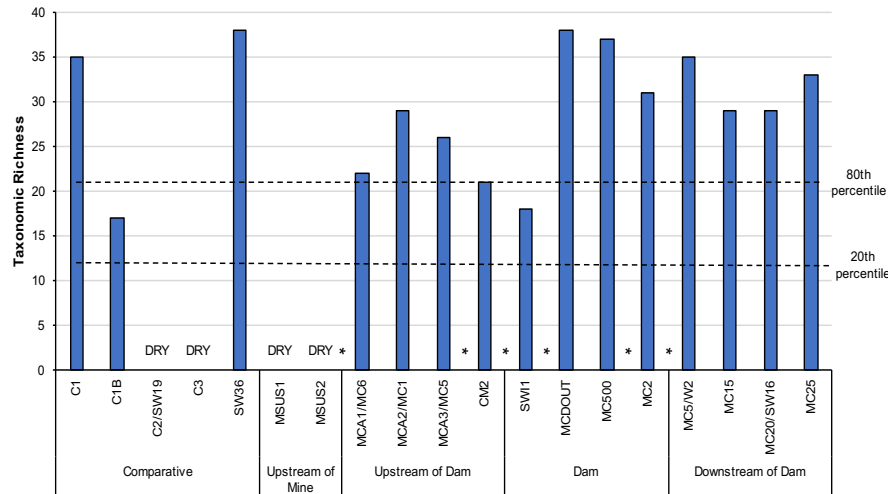


Figure 8.7 Total taxonomic richness in bed habitat in the March 2017 survey

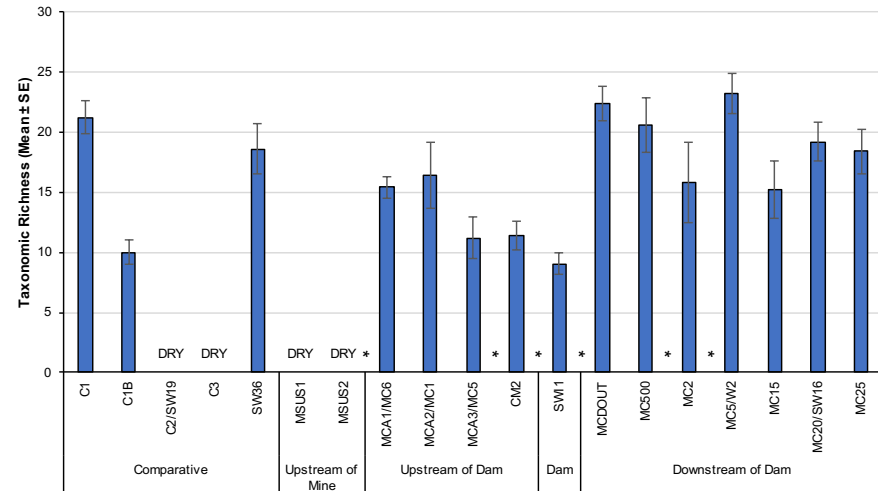


Figure 8.8 Mean taxonomic richness in bed in the March 2017 survey



8.2.3 SIGNAL 2 Scores

SIGNAL 2 scores are based on the sensitivity of macroinvertebrate taxa to pollution or habitat degradation and are weighted for abundance, with a low score (i.e. below the biological WQO) indicating taxa are tolerant to a range of environmental conditions and a high score (i.e. within or above the biological WQO) indicating taxa are more sensitive to such conditions (DEHP 2013). Total SIGNAL 2 scores (i.e. pooled for all samples collected at each site) were below the biological WQOs at most sites, except for comparative site SW36 (downstream of Bjelke-Petersen Dam) and on Meandu Creek within 15 km downstream of Meandu Creek Dam (Figure 8.11 and Figure 8.13). This indicates that in general, taxa in the survey area are relatively tolerant of pollution, although Meandu Creek downstream of Meandu Creek Dam (close to the discharge) supports a greater number of sensitive taxa. SIGNAL 2 scores were also high at comparative site SW36, where flow conditions are similar. This is likely to be related to the perennial flows and the diversity of habitats present at these sites, and is consistent with the results of the 2014 macroinvertebrate survey (Footprints 2014b).

In edge habitat, SIGNAL 2 scores were significantly lower at the dam sites than at the comparative sites and sites on Meandu Creek downstream of Meandu Creek Dam; and significantly lower at the sites on Meandu Creek upstream of Meandu Creek Dam than at the sites downstream of the Dam³¹. The SIGNAL 2 score was highest at site MC2 on Meandu Creek downstream of Meandu Creek Dam and lowest at Dam site SW11 (Figure 8.11 and Figure 8.12). SIGNAL 2 scores in edge habitat at:

- sites MC20/SW16 and MC25 on Meandu Creek downstream of Meandu Creek Dam were below the range recorded at the comparative sites, and all other sites were within or above the range at comparative sites
- sites MCA1/MC6 and MCA2/MC1 on Meandu Creek upstream of Meandu Creek Dam were below the range recorded at the comparative sites, and sites MCA3/MC5 and CM2 were within the range at comparative sites, and
- dam sites were below the range recorded at the comparative sites.

In bed habitat, SIGNAL 2 scores were significantly lower at sites on Meandu Creek upstream of Meandu Creek Dam than at sites downstream³². The SIGNAL 2 score was highest at site MC5/W2 downstream of Meandu Creek Dam and lowest at dam site SW11 (Figure 8.13 and Figure 8.14).

SIGNAL 2 scores in bed habitat at:

³¹ PERMANOVA edge location effect Pseudo- $F_{3,14} = 9.91$, $p = 0.002$; Site (location) effect Pseudo- $F_{14,72} = 5.67$, $p = 0.001$. Significant location pairwise comparisons $p < 0.05$: Downstream of Dam > Dam; Comparative > Dam; Downstream of Dam > Upstream of Dam.

³² PERMANOVA bed location effect Pseudo- $F_{3,11} = 3.66$, $p = 0.036$; Site (location) effect Pseudo- $F_{11,60} = 25.38$, $p = 0.001$; Significant location pairwise comparisons $p < 0.05$: Downstream of Dam > Upstream of Dam.



- sites on Meandu Creek downstream of Meandu Creek Dam were within or close to the range at comparative sites
- site MCA1/MC6 on Meandu Creek upstream of Meandu Creek Dam were below the range recorded at the comparative sites, but at other sites within this reach were within the range recorded at comparative sites, and
- dam sites were below the range recorded at the comparative sites.

SIGNAL 2 / family bi-plots are divided into quadrants, with each quadrant indicative of environmental conditions that may influence a community (see Section 2.2.7.5 and Figure 2.3 for a detailed description of this method). Quadrant boundaries for the SIGNAL 2 / family bi-plot used for this assessment were based on the upper (80th percentile) WQO values for taxonomic richness and SIGNAL scores (Chessman 2003). Plots should be interpreted with caution for macroinvertebrate communities in ephemeral waterways of Queensland (which can often be naturally dominated by higher numbers of tolerant taxa), but provide a guide against which habitat condition can be assessed.

SIGNAL 2 / family bi-plots for macroinvertebrate communities in March 2017 indicated that most sites downstream of Meandu Creek Dam and comparative sites were either in 'reference' condition (favourable habitat and chemically dilute waters; i.e. sites were within quadrant 1 on the bi-plot), or showed some effects from increased salinity and nutrients (which may be natural; i.e. sites were within quadrant 2 on the bi-plot). Sites on Meandu Creek upstream of Meandu Creek Dam and within the dam itself, along with comparative site C1B, were typically indicative of urban, industrial or agricultural pollution or the downstream effects of dams (flow regulation / changing water levels; i.e. sites were within quadrant 4 of the bi-plot), which is not unexpected for sites both upstream of and in Meandu Creek Dam. No sites were within quadrant 3, which is indicative of toxic pollution or harsh physical conditions (Figure 8.9 and Figure 8.10).



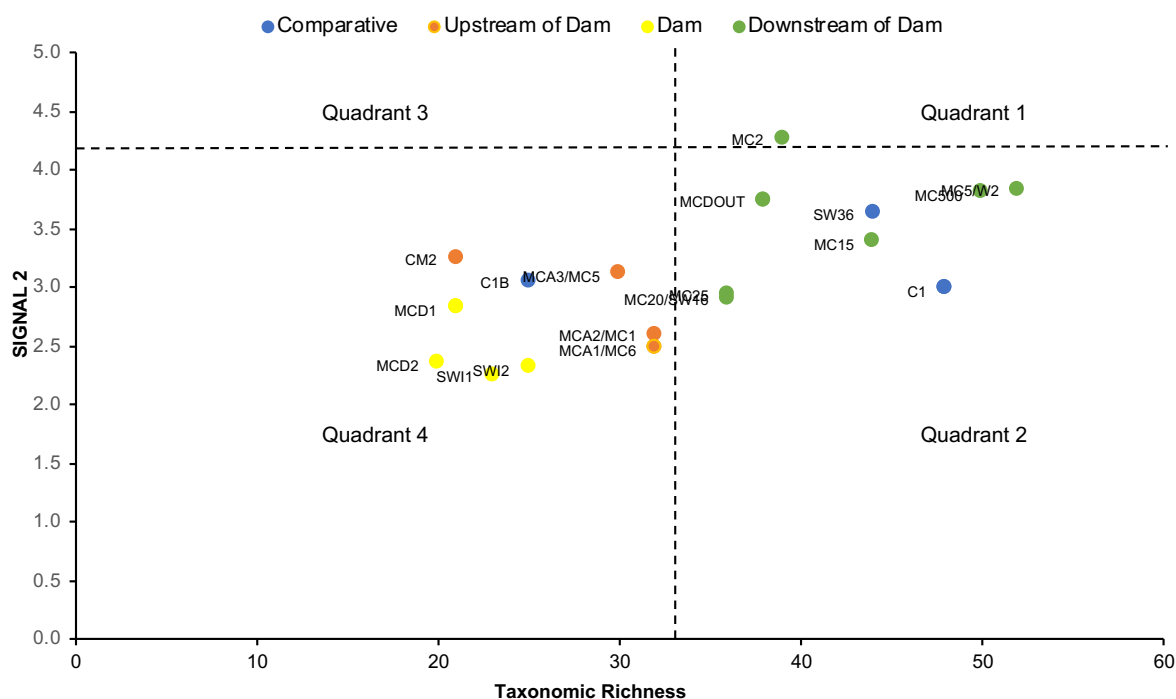


Figure 8.9 SIGNAL 2 / Family bi-plot for edge habitat in the March 2017 survey

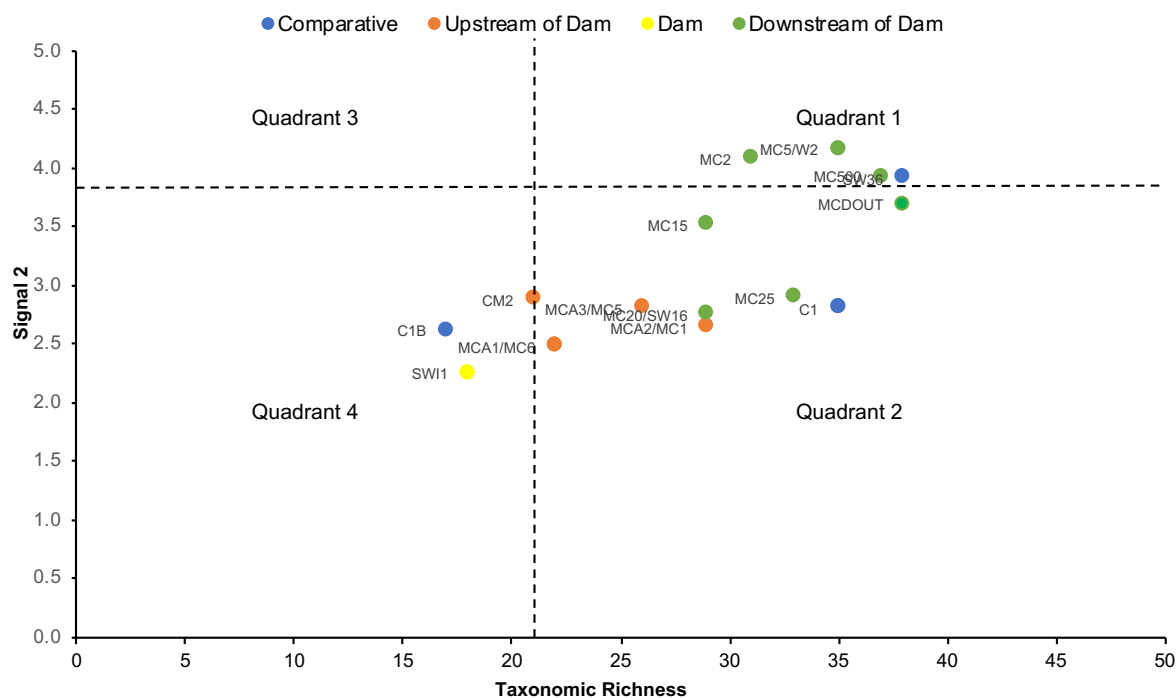


Figure 8.10 SIGNAL 2 / Family bi-plot for bed habitat in the March 2017 survey

Overall, there was a lower diversity and abundance of sensitive macroinvertebrate taxa at sites on Meandu Creek upstream of Meandu Creek Dam compared to sites downstream of Meandu Creek Dam. While this could be related to the water quality at these sites, it could



also be due to other factors such as the lack of flow or poor habitat quality, as low SIGNAL 2 scores were also recorded at two of the comparative sites, and differences between these locations were not significant. The low number of sensitive taxa at the dam sites was likely to be related to the low water levels at the time of survey as well as low habitat diversity (which is typical of impoundments). Perennial flows related to releases from the Meandu Creek Dam have resulted in higher numbers of sensitive taxa (than would be expected to 'naturally' occur in the study area) being present downstream of Meandu Creek Dam.



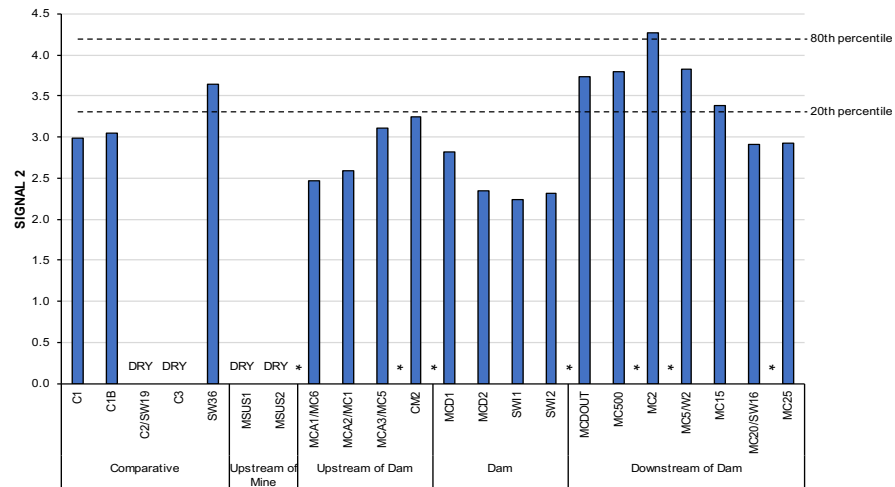


Figure 8.11 Total signal 2 scores in edge habitat in the March 2017 survey

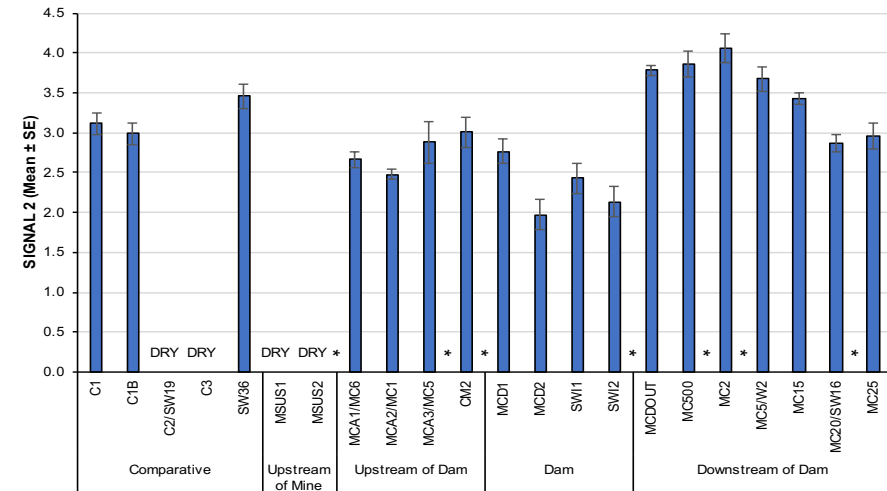


Figure 8.12 Mean signal 2 scores in edge in the March 2017 survey

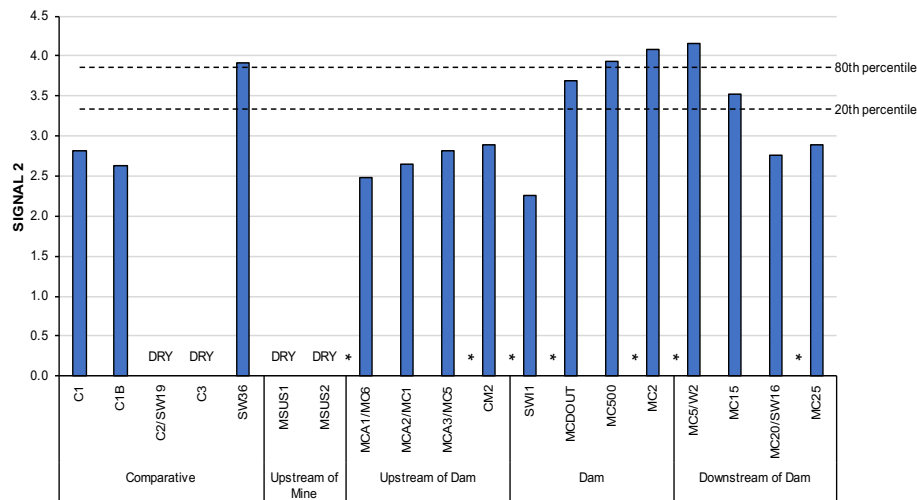


Figure 8.13 Total signal 2 scores in bed habitat in the March 2017 survey

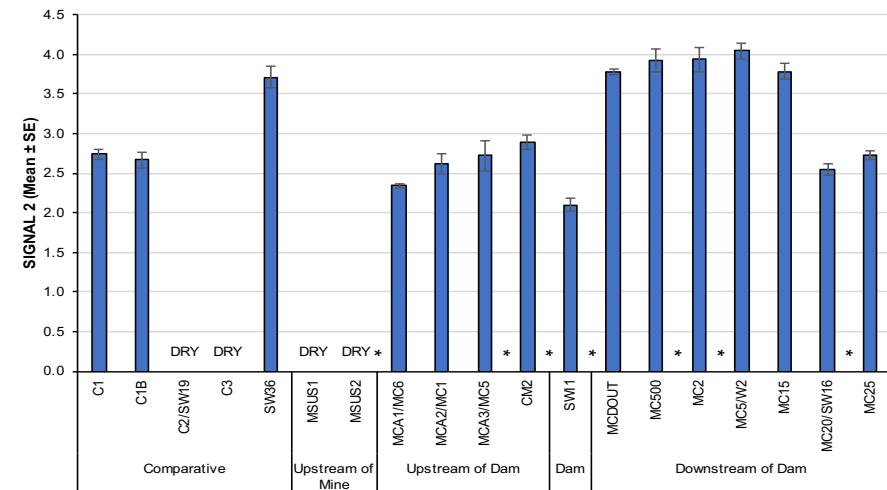


Figure 8.14 Mean signal 2 scores in bed in the March 2017 survey



8.2.4 PET Richness

Total PET Richness (i.e. pooled for all samples collected at each site) was within or exceeded the biological WQO range (DEHP 2013), except at comparative site C1B, site MCA1/MC6 on Meandu Creek upstream of Meandu Creek Dam and dam site SW1 (Figure 8.15 and Figure 8.17). PET Richness generally exceeded the biological WQO range in Meandu Creek downstream of Meandu Creek Dam and at comparative site SW36, which both receive flows from dam releases. These results are generally consistent with those of previous surveys, although PET Richness downstream of Meandu Creek Dam within 500 m of the outlet has improved since the 2014 survey (Footprints 2014b). PET Richness at sites MCDOUT and MC5/W2 was 7 and 9 respectively; much greater than the biological WQO for composite bed habitat. A stonefly (Plecoptera, family Gripopterygidae) was recorded in riffle habitat at site MC5/W2; stoneflies are relatively rare in the aquatic macroinvertebrate communities of the region and more broadly in Queensland (pers. obs.).

In edge habitat, PET Richness was significantly higher at sites on Meandu Creek downstream of Meandu Creek Dam than at sites upstream of and within the dam³³. PET Richness was highest at sites MC500, MC2 and MC5/W2 downstream of the dam, and lowest at dam site SW1 (Figure 8.15 and Figure 8.16). PET Richness scores at sites upstream of, downstream of and within Meandu Creek Dam were within the range recorded at comparative sites.

In bed habitat, PET Richness was significantly higher at sites on Meandu Creek downstream of Meandu Creek Dam than at sites upstream of and within the dam³⁴. PET Richness was highest at sites MCDOUT, MC500, MC2 and MC5/W2 downstream of the dam, and lowest at dam site SW1 (Figure 8.17 and Figure 8.18). PET Richness scores at sites upstream of, downstream of and within Meandu Creek Dam were within the range recorded at comparative sites.

Overall, there was a lower diversity of PET taxa at sites upstream of Meandu Creek Dam compared to sites downstream of the dam. While this could be related to the water quality at these sites, it could also be due to other factors such as the lack of flow or poor habitat quality, as low PET Richness was also recorded at one of the comparative sites, and differences between these locations were not significant. The low number of PET taxa at the dam sites was likely to be related to the low water levels at the time of survey, as well as low habitat diversity (which is typical of impoundments). Perennial flows related to releases from the Meandu Creek Dam have resulted a higher diversity of PET taxa (than would be expected to 'naturally' occur in the study area) downstream of Meandu Creek Dam.

³³ PERMANOVA edge location effect Pseudo- $F_{3,14} = 88.1$, $p = 0.002$; Site (location) effect Pseudo- $F_{14,72} = 5.5$, $p = 0.001$. Significant location pairwise comparisons $p < 0.05$: Downstream of Dam > Dam; Downstream of Dam > Upstream of Dam.

³⁴ PERMANOVA bed location effect Pseudo- $F_{3,11} = 5.34$, $p = 0.022$; Site (location) effect Pseudo- $F_{11,60} = 6.21$, $p = 0.001$; Significant location pairwise comparisons $p < 0.05$: Downstream of Dam > Dam; Downstream of Dam > Upstream of Dam.



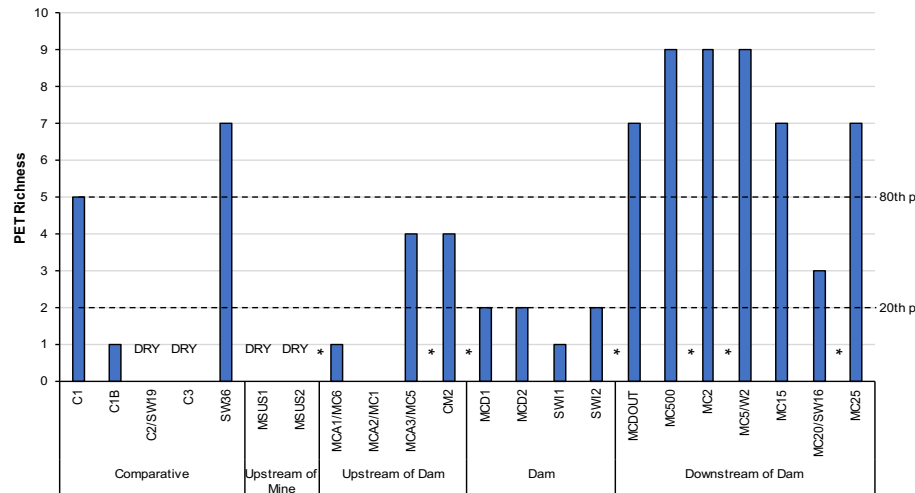


Figure 8.15 Total PET richness in edge habitat in the March 2017 survey

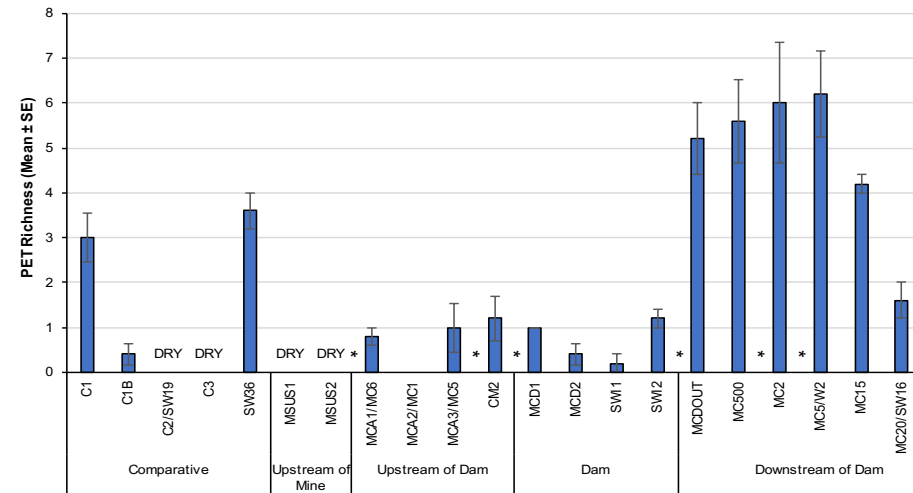


Figure 8.16 Mean PET richness in edge in the March 2017 survey

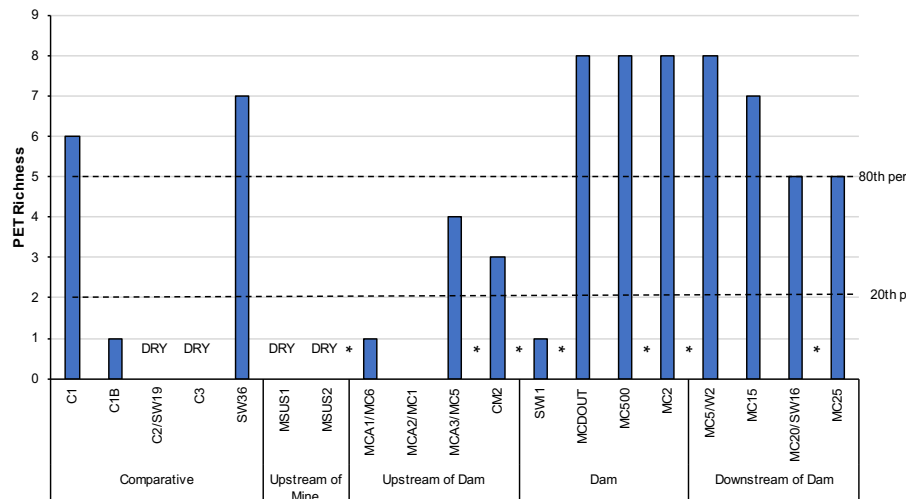


Figure 8.17 Total PET richness in bed habitat in the March 2017 survey

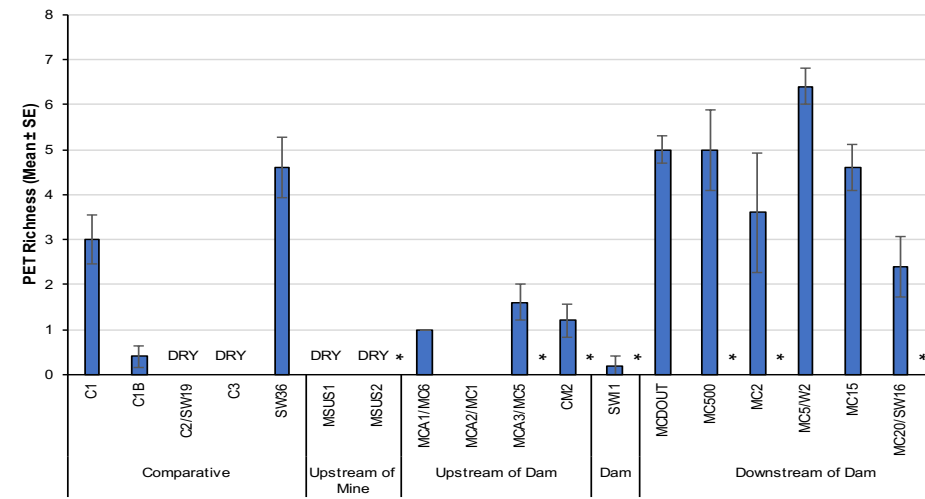


Figure 8.18 Mean PET richness in bed in the March 2017 survey



8.3 Assemblage Composition

8.3.1 Edge Habitat

In edge habitat, the assemblages in the dam differed significantly from the assemblages the other locations (i.e. comparative, sites on Meandu Creek upstream of Meandu Creek Dam and sites on Meandu Creek downstream of Meandu Creek Dam)³⁵. There were also significant differences between sites within each location³⁵.

Assemblages at sites downstream of Meandu Creek Dam and comparative sites (particularly sites SW36 and C1) were most similar to each other (represented by the close clustering of these sites on the nMDS plot in Figure 8.19; note the grouping of comparative sites SW36 and C1 with sites on Meandu Creek downstream of Meandu Creek Dam), with over 90% of the differences in assemblage composition between these locations explained by differences in the abundance of particular taxa, rather than a lack of taxa in any one location (SIMPER; Attachment F).

Most of the differences in assemblage composition between sites on Meandu Creek upstream of Meandu Creek Dam and comparative sites were explained by a higher abundance of macroinvertebrates at comparative sites. More than 40% of the variation between these locations were explained by higher abundances of some common taxa at comparative sites, including an aquatic snail (family Tateidae), non-biting midge larvae (sub-families Chironominae and Tanypodinae) and segmented worms (order Oligochaeta). However, there were some taxa that were present at comparative sites but absent at sites on Meandu Creek upstream of Meandu Creek Dam, including mayflies (family Caenidae – a relatively ubiquitous PET taxa). Sites on Meandu Creek upstream of Meandu Creek Dam also lacked other sensitive PET taxa (e.g. caddisflies, family Calamoceratidae) or taxa that are require flow (e.g. blackfly larvae, family Simuliidae) that were found downstream of Meandu Creek Dam (SIMPER; Attachment F).

8.3.2 Bed Habitat

In bed habitat, the assemblages did not differ significantly between locations³⁶, however there was a substantial difference between sites within locations³⁶. Assemblages at sites close to dam releases (e.g. sites MCDOUT, MC500 and W2 in Meandu Creek downstream of Meandu Creek Dam and comparative site SW36) had similar assemblages (note the close grouping of these sites on the nMDS plot in Figure 8.19).

Similar to edge habitat, assemblages in the bed habitat at sites upstream of Meandu Creek Dam lacked some of the sensitive taxa or taxa that require flow that were found at the comparative sites and sites downstream of Meandu Creek Dam, including families Caenidae and Leptophlebiidae (mayflies), Simuliidae and family Hydropsychidae (a caddisfly)

³⁵ PERMANOVA location effect Pseudo- $F_{3,14} = 2.33$, $p = 0.002$; Site (location) effect Pseudo- $F_{14,72} = 5.25$, $p = 0.001$

³⁶ PERMANOVA location effect Pseudo- $F_{3,11} = 1.37$, $p = 0.12$; Site (location) effect Pseudo- $F_{11,60} = 8.11$, $p = 0.001$



(SIMPER; Attachment F). The assemblage surveyed at the site in the dam lacked a number of taxa present in the other locations (SIMPER; Attachment F).

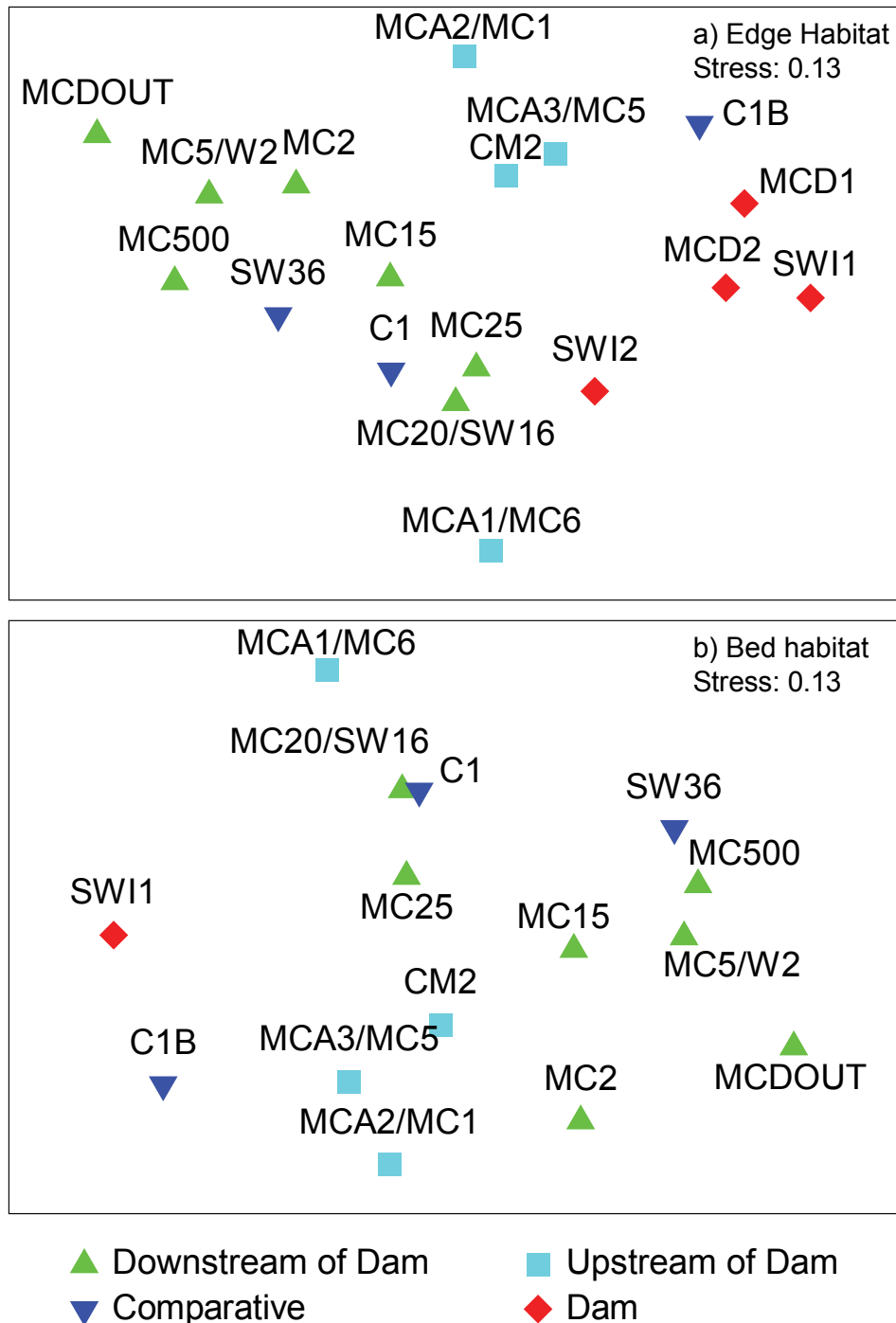


Figure 8.19 nMDS plot for averaged assemblage composition data for a) edge habitat and b) bed habitat in the March 2017 survey; sites grouped closely together had more similar macroinvertebrate assemblage composition than sites further apart



8.4 Correlation with Environmental Variables

8.4.1 Water Quality

The water quality variables best correlated (though only considered to be moderately correlated) with macroinvertebrate assemblage composition in edge and bed habitat were electrical conductivity (and therefore, associated ion concentrations), oxides of nitrogen (concentrations of nitrate and nitrite) and the concentrations of total and dissolved arsenic ³⁷.

Electrical conductivity was lowest at comparative sites, highest at sites on Meandu Creek upstream of Meandu Creek Dam and moderate at sites downstream of the dam. While electrical conductivity may be having some influence on macroinvertebrate assemblages, particularly at the sites on Meandu Creek upstream of Meandu Creek Dam, this influence is only small and there are no negative impacts to assemblages further downstream in Meandu Creek downstream of Meandu Creek Dam. Electrical conductivity alone is only weakly correlated with macroinvertebrate assemblage composition ³⁸.

Concentrations of nitrate and nitrite were highest at some sites on Meandu Creek upstream of Meandu Creek Dam and some sites downstream of the dam. However, there are also a variety of other sources of nitrate and nitrite in Meandu Creek downstream of the dam. There was no evidence that concentrations of nitrite and nitrate downstream of Meandu Creek Dam (which were within the range recorded at sites upstream of Meandu Creek Dam) had a negative impact on macroinvertebrate assemblages. That is, concentrations are unlikely to be toxic.

Concentrations of arsenic were highest in Meandu Creek downstream of Meandu Creek Dam, particularly at the sites closest to the Meandu Creek Dam outlet (Section 4.3; Figure 4.15 and Figure 4.16). Arsenic was also detected at comparative site SW36 downstream of Bjelke-Petersen Dam. However, concentrations of arsenic were below the WQO at these sites, and macroinvertebrate communities were diverse and contained a high number of sensitive taxa in these locations; that is, there were no negative impacts to macroinvertebrates associated with arsenic in water. Concentrations of arsenic in water are related to operation of the Tarong power stations.

8.4.2 Sediment Quality

The concentration of metals in sediment was only weakly correlated with macroinvertebrate assemblage composition in edge habitat, and not correlated with assemblage composition in bed habitat ³⁹.

³⁷ BIOENV BEST Routine for water quality: edge habitat correlation statistic (Rho) = 0.63, p=0.01; bed habitat Rho = 0.44, p=0.01

³⁸ BIOENV BEST Routine for EC only: edge habitat Rho = 0.23, p=0.06; bed habitat Rho = 0.28, p = 0.04

³⁹ BIOENV BEST Routine for sediment quality: edge habitat Rho = 0.27, p=0.03; bed habitat p>0.05



9 Fish

9.1 Results of Historical Surveys

The fish communities of Meandu Creek are not routinely monitored. However, annual monitoring of the power station dams (including Meandu Creek Dam and the Cooling Water Dam) has been completed since 2003 to confirm that there has been no transfer of tilapia (*Oreochromis mossambicus*; a declared noxious species) via pipelines from Boondooma Dam and Wivenhoe Dam to either dam, and to assess the health of populations of stocked species. Across all surveys, a total of 13 species from 10 families have been recorded in the dam, including (ESP 2016, ESP 2017):

- Agassiz's glassfish (*Ambassis agassizi*)
- crimson-spotted rainbowfish (*Melanotaenia duboulayi*)
- fly-specked hardyhead (*Craterocephalus stercusmuscarum*)
- bony bream (*Nematalosa erebi*)
- carp gudgeons (*Hypseleotris* spp.)
- long-finned eel (*Anguilla reinhardtii*)
- purple spotted gudgeon (*Mogurnda adspersa*)
- golden perch (*Macquaria ambigua*)
- Australian bass (*Perca latipes novemaculeata*)
- freshwater catfish (*Tandanus tandanus*)
- Australian smelt (*Retropinna semoni*)
- silver perch (*Bidyanus bidyanus*), and
- spangled perch (*Leiopotherapon unicolor*).

The most recent survey (completed in November 2017) recorded a total of 293 native fish, which is slightly higher than the total caught during the 2016 survey (242 individuals) (ESP 2016; ESP 2017). Fish communities consisted of the same species caught in previous surveys except:

- no Agassiz's glassfish or purple spotted gudgeons were caught in the 2017 survey, however these were caught in the 2016 survey, and
- the long-finned eel was not caught during the 2016 or the 2017 surveys.

One exotic fish species was caught in Meandu Creek Dam in both 2016 and 2017 surveys: the mosquitofish (*Gambusia holbrooki*). Mosquitofish is a declared noxious species under the *Biosecurity Act 2015*. The current study confirms that mosquitofish are present elsewhere in the catchment (Section 9.2).



Analysis of fish tissue specimens completed in 2016 and 2017 revealed that mercury, copper and zinc were present in a number of specimens from a range of species. Cadmium was also present in some specimens in 2016 but was not detected in any specimens in 2017 (ESP 2016; ESP 2017). In 2017, prawn tissue was also analysed for metal concentrations, and copper and zinc were present in all samples taken at both power station dams (ESP 2017). Plant specimens (also analysed in 2017) had copper, lead and zinc present in varying concentrations (ESP 2017).

In 2017, Bjelke Petersen Dam was surveyed as a comparison site. The same species were recorded at the comparative site as were recorded in the power station dams, however two additional species were also recorded; the sleepy cod (*Oxyeleotris lineolatus*), and banded grunter (*Amniataba percooides*). Metal concentrations in fish, prawn and plant specimens were comparable to those in specimens analysed from the power station dams (i.e. the same toxicants were present in specimens at varying concentrations). This indicates that the uptake of metals by biota in dams at the power stations was similar to the comparative dam.

9.2 March 2017 Survey

A total of 5527 native fish comprising 14 species and 9 families were caught across all sites. Native fish species caught included:

- Agassiz's glassfish (*Ambassis agassizi*; Figure 9.1)
- Long-finned eel (*Anguilla reinhardtii*; Figure 9.2)
- Marjorie's hardyhead (*Craterocephalus marjoriae*; Figure 9.3)
- fly-specked hardyhead (*Craterocephalus stercusmuscarum*; Figure 9.4)
- bony bream (*Nematalosa erebi*)
- western carp gudgeon (*Hypseleotris klunzingeri*; Figure 9.5)
- carp gudgeon (*Hypseleotris* spp.; Figure 9.6)
- purple spotted gudgeon (*Mogurnda adspersa*; Figure 9.7)
- flathead gudgeon (*Philypnodon grandiceps*; Figure 9.8)
- crimson spotted rainbowfish (*Melanotaenia duboulayi*; Figure 9.9)
- freshwater catfish (*Tandanus tandanus*; Figure 9.10)
- Australian smelt (*Retropinna semoni*; Figure 9.11)
- barred grunter (*Amniataba percooides*; Figure 9.12), and
- spangled perch (*Leiopotherapon unicolor*; Figure 9.13).

In addition to these native fish, 125 exotic fish comprising 2 species and 2 families were caught:

- mosquitofish (*Gambusia holbrooki*; Figure 9.14), and
- goldfish (*Carassius auratus*; Figure 9.15).



Mosquitofish are declared as restricted noxious fish under the *Biosecurity Act 2014* (DAF 2017a). Mosquitofish are an aggressive fish that compete with native fish for resources and prey on the eggs and larvae of native fish and frogs. They breed in high numbers and can rapidly outnumber native fish and dominate aquatic communities (DAF 2016c). Mosquitofish were caught in Meandu Creek downstream of Meandu Creek Dam, as well as at comparative site SW36. Goldfish are a non-indigenous fish that are declared a pest fish when in the wild (DAF 2017b). Goldfish were caught at site MC15 downstream of Meandu Creek Dam as well as at comparative site SW36. Neither exotic species were caught in Barker Creek upstream of the confluence with Meandu Creek, or in Meandu Creek upstream of the Meandu Creek Dam. Both species are listed to occur throughout the Barker and Barambah creeks drainage sub-basin (EHP 2017c), so it is unlikely that their presence downstream of Meandu Creek Dam is an impact from Meandu Mine or the Tarong power stations.

The crimson-spotted rainbowfish was the most widespread native fish and was caught at all sites except site MCA3/MC5 on Meandu Creek upstream of Meandu Creek Dam. This species is tolerant of high electrical conductivity, varying pH levels and low dissolved oxygen (Pusey et al. 2004).

The following species were only caught at sites on Meandu Creek upstream and/or downstream of Meandu Creek Dam and were not caught at comparative sites:

- fly-specked hardyhead
- bony bream, and
- Australian smelt.

The following species were only found at comparative sites:

- long-finned eel; caught in Barambah Creek only (i.e. downstream of Bjelke-Petersen Dam)
- Marjorie's hardyhead; caught in Barker Creek only
- flathead gudgeon; caught in Barambah Creek only (i.e. downstream of Bjelke-Petersen Dam), and
- barred grunter; caught in Barambah Creek only (i.e. downstream of Bjelke-Petersen Dam).

Overall, the species that were caught are widespread and common across Australia. None are listed threatened species under the Commonwealth *Environment and Biodiversity Conservation Act 1999* (EPBC Act) or Queensland *Nature Conservation Act 1992* (NC Act). Most are tolerant of varied environmental conditions, especially high conductivity (Pusey et al. 2004). There was a difference in the community composition of fish at sites on Meandu Creek upstream and downstream of Meandu Creek Dam compared to comparative sites, however this was likely due to site-specific differences in aquatic habitat characteristics. It is also possible that Bjelke-Petersen Dam restricts the passage of some species from Barambah Creek to upstream catchment areas.





Figure 9.1 Agassiz's glassfish



Figure 9.2 Long-finned eel



Figure 9.3 Marjorie's hardyhead



Figure 9.4 Fly-specked hardyhead



Figure 9.5 Western carp gudgeon



Figure 9.6 Carp gudgeon





Figure 9.7 Purple spotted gudgeon

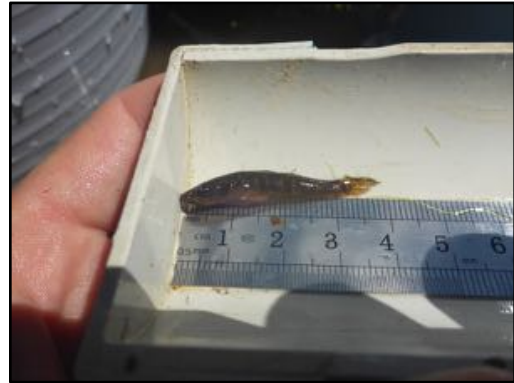


Figure 9.8 Flathead gudgeon



Figure 9.9 Crimson spotted rainbowfish



Figure 9.10 Freshwater catfish



Figure 9.11 Australian smelt



Figure 9.12 Barred grunter





Figure 9.13 Spangled perch



Figure 9.14 Mosquitofish



Figure 9.15 Goldfish

9.2.1 Species Richness

Species richness of fish was highest at comparative site SW36 and was lowest at site MCA3/MC5, followed by site MCA1/MC6, both on Meandu Creek upstream of Meandu Creek Dam. While it is possible that poor water quality is affecting the composition of fish communities here, low species richness at these sites may also be due to:

- their location within the catchment (i.e. they were located towards the upstream reaches of Meandu Creek where flow and lasting pools are minimal and conditions are not ideal for fish species to establish)
- a lack of connectivity at these sites to waterways further downstream to allow fish passage to these locations
- lack of habitat available to support a high diversity of species, and
- changing habitat conditions at the sites as a result of site water management (i.e. water was regularly pumped from site MCA1/MC5 in 2016 and 2017 when water levels were too high, though pumping no longer occurs regularly).

There was also 1 or 2 fewer species present at sites MC5/W2 and MC15 on Meandu Creek downstream of Meandu Creek Dam compared with the comparative sites. However, at these sites there were no substantial differences in water or sediment quality (compared with the



other sites in this reach). The lower richness at these sites is more likely to be related to different availability of habitat at these sites.

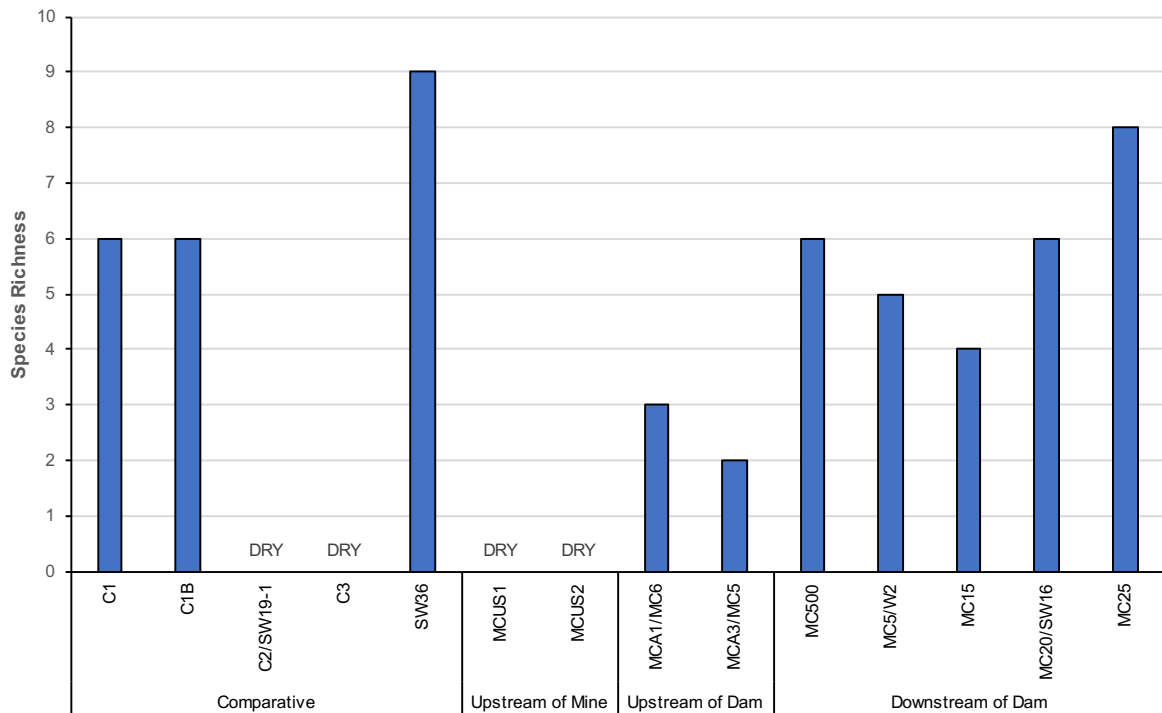


Figure 9.16 Species richness of native fish caught at each site during the field survey

9.2.2 Abundance

The abundance of native fish varied substantially between sites and was lowest at site MCA3/MC5 (14 individuals) on Meandu Creek upstream of Meandu Creek Dam, and highest at site MC25 (2857 individuals) on Meandu Creek downstream of the dam. Abundance at comparative sites ranged from 165 to 1412. Abundance at sites downstream of Meandu Creek Dam closest to the input (i.e. within 15 km of Meandu Creek Dam) was below the range recorded at the comparative sites. This is likely to be related to site-specific habitat factors, and also the availability of connected habitat upstream and downstream for fish to disperse to (whereas fish at comparative sites C1 and C1B were concentrated in pools and easier to sample).

The most abundant fish were:

- Fly specked hardyhead: 2137 individuals caught in total and only at sites on Meandu Creek downstream of Meandu Creek Dam.
- Carp gudgeon: 1452 individuals caught in total and present at comparative sites, and sites on Meandu Creek upstream and downstream of Meandu Creek Dam but most abundant at comparative sites.
- Crimson spotted rainbowfish: 1346 individuals caught in total and present at comparative sites, and sites on Meandu Creek upstream and downstream of Meandu Creek Dam.



Native fish were more abundant than exotic fish at all sites where they were caught, and overall the abundance of exotic fish was still relatively low throughout the survey area: only 125 exotic individuals were caught in total.

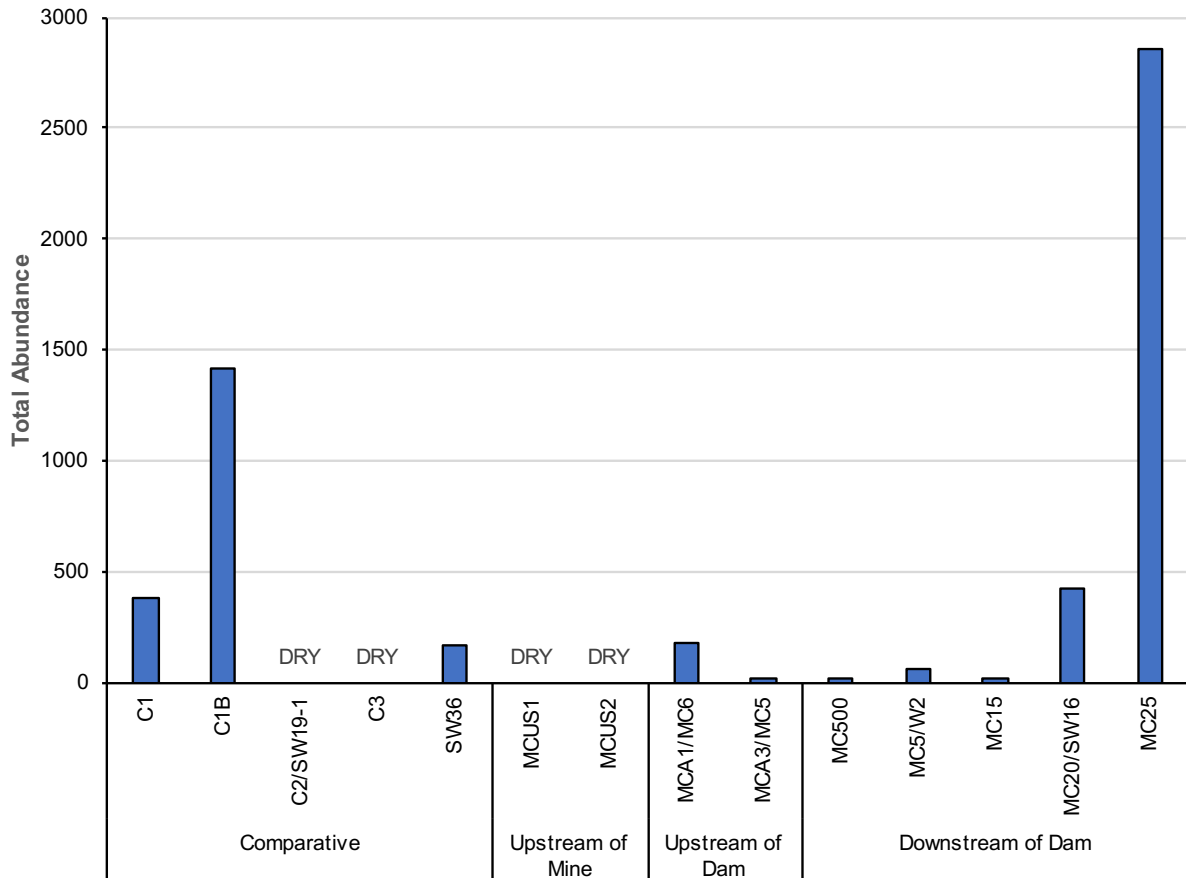


Figure 9.17 Abundance of native fish caught at each site during the field survey



Table 9.1 Abundance of fish caught at each site during the field survey

Family <i>Species</i>	Common Name	Comparative					Meandu Creek upstream of Mine		Meandu Creek upstream of Meandu Creek Dam		Meandu Creek downstream of Meandu Creek Dam					
		C1	C1B	C2/ SW19	C3	SW36	MCUS1	MCUS2	MCA1/ MC6	MCA3/ MC5	MC500	MC5/ W2	MC15	MC20/ SW16	MC25	
Ambassidae																
<i>Ambassis agassizi</i>	Agassiz's glassfish	62	55										7	85	101	
Anguillidae																
<i>Anguilla reinhardtii</i>	Long-finned eel					1										
Atherinidae																
<i>Craterocephalus marjoriae</i>	Marjorie's hardyhead	3														
<i>Craterocephalus stercusmuscarum</i>	Flyspecked hardyhead									1	2	2	311	1857		
Clupeidae																
<i>Nematalosa erebi</i>	Bony bream													1		
Cyprinidae																
<i>Carassius auratus</i> *	Goldfish *					1						9				
Eleotridae																
<i>Hypseleotris klunzingeri</i>	Western carp gudgeon					29			3	5	1		2	15		
<i>Hypseleotris sp.</i>	Carp gudgeon	138	1261			45		3						5		
<i>Mogurnda adspersa</i>	Purple spotted gudgeon	1	2			5		24	11	1						
<i>Philypnodon grandiceps</i>	Flathead gudgeon					2										



Family <i>Species</i>	Common Name	Comparative					Meandu Creek upstream of Mine		Meandu Creek upstream of Meandu Creek Dam		Meandu Creek downstream of Meandu Creek Dam					
		C1	C1B	C2/ SW19	C3	SW36	MCUS1	MCUS2	MCA1/ MC6	MCA3/ MC5	MC500	MC5/ W2	MC15	MC20/ SW16	MC25	
Melanotaeniidae																
Melanotaenia duboulayi	Crimson spotted rainbowfish	166	51			29			148		6	45	2	27	872	
Plotosidae																
Tandanus tandanus	Freshwater catfish	8	42			28					8	3	10	1	1	
Poeciliidae																
Gambusia holbrooki *	Mosquitofish *					48							6	50	11	
Retropinnidae																
Retropinna semoni	Australian smelt														5	
Terapontidae																
Amniataba percoides	Barred grunter					20										
Leiopotherapon unicolor	Spangled perch		1			6					1	5			1	
Total native fish abundance at each site		378	1412	–	–	165	–	–	175	14	22	56	21	427	2857	
Total abundance at each site		378	1412	–	–	214	–	–	175	14	22	56	36	477	2868	

* indicates exotic species

– indicates dry site; not surveyed for fish



9.2.3 Life History Stages

Adult fish dominated native fish communities at most sites, except at site MC15 on Meandu Creek downstream of Meandu Creek Dam (where intermediate fish were dominant; Figure 9.18).

Across all sites there was a low percentage of juvenile fish present (which is likely to be related to the timing of the survey), however no juveniles were present at sites on Meandu Creek upstream or downstream of Meandu Creek Dam within 20 km of the input. This is likely to be related to site-specific factors such as strong flows and / or habitat availability for shelter and protection.

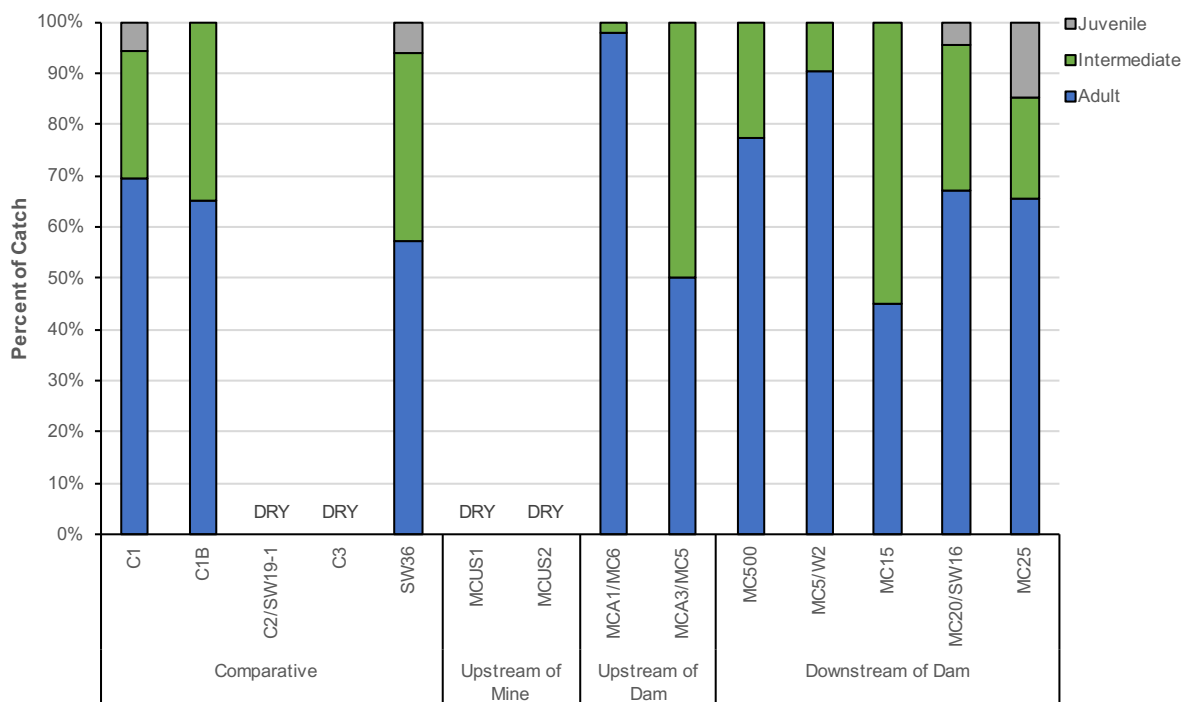


Figure 9.18 Percent of catch of life history stages of native fish caught at each site during the field survey



10 Other Aquatic Vertebrates

Platypus and turtles were caught incidentally during the March 2017 field surveys. All were released unharmed.

One platypus (*Ornithorhynchus anatinus*) was caught at comparative site SW36 (Figure 10.1).

Thirteen (13) native turtles comprising of three species and one family were caught (Table 10.1) including:

- Krefft's River turtle (*Emydura macquarii krefftii*; Figure 10.2)
- eastern snake-necked turtle (*Chelodina longicollis*; Figure 10.3), and
- saw-shelled turtle (*Wollumbina latisternum*; Figure 10.4).

All species captured are common and widespread in Queensland and inhabit broad range of freshwater aquatic habitats including shallow, ephemeral wetlands, flowing streams, deep permanent pools and farm dams. None are listed threatened species under the Commonwealth EPBC Act or Queensland NC Act.

Turtles were caught at all sites on Meandu Creek downstream of Meandu Creek Dam except at site MC500 (which had fast flow not favoured by the above species) and at comparative site SW36.



Figure 10.1 Platypus





Figure 10.2 Krefft's River turtle



Figure 10.3 Eastern snake-necked turtle



Figure 10.4 Saw-shelled turtle



Table 10.1 Turtles caught at each site during the field survey

Family <i>Species</i>	Common Name	Comparative			Meandu Creek upstream of Meandu Creek Dam		Meandu Creek downstream of Meandu Creek Dam				
		C1	C1B	SW36	MCA1/ MC6	MCA3/ MC5	MC500	MC5/W2	MC15	MC20/ SW16	MC25
Chelidae											
<i>Chelodina longicollis</i>	Eastern snake-necked turtle								1		
<i>Emydura macquarii krefftii</i>	Krefft's River turtle			2				1		7	1
<i>Wollumbina latisternum</i>	Saw-shelled turtle										1
Total abundance at each site		0	0	2	0	0	0	1	1	7	2



11 Assessment of AMD Related Impacts

11.1 Environmental Values of Meandu Creek

Meandu Creek downstream of the release point CP3 is considered the surface water receiving environment of potential AMD-related impacts. Release point CP3 is located within Meandu Creek upstream of Meandu Creek Dam. During periods of flows, water in this reach flows into Meandu Creek Dam (3,000 ML storage capacity), where it gets diluted with cooling water blowdown and storm water from the Tarong and Tarong North power stations and released via licensed discharges to Meandu Creek downstream of Meandu Creek Dam.

There are currently no assigned environmental values in Schedule 1 of the EPP (Water) for Meandu Creek. Thus, relevant EVs were assigned from those outlined in Section 6 (2) of the policy, with reference to other relevant sources, such as the Burnett Mary WQIP (BMRG 2015), available literature, previous technical reports and the current field surveys.

Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam form part of the water management systems for Meandu Mine and the Tarong power stations. Thus, the industrial use environmental value (EV) was assigned to Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam. These waters are managed with the aim of protecting the aquatic values of the downstream waterways of Meandu Creek downstream of Meandu Creek Dam, with current compliance limits outlined in the EA's for Meandu Mine and Tarong power stations considered appropriate for management of these waters (published WQOs do not apply to this reach).

EVs assigned to Meandu Creek downstream of Meandu Creek Dam were:

- aquatic ecosystems (moderately disturbed)
- irrigation
- farm supply
- stock watering
- human consumption
- primary recreation
- secondary recreation, and
- industrial use.

Published water quality objectives (WQOs) have been assigned to this reach to manage these EVs. The most stringent WQO (mostly associated with protecting moderately disturbed aquatic ecosystems) was generally assigned. The source of assigned WQOs is outlined in Section 3.3.

11.2 Resilience of Aquatic Communities in Meandu Creek

Resilience is the capacity of a system to experience shocks while retaining the same basic function, structure and feedbacks, and therefore identity (Walker et al 2004). The resilience



of aquatic communities in Meandu Creek was assessed based on the sensitivity of aquatic communities, values and processes within the waterway to tolerate disturbance events (either long term permanent changes or to short-term, moderate impacts). Communities consisting of more sensitive taxa are generally less resilient than those comprising more tolerant taxa, as they are more susceptible to changes in the conditions of their environment.

11.2.1 General Resilience of Aquatic Communities

Aquatic communities in Meandu Creek upstream of Meandu Creek Dam (adjacent to the mine) and within Meandu Creek Dam are considered to have high general resilience (i.e. as a response to unforeseen disturbance) as:

- aquatic communities present have adapted to changes in the catchment, including dams, diversions, mining and power station activities
- macroinvertebrate communities are relatively diverse and include some sensitive taxa, but are generally dominated by tolerant taxa that are able to withstand harsh environmental conditions
- despite a history of disturbance (from dams, diversions, agriculture, mining and power station activities) in the catchment, the aquatic habitat is generally in moderate health, with some sensitive and long-lived species present (fish)
- species in the region tend to be opportunistic (a typical trait of ephemeral systems) and are able to adapt quickly, colonise rapidly and regenerate when conditions are suitable (e.g. local waterholes can 'seed' disturbed areas when conditions are suitable)
- long lived species (e.g. fish) are present, which tend to be more sensitive to bioaccumulation and habitat changes.

Aquatic communities in Meandu Creek downstream of Meandu Creek Dam are considered to have a moderate general resilience (i.e. as a response to unforeseen disturbance) as:

- aquatic communities have historically adapted quickly to long-term changes, including the relatively recent change from an ephemeral to perennial system due the continuous releases from Meandu Creek Dam
- aquatic communities have colonised the waterway relatively quickly following the long-term change from an ephemeral to perennial system due the continuous releases from Meandu Creek Dam
- macroinvertebrate communities are diverse and include many sensitive taxa (making them more sensitive to changes in their environment than communities dominated by tolerant species)
- despite a history of disturbance (from dams, diversions, agriculture, mining and power station activities) in the catchment, the aquatic habitat is in good health, with many sensitive and long-lived species present (fish and turtles)
- species in the region tend to be opportunistic and are able to adapt quickly, colonise rapidly and regenerate when conditions are suitable (e.g. local waterholes can 'seed' disturbed areas when conditions are suitable)



- a diverse range of long lived species are present (e.g. fish and turtles), which tend to be more sensitive to bioaccumulation and habitat changes.

11.2.2 Specific Resilience of Communities to Current Conditions

Communities both upstream and downstream of Meandu Creek Dam are resilient to disturbance from the current Meandu Mine and the Tarong power stations activities, with aquatic communities adapted to the ambient water quality, sediment quality and habitat conditions (particularly to high electrical conductivity and high concentrations of some metals in the water and sediment which were recorded in Meandu Creek adjacent to the mine).

Overall, aquatic communities of Meandu Creek downstream of Meandu Creek Dam have a high specific resilience (i.e. as a response to a specific disturbance) to current mining and power station activities as they have previously shown rapid adaptation and colonisation following changing conditions and are generally in a similar or better condition than would be expected in the broader catchment.

11.3 Current Impacts to the Environmental Values of Meandu Creek

A discussion of the results of the study in relation to key indicators of aquatic ecological condition, including water quality, sediment quality, and aquatic floral and faunal communities, is presented in the Sections 11.3.1 to 11.3.3 below. A summary of the overall current impacts of mine-affected water on the environmental values of Meandu Creek is presented in Section 11.3.4.

11.3.1 Water Quality

The results of historical surface water monitoring completed at Meandu Mine and the Tarong and Tarong North power stations, and of the March 2017 survey, demonstrate that electrical conductivity levels and the concentrations of major ions (including sulfate), nitrate and some dissolved metals are higher in Meandu Creek adjacent to and downstream of Meandu Mine than at comparative sites within the region. This may be indicative of an AMD-related impact; however, other factors such as operation of the Tarong power stations and catchment inputs also influence some of these parameters. Each of the surface water quality parameters potentially impacted are discussed below.

11.3.1.1 Electrical Conductivity

Electrical conductivity is high in Meandu Creek upstream of Meandu Creek Dam, particularly in the reaches adjacent to Meandu Mine. There has also been a trend of increasing electrical conductivity levels at Meandu Mine compliance points CP3 (Meandu Creek prior to discharge to Meandu Creek Dam) and CP1 (Meandu Creek Dam) in the past four years. While it is possible that this may be as a result of AMD, there may be other contributing factors such as ambient rainfall and catchment inflows, and potentially groundwater seepage, to these reaches of the creek. The groundwater assessment undertaken by JBT Consulting identified a high electrical conductivity zone from an airborne geophysics survey along Meandu Creek to the west of the mining area. This zone was interpreted to be related to a combination of factors, including:



- the presence of basaltic clays (from the southern area of the lease) within the Meandu Creek alluvium
- saline seepage from the mining area, and
- saline seepage from high salinity areas to the west of Meandu Creek (e.g. the drainage channel adjacent to GW78, with the electrical conductivity at GW78 >13,000 $\mu\text{S}/\text{cm}$).

Electrical conductivity is a broad indicator of the amount of dissolved inorganic material in waterways (i.e. total concentration of ions). Effects of electrical conductivity on the aquatic ecosystem are generally based on significant changes to the normal range of waterways (Volume 2 of ANZECC & ARM CANZ 2000a). Adverse biological effects are most likely to occur when there are changes to electrical conductivity (more so when there is an increase in the electrical conductivity). Excess salt in freshwater systems can impact aquatic organisms through:

- altering the natural habitat by influencing energy and nutrient cycles, the consumption of oxygen, primary productivity and water clarity (Nielsen et al. 2003)
- modification of species composition of the ecosystem due to changes in the amount and type of food or refuge (ANZECC & ARM CANZ 2000a), and
- direct toxicity caused by physiological responses, such as changes in ionic and water regulation (Hart et al. 1991, Hart et al. 2003).

The electrical conductivity within Meandu Creek downstream of Meandu Creek Dam is maintained within a narrow range during normal mine and power station operating conditions, because the primary source of water to this reach comes from the continuous controlled and monitored discharges from Meandu Creek Dam. While the electrical conductivity levels recorded in Meandu Creek downstream of Meandu Creek Dam is relatively high compared with the comparative sites surveyed in the region, it has not exceeded the WQO (which is based on the long-term 80th percentile value for the sites downstream of the dam) over the past four years. The results of current and historical aquatic biota monitoring confirm that electrical conductivity levels in Meandu Creek downstream of Meandu Creek Dam are not resulting in negative impacts to aquatic biota (Section 11.3.3).

As such, while AMD-related impacts may have contributed to elevated electrical conductivity levels in the surface waters of Meandu Creek upstream of Meandu Creek Dam in the past four years, other factors such as climatic conditions and operation of the Tarong power stations also have a larger influence on the electrical conductivity levels in Meandu Creek Dam. Based on the information presented in this report, there is currently no evidence that electrical conductivity from mine impacted water is having a negative impact on the environmental values of the receiving environment.

11.3.1.2 Sulfate

Concentrations of sulfate in Meandu Creek (both upstream and downstream of Meandu Creek Dam) are higher than concentrations recorded at comparative sites in the region. There has been a general trend of increasing sulfate concentrations at Meandu Mine compliance points CP3 and CP4 in the past 10 years, which may be an AMD-related impact.



However, the concentrations of sulfate have historically been below the WQO (which is based on the stock watering guideline, and not directly applicable to the Meandu Creek upstream of Meandu Creek Dam). The trend of increasing sulfate concentrations was not observed at site CP1 in Meandu Creek Dam, where sulfate concentrations are also influenced by operation of the Tarong power stations. Concentrations of sulfate in Meandu Creek Dam have historically been below the WQO (based on the stock watering guideline), as well as the more stringent drinking water guideline.

As such, while AMD-related impacts may be resulting in elevated sulfate concentrations in the surface waters released from Meandu Mine, there is no evidence of this impact extending to Meandu Creek Dam or Meandu Creek downstream of Meandu Creek Dam. Based on the information presented in this report, there is currently no evidence that the concentration of sulfate in mine impacted water is having a negative impact on the environmental values of the receiving environment.

11.3.1.3 Nitrate

Long-term median concentrations of nitrate have historically been higher at the Meandu Mine compliance point CP3 (0.77 mg/L) than at sites in Meandu Creek adjacent to the mine (0.39 mg/L); median concentrations were lower in the past four years than they have been historically. Long-term median concentrations were higher at the Meandu Creek Dam release point (site W3, 0.8 mg/L) and Meandu Creek 2 km downstream of Meandu Creek Dam (site W2, 1 mg/L) than at the Meandu Mine monitoring sites. Concentrations of oxidised nitrogen in the Meandu Creek downstream of Meandu Creek Dam during the March 2017 survey varied between sites, indicating that there were likely to be other (catchment) inputs of oxidised nitrogen (nitrate and nitrite) to Meandu Creek. While nitrate can be indicative of AMD impacted water, other sources, such as the liberation of elemental geological nitrogen at Meandu Mine, the operation of the Tarong power stations and catchment inputs also influence concentrations of nitrate. Thus, it is not considered to be a key indicator for AMD in this assessment. Based on the information presented in this report, concentrations of nitrate in Meandu Creek are unlikely to be related to AMD impacts, but rather sourced from other inputs including Meandu Mine, the Tarong power stations and catchment inputs.

Nitrate and nitrite are common forms of nitrogen; nitrate is the most commonly available form of nitrogen and is readily assimilated by plants for growth. However, in high concentrations it can cause nuisance plant growth such as algae, which can dominate and change the dynamics of the aquatic ecosystem. Nitrate has also been identified as toxic to certain aquatic crustaceans; causing mortality and detrimental tissue damage to prawns in their early life stages (Volume 2, ANZECC & ARMCANZ 2000a).

Chronic effects of nitrate are not expected unless the concentration of nitrate is higher than 0.7 mg/L, which equates to the default slightly-moderately disturbed toxicant trigger value for the protection of 95% of freshwater species (ANZECC & ARMCANZ 2000a). The 90% species protection trigger level (applicable to highly disturbed systems) is much higher, at 3,400 mg/L (ANZECC & ARMCANZ 2000a). As median concentrations of nitrate are typically close to the 95% species protection trigger level, and well-below the 90% species protection trigger level, it is unlikely that the concentrations of nitrate in Meandu Creek are causing chronic or acute impacts toxicity to most aquatic organisms. The results of current



and historical aquatic biota monitoring did not indicate any negative impacts to aquatic biota in Meandu Creek downstream of Meandu Creek Dam (Section 11.3.3).

11.3.1.4 Cobalt

Concentrations of dissolved cobalt were much higher at Meandu Mine compliance site CP3 than all other sites, including site CP1 on Meandu Creek Dam. Similarly, the concentration of cobalt was highest at site CM2 on Meandu Creek at the Meandu Creek Dam inlet in the March 2017 survey. While not directly applicable, concentrations of dissolved cobalt at sites CP3 were generally below the WQO. Concentrations of cobalt in Meandu Creek Dam and Meandu Creek downstream of the dam are well-below the WQO.

As such, while AMD-related impacts may be resulting in elevated cobalt concentrations in the surface waters released from Meandu Mine, there is no evidence of this impact extending to Meandu Creek Dam or Meandu Creek downstream of Meandu Creek Dam. Concentrations are well-below the WQO for the protection of aquatic ecosystems. Based on the information presented in this report, there is currently no evidence that the concentration of cobalt from mine impacted water is having a negative impact on the environmental values of the receiving environment.

11.3.1.5 Manganese

Historical monitoring results showed that concentrations of dissolved manganese on Meandu Creek upstream of Meandu Creek Dam are variable, but were often highest (and while not directly applicable, above the WQO for ecosystem protection) at compliance point CP3. This may be an AMD-related impact. However, concentrations of dissolved manganese at site CP1 on Meandu Creek Dam were much lower than those recorded at CP3, and were below the WQO. Whilst manganese has not been routinely monitored in Meandu Creek downstream of Meandu Creek Dam, the results of the March 2017 survey indicated that concentrations of manganese in Meandu Creek downstream of Meandu Creek Dam are within the range recorded at comparative sites, and concentrations of dissolved manganese are below the WQO for the protection of aquatic ecosystems.

As such, while AMD-related impacts may be resulting in elevated manganese concentrations in the surface waters released from Meandu Mine, there is no evidence of this impact extending to Meandu Creek Dam or Meandu Creek downstream of Meandu Creek Dam. Based on the information presented in this report, there is currently no evidence that the concentration of manganese from mine impacted water is having a negative impact on the environmental values of the receiving environment.

11.3.1.6 Nickel

Concentrations of dissolved nickel were much higher at Meandu Mine compliance site CP3 than all other sites, including site CP1 on Meandu Creek Dam. Similarly, the concentration of nickel was high at site CM2 on Meandu Creek at the Meandu Creek Dam inlet in the March 2017 survey. While not directly applicable, concentrations of dissolved nickel at sites CP3 and CM2 were below the hardness-modified WQO for nickel. Concentrations of nickel in Meandu Creek Dam and Meandu Creek downstream of the dam are higher than those recorded at the comparative sites in the region, but below the hardness-modified WQO.



Nickel can be present in the environment through natural and anthropogenic sources. It is possible that AMD-related impacts may be resulting in elevated nickel concentrations in the surface waters released from Meandu Mine. However, there are also likely to be catchment sources of nickel to Meandu Creek (e.g. concentrations of nickel in the sediment of Meandu Creek upstream of Meandu Mine were relatively high; Section 5.2.6). Based on the information presented in this report, there is currently no evidence that the concentration of nickel from mine impacted water is having a negative impact on the environmental values of the receiving environment.

11.3.1.7 Zinc

Concentrations of dissolved zinc were much higher at Meandu Mine compliance site CP3 than all other sites, including site CP1 on Meandu Creek Dam. Similarly, site CM2 on Meandu Creek at the Meandu Creek Dam inlet was the only site where dissolved zinc was detected (i.e. recorded in a concentration higher than the laboratory LOR) in the March 2017 survey. While not directly applicable, concentrations of dissolved zinc at site CP3 have generally been below the hardness-modified trigger value for zinc. Long-term median concentrations of dissolved zinc in Meandu Creek Dam and Meandu Creek downstream of the dam are low (close to the laboratory LOR) and below the WQO.

It is possible that AMD-related impacts may be resulting in elevated zinc concentrations in the surface waters released from Meandu Mine. However, there is no evidence of this impact extending downstream to Meandu Creek Dam. Based on the information presented in this report, there is currently no evidence that the concentration of zinc from mine impacted water is having a negative impact on the environmental values of the receiving environment.

11.3.2 Sediment Quality

In the March 2017 survey, there was a general trend of higher concentrations of some metals that may be influenced by AMD (cobalt, manganese, nickel and zinc), particularly at site CM2. In the April 2018 survey, concentrations of dilute acid extractable nickel and zinc (representative of the bioavailable fraction) exceeded the sediment quality guideline-high value (SQG-high) at this site; there are no sediment quality guideline values (SQGVs) for cobalt and manganese. Furthermore, there was not a molar excess of acid volatile sulfides compared to simultaneously extracted metals at site CM2, indicating metals are unlikely to be bound in sulfide complexes and may be dissolved and thus bioavailable to aquatic flora and fauna.

Site CM2 was located at the Meandu Mine inlet to Meandu Creek Dam, and as such receives discharges from the mine that may be affected by AMD. The site was characterised as a narrow pool with substrate dominated by silt. Cumbungi (bulrush) was present in dense stands at this site. Cumbungi is known to have significant sediment-trapping abilities by slowing water flow and trapping suspended sediment in their root systems (Stephens & Dowling 2002). The high concentrations of metals in sediment at site CM2 are likely to be a result of the settlement of fine sediments in the channel, from the slowing of water in Meandu Creek as it enters Meandu Creek Dam and passes through the Cumbungi, decreasing in velocity (Volume 2, ANZECC & ARMCANZ 2000a).



Concentrations of cobalt, nickel and zinc in Meandu Creek Dam were slightly higher than background concentrations in the catchment, with maximum bioavailable concentrations of nickel and zinc exceeding the SQGV at site MCDS2, where Meandu Creek enters Meandu Creek Dam. In contrast, concentrations of manganese were low in Meandu Creek Dam, and within the range of that at comparative sites.

Concentrations of cobalt, manganese, nickel and zinc in the sediment of Meandu Creek within 500 m downstream of Meandu Creek Dam were higher than the background concentrations in the catchment, and above the SQGV for nickel and zinc at site MC500 (where fine sediments are likely to accumulate due to channel morphology). However, the results of biological surveys, including macroinvertebrates in bed habitat (i.e. living in the sediment) showed no evidence of impacts as a result of higher concentrations of metals in the sediment at these sites (Section 11.3.3). Furthermore, additional analysis of sediment in April 2018 showed that concentrations of metals and metalloids in Meandu Creek downstream of Meandu Creek Dam are unlikely to be bioavailable for uptake by aquatic flora and fauna (i.e. there was a molar excess of acid volatile sulphides compared to simultaneously extracted metals).

In summary, it is possible that AMD is resulting in the accumulation of cobalt, manganese, nickel and zinc in the sediment of the Meandu Creek channel between Meandu Mine and Meandu Creek Dam. The dense Cumbungi stands in this channel are likely acting as a sediment trap, resulting in the retention of metals bound to fine sediments (before they enter Meandu Creek Dam).

Historical sediment quality investigations have concluded that Meandu Creek Dam also acts as a sediment trap and a sink for metals (Footprints 2014), with accumulation of the above metals in the dam potentially related to AMD from Meandu Mine. However, other sources of metals in the sediments of the dam include local geology and metal leaching from condensers at Tarong Power Station (prior to their replacement with titanium), as well as the influence of local geology on the cycled water from Boondooma Dam and Wivenhoe Dam. While the concentrations of some metals were higher than background concentrations and the SQGV (where available) in the Meandu Creek, most notably within 500 m of Meandu Creek Dam, there is no evidence to suggest that aquatic flora and fauna are being negatively influenced (refer to Section 11.3.3).

11.3.3 Aquatic Flora and Fauna

11.3.3.1 Aquatic Plants

Results from aquatic plant surveys indicate that AMD is unlikely to be negatively influencing aquatic vegetation downstream of Meandu Creek Dam. Aquatic plants in these reaches are influenced by site-specific factors such as aquatic habitat types and substrate composition.

There was lower taxonomic richness of aquatic plants at sites on Meandu Creek upstream of Meandu Creek Dam than at the comparative sites. It is unclear whether this is related to poor water and sediment quality (including impacts associated with AMD, as discussed above), or poor habitat quality and lower connectivity with natural stream reaches (not related to AMD).



11.3.3.2 Aquatic Macroinvertebrates

There were no statistically significant differences in macroinvertebrate richness, abundance and the presence of sensitive taxa (SIGNAL 2 scores and PET richness) between sites located on Meandu Creek (upstream and downstream of Meandu Creek Dam) and the comparative sites. That is, there was no evidence of an impact to macroinvertebrate assemblages as a result of AMD-related impacts. Macroinvertebrate indices in Meandu Creek (upstream and downstream of the dam) were within the large range of natural variation in macroinvertebrate assemblages throughout the study area, which included comparative sites in ephemeral pools as well as perennial streams (downstream of Bjelke-Petersen Dam).

A similar range of macroinvertebrate taxa were generally recorded at sites in Meandu Creek upstream of Meandu Creek Dam (i.e. sites adjacent to the mine and downstream of mine discharges) and at the ephemeral comparative sites. This highlights the resilience of the macroinvertebrates of the region, including those in Meandu Creek upstream of Meandu Creek Dam, to high electrical conductivity and high concentrations of some metals in the water and sediment (which were recorded in Meandu Creek adjacent to the mine). Although there were no statistically significant differences in macroinvertebrate indices between sites located on Meandu Creek and the comparative sites, there were more subtle differences in composition, with some sensitive taxa recorded at comparative sites but not at sites on Meandu Creek upstream of Meandu Creek Dam; however, this was not the case downstream of Meandu Creek Dam.

Macroinvertebrate community structure (based on SIGNAL 2 / family bi-plots) was not indicative of toxic pollution at any site. A higher proportion of sensitive taxa than would be naturally expected for the region was recorded in Meandu Creek downstream of Meandu Creek Dam (particularly within 15 km of the Meandu Creek Dam release point). This indicates that releases from Meandu Creek Dam are having a positive influence on macroinvertebrate communities downstream of Meandu Creek Dam, which is most likely due to the flow and stable, perennial and diverse habitat created by the constant releases. There was no evidence of acute or chronic toxicity associated with water or sediment quality in Meandu Creek downstream of Meandu Creek Dam.

Taxonomic richness, SIGNAL 2 scores and PET Richness were significantly lower at the Meandu Creek Dam sites than at the comparative sites and downstream of Meandu Creek Dam sites. This is likely to reflect the low habitat diversity of the dam (which is typical of impoundments) as well as the low water levels at the time of the March 2017 survey (and the resulting lack of aquatic habitat at the survey sites). There were no correlations between water or sediment quality and macroinvertebrate community structure that would suggest that electrical conductivity levels or the concentrations of metals in water and sediment were negatively influencing macroinvertebrates within Meandu Creek Dam (or in Meandu Creek upstream and downstream of the dam).

11.3.3.3 Fish and Other Aquatic Vertebrates

Species richness and abundance of fish was low at sites on Meandu Creek upstream of Meandu Creek Dam (adjacent to Meandu Mine). While it is possible that the high electrical conductivity and high concentration of some dissolved metals is affecting the composition of



fish communities here, low species richness and abundance at these sites may also be due to a range of other factors including the upstream location in the catchment and a lack of connectivity with downstream reaches (particularly due to the presence of Meandu Creek Dam); along with poorer habitat quality as a result of the construction of diversions and mine water management. There was no obvious evidence of toxic effects to fish in this reach, such as obvious signs of ill-health (skin lesions etc.), suggesting that some native fish species found in the region (gudgeons and rainbowfish) are resilient to variable and sometimes poor water quality.

In general, the range of fish species recorded in Meandu Creek downstream of Meandu Creek Dam was similar to that recorded at the comparative sites in the region. The presence of a variety of native fish and turtles in the Meandu Creek downstream of Meandu Creek Dam confirms its suitability as habitat for a range of native aquatic fauna species, and provide further evidence that potential AMD-related impacts to water and sediment quality are not having a negative impact on the environmental values of the receiving environment.

11.3.4 Summary

It is possible that AMD is resulting in higher electrical conductivity levels and concentrations of ions (including sulfate), nitrate and some metals (notably cobalt, manganese, nickel and zinc) in the waters discharged from Meandu Mine to Meandu Creek Dam. However, in many cases the impact does not extend to or beyond Meandu Creek Dam, and other factors (such as climatic conditions, catchment-related inputs and operation of the Tarong and Tarong North power stations) also influence concentrations of these parameters in the dam. Long-term trends indicate that concentrations of all water quality parameters are generally below the relevant WQOs in Meandu Creek downstream of Meandu Creek Dam.

It is possible that AMD is resulting in the accumulation of the metals (cobalt, manganese, nickel and zinc) in sediment, mostly within the channel running between Meandu Mine and Meandu Creek Dam, and in Meandu Creek Dam. There are also relatively high concentrations of some metals in sediments close to (within 500 m of) Meandu Creek Dam, in areas where fine sediments settle, though sources from power station operation may also be contributing to this.

However, there is no evidence that impacts to water and sediment quality are resulting in negative impacts to the environmental values of Meandu Creek. Aquatic flora and fauna communities upstream of Meandu Creek Dam generally demonstrate resilience to poor water quality (e.g. high electrical conductivity and concentrations of ions, nitrate and some metals). However, these communities are likely affected by poor connectivity to downstream environments and impacts associated with mine water management (e.g. creation of diversion channels and management of water levels by pumping).

Aquatic flora and fauna communities in Meandu Creek downstream of Meandu Creek Dam are in a similar or better condition than would be expected in the broader catchment. The perennial flow regime of Meandu Creek downstream of Meandu Creek Dam, as a result of consistent releases from Meandu Creek Dam, allows for stable and diverse aquatic habitats to occur, which in turn are colonised by a diverse range of macroinvertebrates (including some sensitive and very sensitive taxa), along with aquatic plants, fish and turtles where there is suitable habitat. This confirms that the quality of water released from Meandu Creek



Dam, and the sediment quality of the Meandu Creek downstream of Meandu Creek Dam, is suitable for protecting the downstream aquatic ecosystem.

To date there is no evidence of environmental harm to the environmental values of the Meandu Creek receiving environment as a result of AMD from Meandu Mine.

11.4 Future Potential Impacts to the Environmental Values of Meandu Creek

11.4.1 Build-up of metals in Sediment Downstream of Meandu Creek Dam

The results of the current assessment suggest that the greatest build-up of metals in sediment is occurring within Meandu Creek upstream of Meandu Creek Dam (in the channel between Meandu Mine compliance point CP3 and the dam) and within Meandu Creek Dam. Currently at site CM2, upstream of the Dam, these metals may be bioavailable to aquatic flora and fauna (as indicated by results from the April 2018 survey, which showed that sediments at this site did not contain a molar excess of acid volatile sulfides compared to simultaneously extracted metals). This site is located in the reach of Meandu Creek than widens into Meandu Creek Dam, it also contains a high abundance of instream Cumbungi rushes. A combination of these factors is likely resulting in the baffling of fine sediments and particles out of the water column and into the creek bed at this site. Further downstream of Meandu Creek Dam, while sediment-bound metals are settling in some areas, this is restricted to reaches close to (i.e. within 500 m of) Meandu Creek Dam, and the results of aquatic flora and fauna surveys demonstrate that this is not resulting in negative impacts to the environmental values of the receiving environment.

Currently, the concentrations of the metals in sediment are unlikely to be bioavailable in Meandu Creek downstream of Meandu Creek Dam. The dilute acid extractable concentrations (representing the bioavailable fraction) of metals were generally below the SQGV. Where the bioavailable fraction exceeded the SQGV (i.e nickel and zinc at MC500, 500m downstream of Meandu Creek Dam), there was a molar excess of acid volatile sulfides compared to simultaneously extracted metals, indicating metals are likely to be bound to sulphide complexes, and are of low risk to causing acute or chronic impacts to aquatic flora and fauna.

The chemistry of the water overlying the sediment plays a large role in determining whether sediment-bound metals are released into the water column; in particular, the pH, electrical conductivity and hardness of water. Under current water chemistry conditions, there is no evidence of negative impacts to the environmental values of Meandu Creek downstream of Meandu Creek Dam. Therefore, ongoing monitoring of relevant water quality parameters in line with the Meandu Mine EA (EPML00709113) and Tarong power stations EA (EPPR00971913), including the Meandu Creek REMP, will be sufficient to protect the environmental values of this reach. As discussed in Sections 11.4.2 , 11.4.3 , and 11.5 below, ongoing monitoring of relevant water quality parameters in line with the EA for Meandu Mine and Tarong power stations will ensure detection in the event that water quality conditions change in future.



11.4.2 Elevated Metal Concentrations in Meandu Creek Surface Waters

The concentrations of dissolved metals in the Meandu Creek receiving environment were equal to or below the relevant WQOs during the field assessment, and are therefore unlikely to be toxic to aquatic flora and fauna. The results of aquatic flora and fauna surveys confirm this, with no impacts detected to communities in the receiving environment.

Provided that water quality is monitored into the future, and concentrations of metals and metalloids remain below the relevant WQOs and / or within the historical range, no future impacts from elevated metal concentrations in Meandu Creek surface waters are expected.

11.4.3 Changes to the Physical Water Quality in Meandu Creek Dam

The Notice discusses the potential for *alteration of the pH of Meandu Creek Dam waters and release of sediment-bound contaminants to the downstream environment*. Long-term impacts to pH as a result of AMD from Meandu Mine have not been noted to date in the surface waters of Meandu Creek upstream of Meandu Creek Dam, or in the dam. This is a result of the current monitoring and management of pH on-site. Further, as release water from Meandu Mine moves downstream, it is diluted with the large volume of water in Meandu Creek Dam. The pH of water downstream of Meandu Creek Dam is thus likely to mainly influenced by the Tarong power stations.

The very high hardness of water in Meandu Creek (including upstream of, within and downstream of Meandu Creek Dam) is likely having a protective effect on aquatic flora and fauna, by reducing the toxicity of some metals. Where the water hardness continues to be monitored and managed to remain within the historical range in Meandu Creek downstream of Meandu Creek Dam, an increase in the toxicity of metals in water is not expected to occur.

Where pH, electrical conductivity and water hardness continue to be monitored and managed to remain within the acceptable range (i.e. EA limits / WQO range), the release of sediment-bound contaminants to the water column in Meandu Creek downstream of Meandu Creek Dam is not expected to occur.

11.4.4 Elevated Salinity Levels in Meandu Creek Surface Waters

Provided that discharges from Meandu Creek Dam do not cause sudden and drastic increases or decreases to the electrical conductivity in Meandu Creek downstream of Meandu Creek Dam, it is unlikely that the aquatic ecosystem (that has adapted to the current electrical conductivity range) will experience any acute or chronic effects. Electrical conductivity levels in the water released from Meandu Creek Dam are currently monitored and managed through the EA for the Tarong power stations (EPPR00971913). Gradual increases in the electrical conductivity of water released from Meandu Creek Dam are permitted under this EA in response to drought conditions, when the electrical conductivity of water sourced from Wivenhoe and Boondoomba dams is expected to increase. A number of studies and investigations have been completed to confirm that a gradual increase in electrical conductivity levels in the receiving environment will not result in environmental harm, and that releases of water with high electrical conductivity under drought conditions are more beneficial to the environmental values of this reach than ceasing releases



altogether (IMEMS 2016). Further, increased monitoring is triggered during drought conditions to assess any impacts to receiving environment values associated with elevated electrical conductivity levels.

11.5 Measures to Prevent Future Potential Impacts

The current study is considered sufficient in confirming that AMD is not having a negative impact on the environmental values of the receiving environment. Long-term, ongoing monitoring of water quality parameters (as such pH, water hardness and electrical conductivity) under the sites EA and current Meandu Creek REMP is recommended, in order to detect potential impacts in future. This includes:

- Ongoing monitoring of key physico-chemical water quality parameters, including pH and electrical conductivity, in the vicinity Meandu Mine, including at the Meandu Creek Dam discharge point and pH, hardness and electrical conductivity in Meandu Creek downstream of Meandu Creek Dam. Frequency and monitoring locations vary for each parameter, but are considered sufficient in detecting any substantial changes to water chemistry that could result in increasing effects of metal concentrations in water quality on aquatic flora and fauna in the Meandu Creek downstream of Meandu Creek Dam. Where a potential impact is detected, additional monitoring and response will be triggered.
- Three-yearly monitoring of sediment quality, particularly of metals which are potentially indicative of AMD and were above the SQGV in March 2017 and April 2018 immediately downstream of Meandu Creek Dam. Where a potential impact is detected, additional monitoring and response will be triggered.
- Three-yearly monitoring of macroinvertebrate communities, which act as biological indicators of aquatic ecosystem health. Quantitative sampling at each site allows for more rigorous statistical analyses that can be used to detect any potential adverse impacts in the receiving environment.

It is recommended that the current REMP is updated to include all key indicators for AMD. To do this monitoring the concentration of iron and manganese in the water quality and the concentration of cobalt, iron and manganese in the sediment will need to be incorporated in the Meandu Creek REMP.

Where pH or electrical conductivity change and are outside the WQOs or historical range, and / or water hardness decreases so that it is no longer considered to be moderately hard, an additional investigation procedure will be triggered, as per the recommendations in the current EA and Meandu Creek REMP.

Meandu Creek upstream of the dam (adjacent to the mine) is managed for the industrial use environmental value, which does not include specific limits for the concentrations of metals and metalloids designed to protect aquatic ecosystem values. This area is also managed to protect the aquatic ecosystem environmental value of Meandu Creek downstream of the dam, which currently shows no evidence of negative impacts to environmental values as a result of AMD. As discussed above, where current water quality conditions (particularly pH, electrical conductivity and hardness) remain the same, future impacts are considered unlikely. However, there is a build-up of metals (particularly nickel and zinc) in sediment in



the channel between Meandu Mine compliance point CP3 and the dam (detected at site CM2), which may be related to AMD. While Meandu Creek upstream of Meandu Creek Dam is not managed to protect aquatic ecosystem values, further lines of evidence to determine the acute or chronic toxicity of sediment at site CM2 could be considered to understand the toxicity at this site. In accordance with the *Revision of the Sediment Quality Guidelines* (Simpson et al 2013), the following lines of evidence could be assessed:

- Direct toxicity tests (three tests, including one whole sediment test), and
- The concentration of metals in local biota tissue to assess bioaccumulation (this has been previously completed at Meandu Creek Dam, however metal concentrations in sediment at site CM2 are higher than those in the dam).



12 Conclusions

There is currently no evidence of negative impacts to the environmental values of Meandu Creek as a result of AMD from Meandu Mine. Overall, aquatic ecological communities in the vicinity of the mine are resilient and in moderate to good health, particularly in Meandu Creek downstream of Meandu Creek Dam. Water quality conditions, including hardness and pH, are likely to be reducing the toxicity of metals in water. Further, metals in sediments in some areas of Meandu Creek downstream of Meandu Creek Dam are likely to be immobilised by the availability of sulfides and are unlikely to cause acute or chronic toxicity to aquatic flora and fauna. Where water quality conditions remain unchanged (i.e. remain within the historical range and / or comply with WQOs where applicable), no further lines of investigation are considered necessary to prevent environmental harm on aquatic environmental values occurring from AMD at Meandu Mine.

Conditions C5 and C6 of the Meandu Mine EA include daily monitoring of pH, turbidity and electrical conductivity and outline contaminant limits for the release points. Controlling these parameters in the release water will minimise the potential for environmental harm in the downstream receiving environment. The Meandu Creek REMP has been prepared to satisfy conditions WT14, WT15, WT16 and WT24 of the Tarong and Tarong North EA. Relevant to Meandu Mine, this REMP monitors water quality (physical parameters, ions, metals and metalloids) at two sites in Meandu Creek downstream of Meandu Creek Dam and three control (or background) sites weekly to yearly (depending on the parameter). Sediment quality (metals and metalloids) is monitored at eight sites in Meandu Creek Dam, seven sites in Meandu Creek downstream of Meandu Creek Dam and six control sites every three years. Macroinvertebrate communities are monitored at three sites in Meandu Creek Dam, seven sites in Meandu Creek downstream of Meandu Creek Dam as well as four control sites every three years. Water quality objectives, sediment quality trigger limits and investigation procedures (based on those outlined in ANZECC (2000) and Simpson (2013) and including toxicity investigations) are designed to protect the environmental values of Meandu Creek downstream of Meandu Creek Dam. The Meandu Creek REMP is considered sufficient to protect environmental values in Meandu Creek downstream of Meandu Creek Mine. However, key AMD indicators (including concentrations of cobalt, nickel, iron, manganese and zinc) in the water and sediment will be included in the Meandu Creek REMP. Overall, given there is currently no evidence of negative impacts to environmental values of Meandu Creek, current monitoring in compliance with the Meandu Mine and Tarong power stations EAs are considered sufficient for ongoing protection of environmental values.

Upstream of Meandu Creek Dam, site CM2 has abundant reeds and fine sediments, and appears to be effectively trapping metals and reducing transportation further downstream to the receiving environment. Further lines of evidence (e.g. toxicity and bioaccumulation) at site CM2 could be implemented to understand the potential impacts at this site.

A summary of investigation outcomes in relation to the relevant surface water quality and aquatic ecology requirements of the Notice are summarised in Table 12.1 overleaf.



Table 12.1 The Notice requirements and summary of corresponding investigation outcomes, including the relevant section of this report where each requirement is addressed

Reference of Notice	Details of Notice Requirement	Summary of Investigation Outcomes
B2	The characterise of Meandu Creek must:	There are currently no assigned EVs in Schedule 1 of the EPP (Water) for Meandu Creek. Relevant EVs were assigned from those outlined in Section 6 (2) of the policy, with reference to other relevant sources, such as the Burnett Mary WQIP (BMRG 2015), available literature, previous technical reports and field surveys.
(i)	- identify any environmental values (EVs) and water quality objectives (WQOs) scheduled for Meandu Creek under the Environmental Protection (Water) Policy 2009 (EPP Water)	Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam form part of the water management systems for Meandu Mine and the Tarong power stations, and thus, the industrial use EV was assigned, as discussed in Section 3.1.1. Current compliance limits outlined in the EA's for Meandu Mine and Tarong power stations are considered appropriate for management of these waters (published WQOs do not apply to this reach), as discussed in Section 3.3.1.
(ii)	- if none are identified, propose EVs/WQOs where required for Meandu Creek	EVs assigned to Meandu Creek downstream of Meandu Creek Dam are discussed in Section 3.1.3, and are: • aquatic ecosystems (moderately disturbed) • irrigation • farm supply • stock watering • human consumption • primary recreation • secondary recreation, and • industrial use. Published water quality objectives (WQOs) have been assigned to this reach to manage these EVs. The most stringent WQO (mostly associated with protecting moderately disturbed aquatic



Reference of Notice	Details of Notice Requirement	Summary of Investigation Outcomes
		ecosystems) was generally assigned. The source of assigned WQOs for Meandu Creek downstream of Meandu Creek Dam is discussed in Section 3.3.2 and outlined in Table 3.2.
(iii)	- provide a description of the existing qualities, characteristics and resilience of Meandu Creek, and	Meandu Creek upstream of Meandu Creek Dam, adjacent to Meandu Mine, is an intermittent waterway with several disjointed, non-flowing pools along the channel, and has been diverted in several places. Meandu Creek Dam is a large earth filled constructed dam. Meandu Creek downstream of Meandu Creek Dam exhibits long periods of continual flow from Meandu Creek Dam releases, characteristic of a perennial waterway. Overall, aquatic communities of Meandu Creek downstream of Meandu Creek Dam are highly resilient to current mining and power station activities as they have adapted quickly to changing conditions (ephemeral to perennial waterway) yet contains some sensitive (e.g. macroinvertebrates) and long-lived species such as fish and turtle that are generally sensitive to bioaccumulation or ecosystem changes. Existing water quality, sediment quality as well as aquatic habitat, flora and fauna are detailed in Sections 4 to 10.
(iv)	- with reference to items (i) to (iii) above determine the mine-affected water release quality that must be achieved to protect the relevant EVs of Meandu Creek.	Based on the information presented in this report, there is currently no evidence that mine-affected water is having a negative impact on the environmental values of the receiving environment, as discussed in Section 11. Thus, current release conditions within Meandu Mine's EA and monitoring requirements outlined in the Meandu Creek REMP are considered sufficient to protect the relevant EVs of Meandu Creek.
B4	Determine whether AMD at Meandu Mine has impacted on or has the potential to impact on the environmental values of surface waters including Meandu Creek. The studies must include:	Based on the information presented in this report, there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment, as discussed in Section 11. Water quality conditions, including hardness and pH, are likely to be reducing the toxicity of metals in water. Further, metals in sediments in Meandu Creek downstream of Meandu Creek Dam are likely to be immobilised by the availability of sulfide complexes and are unlikely to cause acute or chronic toxicity to aquatic flora and fauna. Where water quality conditions remain unchanged (i.e. remain within the historical range and



Reference of Notice	Details of Notice Requirement	Summary of Investigation Outcomes
		comply with WQOs where applicable), potential AMD impacts on aquatic environmental values are considered unlikely.
(i)	- water quality investigations to determine any impacts on environmental values of surface waters (Meandu Creek) that have occurred as a result of AMD at Meandu Mine	The results of historical surface water monitoring completed at Meandu Mine and the Tarong and Tarong North power stations, and of the March 2017 survey, demonstrated that electrical conductivity levels and the concentrations of major ions (including sulfate) and some dissolved metals are higher in Meandu Creek adjacent to and downstream of Meandu Mine than at comparative sites within the region (as discussed in Section 4). This may be indicative of an AMD-related impact; however, other factors such as operation of the Tarong power stations and catchment inputs also influence some of these parameters. Regardless of this, based on the information presented in this report, there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment.
(ii)	- water quality investigations to determine future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine	Future potential impacts on environmental values of surface water (Meandu Creek) resulting from AMD at Meandu Mine are discussed in Section 11.4, and are considered unlikely given: - the information presented in this report shows there is currently no evidence that AMD impacted water is having a negative impact on the environmental values of the receiving environment. - AMD issues at Meandu Mine will be managed through the implementation of changes to the mining and placement of mined materials, with Stanwell committed to proactive long term resolution of the AMD issue and development of potential engineering options that may be implemented at Meandu Mine to mitigate any potential environmental impacts associated with AMD. This includes initial measures including interim lime dosing and changes to monitoring and operations. Further changes are potentially required to the way mining, mine waste, mine water, landform design and rehabilitation are managed at Meandu Mine. - water quality will continue to be managed in line with the Meandu Mine and Tarong power stations EAs, including compliance monitoring and the Meandu Creek REMP.
(iii)	- identify short term and long term measures including (if relevant) further	In addition to long term and short term commitment to managing AMD at Meandu Mine outlined above, the following measures are recommended and are discussed in Section 11.5:



Reference of Notice	Details of Notice Requirement	Summary of Investigation Outcomes
	lines of investigation, monitoring requirements, and operational or mine planning measures that should be developed and/ or implemented to prevent environmental harm occurring from AMD at Meandu Mine.	- include key AMD indicators in the Meandu Mine REMP - further assess the toxicity of metals at cite CM2 (downstream of release point CP3 and upstream of Meandu Creek Dam) in line with the <i>Revision of the Sediment Quality Guidelines</i>, including further sediment toxicity test and bioavailability testing at site CM2.



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Attachment A Chain of Custody and Laboratory Analysis Certificates for Water Samples





CHAIN OF CUSTODY

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1. 1990年12月，中共中央、国务院作出《关于实行“菜篮子”工程责任制考核规定的通知》，要求各地把“菜篮子”工程列入国民经济和社会发展的总体规划，作为考核各级政府的重要指标。

the authors of the book, and the book is a valuable addition to the literature on the history of the United States.

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Conclusions

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Environmental

CERTIFICATE OF ANALYSIS

Work Order	: EB1706230	Page	: 1 of 16
Client	: ECOLOGICAL SERVICE PROFESSIONALS	Laboratory	: Environmental Division Brisbane
Contact	: Kate Maguire	Contact	: Customer Services EB
Address	: PO BOX 5935 MANLY 4179	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: 1704 SCL MONITORING	Date Samples Received	: 29-Mar-2017 13:58
Order number	: ----	Date Analysis Commenced	: 30-Mar-2017
C-O-C number	: ----	Issue Date	: 05-Apr-2017 14:27
Sampler	: AARON DUNLOP		
Site	: ----		
Quote number	: BN/070/17 V2		
No. of samples received	: 48		
No. of samples analysed	: 48		



Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

Δ = This result is computed from individual analyte detections at or above the level of reporting

Ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- EG005T (Total Metals by ICP-AES), Sample EB1706230-020 (MCUS2) shows poor spike recovery due to matrix interference. Confirmed by re-extraction and re-analysis.



Analytical Results

Sub-Matrix: WATER
(Matrix: WATER)

Client sample ID

Client sampling date / time

Compound	CAS Number	LOR	Unit	MCD OUT	SW36	CM2_R1	CM2_R2	MC5W2
				[25-Mar-2017]	[24-Mar-2017]	[28-Mar-2017]	[28-Mar-2017]	[25-Mar-2017]
				EB1706230-001	EB1706230-002	EB1706230-003	EB1706230-004	EB1706230-005
			Result		Result	Result	Result	Result

EA015: Total Dissolved Solids dried at 180 ± 5 °C

Total Dissolved Solids @180°C	---	10	mg/L	1230	717	1090	1100	1260
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EA065: Total Hardness as CaCO3

Total Hardness as CaCO3	---	1	mg/L	459	268	383	385	469
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ED037P: Alkalinity by PC-Titrator

Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	99	129	59	88	100
Total Alkalinity as CaCO3	---	1	mg/L	99	129	59	88	100

ED041G: Sulfate (Turbidimetric) as SO4 2- by DA

Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	176	22	271	270	172
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ED045G: Chloride by Discrete Analyser

Chloride	16887-00-6	1	mg/L	482	289	405	408	489
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ED093F: Dissolved Major Cations

Calcium	7440-70-2	1	mg/L	60	38	48	47	61
Magnesium	7439-95-4	1	mg/L	75	42	64	65	77
Sodium	7440-23-5	1	mg/L	225	111	250	250	229
Potassium	7440-09-7	1	mg/L	20	10	16	16	20

EG020F: Dissolved Metals by ICP-MS

Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L	0.007	0.002	<0.001	<0.001	0.004
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	0.006	0.006	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	0.575	0.514	0.763	0.848	0.114
Molybdenum	7439-98-7	0.001	mg/L	0.002	<0.001	0.001	0.001	0.002
Nickel	7440-02-0	0.001	mg/L	0.002	<0.001	0.011	0.011	0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	0.008	0.008	<0.005
Boron	7440-42-8	0.05	mg/L	0.10	<0.05	0.07	0.06	0.10
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05

EG020T: Total Metals by ICP-MS



Analytical Results

Sub-Matrix: WATER (Matrix: WATER)		Client sample ID		MCD OUT	SW36	CM2_R1	CM2_R2	MC5W2
Client sampling date / time				[25-Mar-2017]	[24-Mar-2017]	[28-Mar-2017]	[28-Mar-2017]	[25-Mar-2017]
Compound	CAS Number	LOR	Unit	EB1706230-001	EB1706230-002	EB1706230-003	EB1706230-004	EB1706230-005
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - continued								
Aluminium	7429-90-5	0.01	mg/L	0.12	<0.01	0.40	0.46	0.10
Arsenic	7440-38-2	0.001	mg/L	0.007	0.002	<0.001	<0.001	0.005
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	0.029	0.029	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	0.001	0.002	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	0.733	0.553	2.01	2.20	0.255
Molybdenum	7439-98-7	0.001	mg/L	0.002	<0.001	0.002	0.002	0.002
Nickel	7440-02-0	0.001	mg/L	0.004	<0.001	0.022	0.022	0.003
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	0.093	0.102	<0.005
Boron	7440-42-8	0.05	mg/L	0.14	0.07	0.09	0.10	0.14
Iron	7439-89-6	0.05	mg/L	0.10	0.08	1.48	1.64	0.39
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.5	0.3	0.3	0.2	0.5
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N		0.01	mg/L	0.07	0.06	0.26	0.26	0.24
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N		0.1	mg/L	0.8	0.7	0.4	0.4	0.6
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
Total Nitrogen as N		0.1	mg/L	0.9	0.8	0.7	0.7	0.8
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P		0.01	mg/L	0.04	0.12	0.02	0.03	0.11
EN055: Ionic Balance								
Total Anions		0.01	meq/L	19.2	11.2	18.2	18.9	19.4
Total Cations		0.01	meq/L	19.5	10.4	18.9	19.0	19.8
Ionic Balance		0.01	%	0.58	3.47	1.88	0.24	1.22



Analytical Results

Sub-Matrix: WATER
(Matrix: WATER)

Compound	CAS Number	Client sample ID		LR	A1/MC6	A2/MC1	A3/MC5	MC500
		Client sampling date / time	Unit					
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	---	10	mg/L	<10	2180	2420	2520	1260
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	---	1	mg/L	<1	461	538	656	463
ED037P: Alkalinity by PC-Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	<1	290	354	284	96
Total Alkalinity as CaCO3	---	1	mg/L	<1	290	354	284	96
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	255	180	272	177
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	<1	937	1060	1040	482
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	56	62	65	60
Magnesium	7439-95-4	1	mg/L	<1	78	93	120	76
Sodium	7440-23-5	1	mg/L	<1	709	761	697	225
Potassium	7440-09-7	1	mg/L	<1	13	10	13	20
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.006
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	0.003	0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	<0.001	0.268	2.36	0.991	0.370
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.002
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.002
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	7440-42-8	0.05	mg/L	<0.05	0.16	0.14	0.09	0.10
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	0.36	<0.05	<0.05
EG020T: Total Metals by ICP-MS								



Analytical Results

Sub-Matrix: WATER (Matrix: WATER)		Client sample ID		LR	A1/MC6	A2/MC1	A3/MC5	MC500
Client sampling date / time		[29-Mar-2017]	[27-Mar-2017]	[27-Mar-2017]	[28-Mar-2017]	[25-Mar-2017]		
Compound	CAS Number	LOR	Unit	EB1706230-006	EB1706230-007	EB1706230-008	EB1706230-009	EB1706230-010
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - continued								
Aluminium	7429-90-5	0.01	mg/L	<0.01	0.05	0.02	0.02	0.12
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.007
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	0.0002
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	0.003	0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	<0.001	0.324	2.62	1.24	0.566
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.002
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.004
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	7440-42-8	0.05	mg/L	<0.05	0.20	0.19	0.12	0.13
Iron	7439-89-6	0.05	mg/L	<0.05	0.15	1.42	1.48	0.15
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	0.3	0.2	0.2	0.5
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N		0.01	mg/L	<0.01	0.01	0.14	0.06	0.16
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N		0.1	mg/L	<0.1	0.3	0.3	0.4	0.8
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
Total Nitrogen as N		0.1	mg/L	<0.1	0.3	0.4	0.5	1.0
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P		0.01	mg/L	<0.01	0.02	0.06	<0.01	<0.01
EN055: Ionic Balance								
Total Anions		0.01	meq/L	<0.01	37.5	40.7	40.7	19.2
Total Cations		0.01	meq/L	<0.01	40.4	44.1	43.8	19.5
Ionic Balance		0.01	%	----	3.66	3.99	3.66	0.90



Analytical Results

Sub-Matrix: WATER (Matrix: WATER)		Client sample ID		MC2	MC15	MC20	MC25	C1	
Compound	CAS Number	LOR	Unit	[26-Mar-2017] EB1706230-011 Result	[24-Mar-2017] EB1706230-012 Result	[25-Mar-2017] EB1706230-013 Result	[24-Mar-2017] EB1706230-014 Result	[26-Mar-2017] EB1706230-015 Result	
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C			10	mg/L	1240	1210	1240	1220	801
EA065: Total Hardness as CaCO3									
Total Hardness as CaCO3			1	mg/L	459	459	456	471	372
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1	
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	11	
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	95	99	108	107	166	
Total Alkalinity as CaCO3	----	1	mg/L	95	99	108	107	177	
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	176	169	168	168	4	
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L	473	483	492	493	315	
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L	60	60	59	60	60	
Magnesium	7439-95-4	1	mg/L	75	75	75	78	54	
Sodium	7440-23-5	1	mg/L	228	230	226	234	100	
Potassium	7440-09-7	1	mg/L	20	19	19	20	4	
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	
Arsenic	7440-38-2	0.001	mg/L	0.006	0.003	0.002	0.002	<0.001	
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	
Manganese	7439-96-5	0.001	mg/L	0.053	0.024	0.008	0.027	0.004	
Molybdenum	7439-98-7	0.001	mg/L	0.002	0.002	0.002	0.002	<0.001	
Nickel	7440-02-0	0.001	mg/L	0.002	<0.001	<0.001	<0.001	<0.001	
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	
Boron	7440-42-8	0.05	mg/L	0.10	0.10	0.10	0.10	<0.05	
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	
EG020T: Total Metals by ICP-MS									



Analytical Results

Sub-Matrix: WATER (Matrix: WATER)		Client sample ID		MC2	MC15	MC20	MC25	C1
Client sampling date / time		[26-Mar-2017]	[24-Mar-2017]	[25-Mar-2017]	[24-Mar-2017]	[26-Mar-2017]		
Compound	CAS Number	LOR	Unit	EB1706230-011	EB1706230-012	EB1706230-013	EB1706230-014	EB1706230-015
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Aluminium	7429-90-5	0.01	mg/L	0.05	0.34	0.07	0.07	0.19
Arsenic	7440-38-2	0.001	mg/L	0.006	0.003	0.002	0.002	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	0.152	0.050	0.010	0.030	0.034
Molybdenum	7439-98-7	0.001	mg/L	0.002	0.002	0.002	0.002	<0.001
Nickel	7440-02-0	0.001	mg/L	0.003	0.002	0.002	0.001	<0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	7440-42-8	0.05	mg/L	0.14	0.13	0.13	0.14	<0.05
Iron	7439-89-6	0.05	mg/L	0.09	0.43	0.13	0.15	0.38
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.5	0.5	0.5	0.5	0.3
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N		0.01	mg/L	0.26	0.09	0.03	0.02	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N		0.1	mg/L	0.6	0.6	1.0	0.7	0.6
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
Total Nitrogen as N		0.1	mg/L	0.9	0.7	1.0	0.7	0.6
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P		0.01	mg/L	0.09	0.02	0.10	0.06	0.06
EN055: Ionic Balance								
Total Anions		0.01	meq/L	18.9	19.1	19.5	19.5	12.5
Total Cations		0.01	meq/L	19.6	19.6	19.4	20.1	11.9
Ionic Balance		0.01	%	1.79	1.38	0.26	1.42	2.52

FORGET THE 4-11 MODEL - BUILD MORE



Analytical Results

Sub-Matrix: WATER (Matrix: WATER)		Client sample ID		C1B	BC1	BC2		
		Client sampling date / time		[26-Mar-2017]	[29-Mar-2017]	[29-Mar-2017]		
Compound	CAS Number	LOR	Unit	EB1706230-016	EB1706230-017	EB1706230-018		
				Result	Result	Result		
EG020T: Total Metals by ICP-MS - Continued								
Aluminum	7429-90-5	0.01	mg/L	0.09	0.15	0.53		
Arsenic	7440-38-2	0.001	mg/L	<0.001	0.003	0.002		
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001		
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001		
Cobalt	7440-48-4	0.001	mg/L	<0.001	0.002	<0.001		
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001		
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001		
Manganese	7439-96-5	0.001	mg/L	0.759	0.922	0.055		
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001		
Nickel	7440-02-0	0.001	mg/L	<0.001	0.003	<0.001		
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01		
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01		
Zinc	7440-66-6	0.005	mg/L	<0.005	0.005	<0.005		
Boron	7440-42-8	0.05	mg/L	<0.05	0.30	<0.05		
Iron	7439-89-6	0.05	mg/L	0.74	1.25	0.45		
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001		
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001		
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.3	0.5	0.3		
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N		0.01	mg/L	<0.01	<0.01	0.01		
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N		0.1	mg/L	0.7	2.8	0.2		
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
Total Nitrogen as N		0.1	mg/L	0.7	2.8	0.2		
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P		0.01	mg/L	0.30	0.10	0.01		
EN055: Ionic Balance								
Total Anions		0.01	meq/L	11.5	48.3	4.05		
Total Cations		0.01	meq/L	10.9	54.3	3.95		
Ionic Balance		0.01	%	2.83	5.87	1.20		

Attachment B Chain of Custody and Laboratory Analysis Certificates for Sediment Samples





CHAIN OF CUSTODY

no laboratory generated

INSTRUCTIONS TO THE USER
This form is to be completed by the person who has possession of the sample at the time of collection. It is to be completed by the person who has possession of the sample at the time of collection. It is to be completed by the person who has possession of the sample at the time of collection.

INSTRUCTIONS TO THE USER
This form is to be completed by the person who has possession of the sample at the time of collection. It is to be completed by the person who has possession of the sample at the time of collection. It is to be completed by the person who has possession of the sample at the time of collection.

INSTRUCTIONS TO THE USER
This form is to be completed by the person who has possession of the sample at the time of collection. It is to be completed by the person who has possession of the sample at the time of collection. It is to be completed by the person who has possession of the sample at the time of collection.

INSTRUCTIONS TO THE USER
This form is to be completed by the person who has possession of the sample at the time of collection. It is to be completed by the person who has possession of the sample at the time of collection. It is to be completed by the person who has possession of the sample at the time of collection.

CLIENT: **Environmental Service Professionals**OFFICE: **MANLY WEST**PROJECT: **SUB MOUNTAINS**PROJECT NO.: **1704**PROJECT MANAGER: **KATE MAQUIRE**CLIENT: **AD**CONTACT: **MR. KATE MAQUIRE**CONTACT NO.: **0422 537 807**CONTACT EMAIL: **kate.maquire@adelaide.gov.au**CONTACT ADDRESS: **29/3/17**CONTACT PHONE: **29/3/17**CONTACT FAX: **29/3/17**CONTACT MOBILE: **29/3/17**CONTACT OTHER: **29/3/17**CONTACT COMMENTS: **29/3/17**CONTACT SIGNATURE: **29/3/17**CONTACT DATE: **29/3/17**CONTACT TIME: **29/3/17**CONTACT LOCATION: **29/3/17**CONTACT WEATHER: **29/3/17**CONTACT COMMENTS: **29/3/17**CONTACT SIGNATURE: **29/3/17**CONTACT DATE: **29/3/17**CONTACT TIME: **29/3/17**CONTACT LOCATION: **29/3/17**CONTACT WEATHER: **29/3/17**CONTACT COMMENTS: **29/3/17**CONTACT SIGNATURE: **29/3/17**CONTACT DATE: **29/3/17**CONTACT TIME: **29/3/17**CONTACT LOCATION: **29/3/17**CONTACT WEATHER: **29/3/17**CONTACT COMMENTS: **29/3/17**CONTACT SIGNATURE: **29/3/17**CONTACT DATE: **29/3/17**CONTACT TIME: **29/3/17**CONTACT LOCATION: **29/3/17**CONTACT WEATHER: **29/3/17**CONTACT COMMENTS: **29/3/17**CONTACT SIGNATURE: **29/3/17**CONTACT DATE: **29/3/17**CONTACT TIME: **29/3/17**CONTACT LOCATION: **29/3/17**CONTACT WEATHER: **29/3/17**

AL, As, Ba, Cd, Cr, Co, Cu, Pb, Fe, Mn, Ni, Mo, Ag, Se, V, Zn, Hg

Additional Information

Signature of the person who has possession of the sample at the time of collection.



CHAIN OF CUSTODY

doi:10.1017/S0022292410000593

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☐ **Shipping:** You'll need to ship this to:

the 1990s, the number of people who have been killed in the conflict has increased. The number of people who have been killed in the conflict has increased.

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10

152m 2m

Math 170/180

NAME _____

KSEIIS, Mijic+V

7

Method is not in other publications

Address to Paul F. No. 10000, address to

estados, no que se refere ao grau de

1131

10

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Materials

1000

cont

5296

CM2-R1

CM7-R2

Mr C / Mr 2

Price / Value

All/mc/b

52/MC1

A3/ML5

M4500

1000	1000
1000	1000

23147

MCL5

M620

Mc25

1

100

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1000



Environmental

CERTIFICATE OF ANALYSIS

Work Order	: EB1706230	Page	: 1 of 16
Client	: ECOLOGICAL SERVICE PROFESSIONALS	Laboratory	: Environmental Division Brisbane
Contact	: Kate Maguire	Contact	: Customer Services EB
Address	: PO BOX 5935 MANLY 4179	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: 1704 SCL MONITORING	Date Samples Received	: 29-Mar-2017 13:58
Order number	: ----	Date Analysis Commenced	: 30-Mar-2017
C-O-C number	: ----	Issue Date	: 05-Apr-2017 14:27
Sampler	: AARON DUNLOP		
Site	: ----		
Quote number	: BN/070/17 V2		
No. of samples received	: 48		
No. of samples analysed	: 48		



Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

Δ = This result is computed from individual analyte detections at or above the level of reporting

Ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- EG005T (Total Metals by ICP-AES), Sample EB1706230-020 (MCUS2) shows poor spike recovery due to matrix interference. Confirmed by re-extraction and re-analysis.



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)		Client sample ID		MCUS1	MCUS2	MCDS1	MCDS2	MCDS3
Client sampling date / time		[27-Mar-2017]	[27-Mar-2017]	[28-Mar-2017]	[28-Mar-2017]	[28-Mar-2017]	[28-Mar-2017]	[28-Mar-2017]
Compound	CAS Number	LOR	Unit	EB1706230-019	EB1706230-020	EB1706230-021	EB1706230-022	EB1706230-023
			Result	Result	Result	Result	Result	Result
EA055: Moisture Content								
Moisture Content (dried @ 103°C)		1	%	28.0	12.5	41.4	44.6	66.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	29000	14600	9740	9430	17400
Arsenic	7440-38-2	5	mg/kg	<5	<5	9	10	49
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	104	73	32	28	145
Cobalt	7440-48-4	2	mg/kg	50	14	19	11	13
Copper	7440-50-8	5	mg/kg	33	15	30	28	243
Iron	7439-89-6	50	mg/kg	154000	52500	22800	20000	29400
Lead	7439-92-1	5	mg/kg	10	8	22	22	19
Manganese	7439-96-5	5	mg/kg	3300	690	199	174	429
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	2
Nickel	7440-02-0	2	mg/kg	44	18	28	22	26
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	7
Vanadium	7440-62-2	5	mg/kg	148	82	47	42	76
Zinc	7440-66-6	5	mg/kg	81	36	108	77	242
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	0.2



Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Client sample ID

Client sampling date / time

Sub-Matrix: SOIL (Matrix: SOIL)		Client sample ID		MCDs4	MCDs5	MCDs6	MCDs7	MCDs8
Client sampling date / time				[28-Mar-2017]	[28-Mar-2017]	[28-Mar-2017]	[28-Mar-2017]	[28-Mar-2017]
Compound	CAS Number	LOR	Unit	Result	Result	Result	Result	Result
				EB1706230-024	EB1706230-025	EB1706230-026	EB1706230-027	EB1706230-028

EA055: Moisture Content

Moisture Content (dried @ 103°C)	1	%	54.5	71.9	59.0	21.4	29.6

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	11800	14800	11400	1870	5020
Arsenic	7440-38-2	5	mg/kg	21	43	9	<5	17
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	74	109	33	6	36
Cobalt	7440-48-4	2	mg/kg	22	31	27	6	11
Copper	7440-50-8	5	mg/kg	153	142	36	16	90
Iron	7439-89-6	50	mg/kg	25800	23100	16700	2390	8620
Lead	7439-92-1	5	mg/kg	22	33	25	<5	8
Manganese	7439-96-5	5	mg/kg	181	370	521	58	200
Molybdenum	7439-98-7	2	mg/kg	4	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	58	45	29	6	15
Selenium	7782-49-2	5	mg/kg	7	6	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	49	64	45	7	24
Zinc	7440-66-6	5	mg/kg	247	250	105	34	91
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	0.2	0.2	0.1	<0.1	<0.1



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)		Client sample ID		MC5/M2		A1/MC6		A2/MC1		A3/MC5		MC500	
Client sampling date / time				[25-Mar-2017]		[27-Mar-2017]		[27-Mar-2017]		[28-Mar-2017]		[25-Mar-2017]	
Compound	CAS Number	LOR	Unit	EB1706230-034 Result		EB1706230-035 Result		EB1706230-036 Result		EB1706230-037 Result		EB1706230-038 Result	
EA055: Moisture Content													
Moisture Content (dried @ 103°C)		----	1	%	53.1	23.9	68.4	47.1	67.6				
EG005T: Total Metals by ICP-AES													
Aluminium	7429-90-5	50	mg/kg	14000	4890	12700	9980	11500					
Arsenic	7440-38-2	5	mg/kg	14	<5	8	8	33					
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50					
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1					
Chromium	7440-47-3	2	mg/kg	26	21	26	16	64					
Cobalt	7440-48-4	2	mg/kg	25	6	23	42	86					
Copper	7440-50-8	5	mg/kg	82	6	22	20	75					
Iron	7439-89-6	50	mg/kg	27100	19600	34300	25600	27400					
Lead	7439-92-1	5	mg/kg	16	55	17	19	23					
Manganese	7439-96-5	5	mg/kg	2220	199	823	2280	11400					
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2					
Nickel	7440-02-0	2	mg/kg	22	6	20	37	71					
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	8					
Vanadium	7440-62-2	5	mg/kg	70	37	44	35	74					
Zinc	7440-66-6	5	mg/kg	122	48	75	154	319					
EG035T: Total Recoverable Mercury by FIMS													
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	0.1					



Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Client sample ID

Client sampling date / time

Sub-Matrix: SOIL (Matrix: SOIL)		Client sample ID		MC2	MC15	MC20	MC25	C1
Client sampling date / time								
Compound	CAS Number	LOR	Unit	Result	Result	Result	Result	Result
				[26-Mar-2017]	[24-Mar-2017]	[25-Mar-2017]	[24-Mar-2017]	[26-Mar-2017]
				EB1706230-039	EB1706230-040	EB1706230-041	EB1706230-042	EB1706230-043

EA055: Moisture Content

Moisture Content (dried @ 103°C)	
1	18.8
%	31.4
	37.5
	19.2
	66.1

EG005T: Total Metals by ICP-AES

Aluminum	7429-90-5	50	mg/kg	1110	8280	26000	1840	18700
Arsenic	7440-38-2	5	mg/kg	<5	12	6	<5	<5
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	4	54	33	12	30
Cobalt	7440-48-4	2	mg/kg	<2	21	27	8	23
Copper	7440-50-8	5	mg/kg	<5	12	24	<5	21
Iron	7439-89-6	50	mg/kg	2530	45200	64600	7740	50300
Lead	7439-92-1	5	mg/kg	<5	11	10	<5	9
Manganese	7439-96-5	5	mg/kg	831	777	383	49	345
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	4	14	29	5	25
Selenium	7782-49-2	5	mg/kg	<5	<5	10	<5	16
Vanadium	7440-62-2	5	mg/kg	7	72	91	14	83
Zinc	7440-66-6	5	mg/kg	7	21	106	11	112
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1



CHAIN OF CUSTODY

ALS Laboratory - Brisbane

ALSO USE FOR: Chain of Custody for Soil

ALSO USE FOR: Chain of Custody for Water

ALSO USE FOR: Chain of Custody for Air

ALSO USE FOR: Chain of Custody for Sediment

ALSO USE FOR: Chain of Custody for Plant

ALSO USE FOR: Chain of Custody for Fish

ALSO USE FOR: Chain of Custody for Invertebrates

ALSO USE FOR: Chain of Custody for Microbes

ALSO USE FOR: Chain of Custody for Fungi

ALSO USE FOR: Chain of Custody for Bacteria

ALSO USE FOR: Chain of Custody for Viruses

ALSO USE FOR: Chain of Custody for Parasites

ALSO USE FOR: Chain of Custody for Mammals

ALSO USE FOR: Chain of Custody for Birds

ALSO USE FOR: Chain of Custody for Reptiles

ALSO USE FOR: Chain of Custody for Amphibians

CLIENT: Ecological Services Professionals		TURNAROUND REQUIREMENTS: ☐ Standard TAT 5 business days		FOR LABORATORY USE ONLY (Contd.)	
SERVICE: Remediation		☐ Standard TAT may be longer for some work e.g. BSA Toxic Chemicals		Labile Test Result	
PRODUCT: Confidential - Fencing Substation		PROJECT NO.: 1754		Freeze vs. Thaw: no freeze present (see report)	
ORDER NUMBER: PURCHASE ORDER NO.		ALS QUOTE NO.: BRISQHS		Refrigerate Samples Temperature as Requested	
PROJECT MANAGER: Kate Fanning		COUNTRY OF ORIGIN: Australia		Other comments	
CONTACT PH: 0433 839 867		TQC REQUIREMENT NUMBER (if any)		DATE/TIME	
SAMPLER: Rebecca King		SAMPLER MOBILE: 0433 839 878		RECEIVED BY: K. Leary	
COC Enabled to ALST (YES / NO)		ESQ (FORMAT or default)		RECEIVED BY: K. Leary	
Email Reports to (add default to PM if no other addresses are listed) rebecca.king@ecsp.com.au		DATE/TIME: 15/4/18 15:30		DATE/TIME: 15/4/18 8:30	
Email Invoices to (add default to PM if no other addresses are listed) rebecca.king@ecsp.com.au		DATE/TIME: 15/4/18 15:30		DATE/TIME: 15/4/18 8:30	

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL

ALS USE ONLY	SAMPLE DETAILS (SAMPLE NO, DATE/TIME)			CONTAINER INFORMATION		ANALYSIS REQUIRED INCLUDING STATISTICS (See Chain of Custody for details)									
LAB ID	SAMPLE NO	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (codes defined)	Volume ML/L	Temp REF/CL	Temp REF/CL	Temp REF/CL	Temp REF/CL	Temp REF/CL	Temp REF/CL	Temp REF/CL	Temp REF/CL	Temp REF/CL	Temp REF/CL
1	MC051401	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
2	MC051402	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
3	MC051403	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
4	MC051404	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
5	MC051405	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
6	MC051406	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
7	MC051407	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
8	MC051408	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
9	MC051409	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
10	MC051410	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
11	MC051411	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
12	MC051412	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
13	MC051413	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
14	MC051414	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
15	MC051415	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
16	MC051416	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
17	MC051417	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
18	MC051418	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
19	MC051419	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
20	MC051420	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
21	MC051421	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
22	MC051422	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
23	MC051423	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
24	MC051424	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
25	MC051425	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
26	MC051426	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
27	MC051427	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
28	MC051428	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
29	MC051429	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
30	MC051430	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
31	MC051431	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
32	MC051432	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
33	MC051433	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
34	MC051434	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
35	MC051435	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
36	MC051436	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
37	MC051437	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
38	MC051438	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
39	MC051439	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
40	MC051440	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
41	MC051441	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
42	MC051442	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
43	MC051443	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
44	MC051444	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
45	MC051445	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
46	MC051446	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
47	MC051447	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
48	MC051448	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
49	MC051449	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
50	MC051450	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
51	MC051451	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
52	MC051452	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
53	MC051453	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
54	MC051454	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
55	MC051455	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
56	MC051456	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
57	MC051457	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
58	MC051458	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
59	MC051459	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
60	MC051460	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
61	MC051461	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
62	MC051462	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
63	MC051463	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
64	MC051464	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
65	MC051465	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
66	MC051466	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
67	MC051467	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
68	MC051468	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
69	MC051469	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
70	MC051470	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
71	MC051471	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
72	MC051472	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
73	MC051473	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
74	MC051474	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
75	MC051475	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
76	MC051476	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
77	MC051477	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
78	MC051478	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
79	MC051479	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
80	MC051480	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
81	MC051481	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
82	MC051482	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
83	MC051483	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
84	MC051484	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
85	MC051485	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
86	MC051486	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
87	MC051487	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
88	MC051488	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
89	MC051489	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
90	MC051490	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
91	MC051491	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
92	MC051492	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
93	MC051493	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
94	MC051494	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
95	MC051495	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
96	MC051496	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
97	MC051497	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
98	MC051498	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
99	MC051499	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/
100	MC051500	14/4/18	sediment		3	/	/	/	/	/	/	/	/	/	/

Environmental Division
Brisbane
Work Order Reference
EB1809356



Telephone: +61-7-3263 7000

Notes: 1. Chain of Custody - If a sample is not analysed within the specified time frame, the sample must be stored

CERTIFICATE OF ANALYSIS

Work Order : **EB1809356**
Client : **ECOLOGICAL SERVICE PROFESSIONALS**
Contact : Kate Keating
Address : PO BOX 5935
 MANLY NSW, AUSTRALIA 4179
Telephone : ----
Project : 1704-Confidential-Tarong Sediment
Order number :
C-O-C number : ----
Sampler : REBECCA KING
Site : ----
Quote number : BN/063/18
No. of samples received : 54
No. of samples analysed : 54

Page : 1 of 24
Laboratory : Environmental Division Brisbane
Contact : Customer Services EB
Address : 2 Byth Street Stafford QLD Australia 4053
Telephone : +61-7-3243 7222
Date Samples Received : 16-Apr-2018 08:30
Date Analysis Commenced : 17-Apr-2018
Issue Date : 01-May-2018 17:43



This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Andrew Epps	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

Ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- EG005DH (1M HCl Extractable Metals): Sample EB1809356-031 (MCDS4 - R1) shows poor duplicate result due to sample heterogeneity. Confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): Sample EB1809356-011 (MCA2 - R2), EB1809356-031 (MCDS4 - R1) and EB1809356-041 (MC20 - R2) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005DH (1M HCl Extractable Metals): Sample EB1809356-002 (MCUS1 - R2) shows poor spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): Sample EB1809356-051 (SW36 - R3) shows poor duplicate results due to sample heterogeneity. Confirmed by re-extraction and re-analysis.



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCUS1 - R1	MCUS1 - R2	MCUS1 - R3	MCUS2 - R1	MCUS2 - R2
Client sampling date / time				14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-001	EB1809356-002	EB1809356-003	EB1809356-004	EB1809356-005
				Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals								
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg	0.6	0.5	0.6	2.0	0.6
EA038 / EG005: Simultaneously Extracted Metals								
Aluminium	7429-90-5	50	mg/kg	3180	3580	4010	1620	2890
Arsenic	7440-38-2	1.0	mg/kg	1.1	1.0	1.0	<1.0	1.4
Cadmium	7440-43-9	0.1	mg/kg	0.1	0.1	0.1	<0.1	0.1
Cobalt	7440-48-4	0.5	mg/kg	9.6	13.8	12.4	5.1	9.0
Chromium	7440-47-3	1.0	mg/kg	3.1	3.8	4.2	1.9	3.3
Copper	7440-50-8	1.0	mg/kg	16.4	18.0	20.0	6.8	14.3
Iron	7439-89-6	50	mg/kg	7530	10100	9900	2070	7680
Lead	7439-92-1	1.0	mg/kg	6.2	6.3	6.8	6.4	7.8
Manganese	7439-96-5	10	mg/kg	707	1060	916	308	438
Nickel	7440-02-0	1.0	mg/kg	6.6	8.9	9.7	1.8	5.0
Vanadium	7440-62-2	2.0	mg/kg	31.6	39.8	44.8	11.8	24.7
Zinc	7440-66-6	1.0	mg/kg	18.9	18.6	18.2	4.8	13.2
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	12.7	12.8	14.2	5.8	10.6
EA150: Particle Sizing								
+75µm	----	1	%	9	19	15	52	36
+150µm	----	1	%	6	16	12	49	33
+300µm	----	1	%	3	13	8	44	25
+425µm	----	1	%	2	10	6	39	19
+600µm	----	1	%	2	8	4	33	13
+1180µm	----	1	%	1	4	1	22	4
+2.36mm	----	1	%	<1	<1	<1	8	<1
+4.75mm	----	1	%	<1	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	91	81	85	48	64
Sand (>75 µm)	----	1	%	9	17	15	40	35
Gravel (>2mm)	----	1	%	<1	2	<1	12	1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

Client sampling date / time				MCUS1 - R1	MCUS1 - R2	MCUS1 - R3	MCUS2 - R1	MCUS2 - R2
				14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00	14-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-001	EB1809356-002	EB1809356-003	EB1809356-004	EB1809356-005
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	2410	2200	2760	990	2100
Arsenic	7440-38-2	1.0	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.5	mg/kg	6.6	7.4	7.0	2.5	5.3
Chromium	7440-47-3	1.0	mg/kg	1.7	1.6	1.8	<1.0	1.5
Copper	7440-50-8	1.0	mg/kg	9.5	9.5	10.5	3.5	7.8
Iron	7439-89-6	50	mg/kg	4850	6430	5930	970	4540
Lead	7439-92-1	1.0	mg/kg	3.6	3.4	3.5	2.7	4.4
Manganese	7439-96-5	10	mg/kg	530	552	531	154	240
Nickel	7440-02-0	1.0	mg/kg	4.2	4.9	5.5	<1.0	3.2
Vanadium	7440-62-2	2.0	mg/kg	20.0	21.1	24.5	6.3	13.6
Zinc	7440-66-6	1.0	mg/kg	9.2	10.1	10.8	2.3	8.0
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	23500	22500	24500	10900	14600
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	17	24	28	13	11
Iron	7439-89-6	50	mg/kg	60900	98800	109000	41800	43800
Manganese	7439-96-5	5	mg/kg	1040	1380	1650	734	369
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	98	108	125	73	80
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	76	77	88	61	64
Copper	7440-50-8	5	mg/kg	24	26	30	13	17
Lead	7439-92-1	5	mg/kg	8	8	10	6	8
Nickel	7440-02-0	2	mg/kg	24	29	33	13	18
Zinc	7440-66-6	5	mg/kg	56	68	76	28	42

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	3.88	4.02	2.57	0.72	5.47
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Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCUS2 - R3	MCA1 - R1	MCA1 - R2	MCA1 - R3	MCA2 - R1
Client sampling date / time				14-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-006	EB1809356-007	EB1809356-008	EB1809356-009	EB1809356-010
				Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals								
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg	0.6	9.1	9.1	4.4	45.7
EA038 / EG005: Simultaneously Extracted Metals								
Aluminium	7429-90-5	50	mg/kg	1330	2110	1700	2330	2370
Arsenic	7440-38-2	1.0	mg/kg	<1.0	2.1	2.4	2.2	1.1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	0.1	0.2	<0.1	0.3
Cobalt	7440-48-4	0.5	mg/kg	3.8	14.4	16.0	9.5	8.7
Chromium	7440-47-3	1.0	mg/kg	1.8	5.4	3.2	6.1	4.2
Copper	7440-50-8	1.0	mg/kg	5.9	11.6	12.6	10.8	14.1
Iron	7439-89-6	50	mg/kg	1610	28900	9330	7240	13000
Lead	7439-92-1	1.0	mg/kg	4.4	15.2	13.3	13.1	17.7
Manganese	7439-96-5	10	mg/kg	225	6500	2640	721	1610
Nickel	7440-02-0	1.0	mg/kg	1.3	8.5	12.3	5.4	13.4
Vanadium	7440-62-2	2.0	mg/kg	10.5	24.5	16.5	23.6	24.2
Zinc	7440-66-6	1.0	mg/kg	4.0	34.3	49.0	16.8	66.2
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	5.3	48.0	47.2	33.8	56.6
EA150: Particle Sizing								
+75µm	----	1	%	60	35	14	18	9
+150µm	----	1	%	57	30	11	16	7
+300µm	----	1	%	49	20	7	12	6
+425µm	----	1	%	41	14	6	10	5
+600µm	----	1	%	34	10	5	8	5
+1180µm	----	1	%	21	5	4	4	4
+2.36mm	----	1	%	10	2	1	1	2
+4.75mm	----	1	%	4	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	40	65	86	82	91
Sand (>75 µm)	----	1	%	47	32	12	16	6
Gravel (>2mm)	----	1	%	13	3	2	2	3
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCUS2 - R3	MCA1 - R1	MCA1 - R2	MCA1 - R3	MCA2 - R1
Client sampling date / time				14-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-006	EB1809356-007	EB1809356-008	EB1809356-009	EB1809356-010
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	920	1150	1300	1590	1470
Arsenic	7440-38-2	1.0	mg/kg	<1.0	1.2	1.4	1.4	1.1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.5	mg/kg	2.3	8.8	10.9	6.4	4.7
Chromium	7440-47-3	1.0	mg/kg	<1.0	1.6	1.6	2.4	2.0
Copper	7440-50-8	1.0	mg/kg	3.2	6.6	8.4	6.4	10.4
Iron	7439-89-6	50	mg/kg	850	19200	7440	4070	7250
Lead	7439-92-1	1.0	mg/kg	2.5	6.9	9.2	7.9	9.6
Manganese	7439-96-5	10	mg/kg	143	4960	2100	620	794
Nickel	7440-02-0	1.0	mg/kg	<1.0	5.4	8.5	3.4	7.5
Vanadium	7440-62-2	2.0	mg/kg	6.1	11.4	11.8	15.5	13.3
Zinc	7440-66-6	1.0	mg/kg	2.1	19.0	34.7	10.4	35.4
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	10300	9490	11800	13400	3840
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	15	14	21	10	6
Iron	7439-89-6	50	mg/kg	45900	35600	35800	28000	9030
Manganese	7439-96-5	5	mg/kg	763	5030	1030	491	444
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	81	42	60	51	16
Arsenic	7440-38-2	5	mg/kg	<5	6	7	<5	<5
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	64	30	31	31	9
Copper	7440-50-8	5	mg/kg	13	13	17	15	11
Lead	7439-92-1	5	mg/kg	7	11	17	13	9
Nickel	7440-02-0	2	mg/kg	14	11	20	12	9
Zinc	7440-66-6	5	mg/kg	28	40	104	31	31

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	0.50	2.52	2.25	1.13	6.24
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Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCA2 - R2	MCA2 - R3	MCA3 - R1	MCA3 - R2	MCA3 - R3
Client sampling date / time				13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-011	EB1809356-012	EB1809356-013	EB1809356-014	EB1809356-015
				Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals								
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg	58.4	37.8	11.4	2.1	0.9
EA038 / EG005: Simultaneously Extracted Metals								
Aluminium	7429-90-5	50	mg/kg	1870	2720	720	1410	1930
Arsenic	7440-38-2	1.0	mg/kg	1.3	1.1	7.6	4.5	3.6
Cadmium	7440-43-9	0.1	mg/kg	0.3	0.3	<0.1	0.2	0.2
Cobalt	7440-48-4	0.5	mg/kg	14.1	9.9	58.7	38.8	29.8
Chromium	7440-47-3	1.0	mg/kg	4.2	6.1	2.4	2.3	2.1
Copper	7440-50-8	1.0	mg/kg	13.4	9.9	9.0	13.4	12.6
Iron	7439-89-6	50	mg/kg	16800	15500	55800	15300	7930
Lead	7439-92-1	1.0	mg/kg	18.9	20.5	7.6	12.2	13.2
Manganese	7439-96-5	10	mg/kg	2520	991	11100	5010	3090
Nickel	7440-02-0	1.0	mg/kg	14.6	12.7	23.0	20.8	16.9
Vanadium	7440-62-2	2.0	mg/kg	25.0	28.2	8.7	13.1	14.6
Zinc	7440-66-6	1.0	mg/kg	83.4	67.7	73.0	80.6	69.6
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	54.3	49.2	66.4	40.1	36.4
EA150: Particle Sizing								
+75µm	----	1	%	8	16	24	45	48
+150µm	----	1	%	7	16	20	38	37
+300µm	----	1	%	7	14	16	28	22
+425µm	----	1	%	6	13	14	23	16
+600µm	----	1	%	5	11	11	17	12
+1180µm	----	1	%	4	4	6	9	6
+2.36mm	----	1	%	3	1	2	5	3
+4.75mm	----	1	%	1	<1	<1	2	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	92	84	76	55	52
Sand (>75 µm)	----	1	%	5	14	21	39	44
Gravel (>2mm)	----	1	%	3	2	3	6	4
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCA2 - R2	MCA2 - R3	MCA3 - R1	MCA3 - R2	MCA3 - R3
Client sampling date / time				13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-011	EB1809356-012	EB1809356-013	EB1809356-014	EB1809356-015
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	1130	1340	590	900	1050
Arsenic	7440-38-2	1.0	mg/kg	1.4	1.1	5.8	2.0	1.8
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	0.2
Cobalt	7440-48-4	0.5	mg/kg	7.6	4.7	54.4	21.8	16.0
Chromium	7440-47-3	1.0	mg/kg	1.9	3.1	<1.0	<1.0	<1.0
Copper	7440-50-8	1.0	mg/kg	11.0	10.2	7.1	8.8	7.4
Iron	7439-89-6	50	mg/kg	8610	6860	53700	7810	4250
Lead	7439-92-1	1.0	mg/kg	9.6	10.6	5.8	7.8	7.2
Manganese	7439-96-5	10	mg/kg	1380	452	11500	2810	1880
Nickel	7440-02-0	1.0	mg/kg	8.4	6.2	19.3	12.6	9.6
Vanadium	7440-62-2	2.0	mg/kg	13.1	13.1	7.6	7.9	8.2
Zinc	7440-66-6	1.0	mg/kg	43.5	28.8	67.0	49.1	50.5
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	5700	6220	4090	6300	7210
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	10	8	79	45	27
Iron	7439-89-6	50	mg/kg	14000	14900	52600	22400	17700
Manganese	7439-96-5	5	mg/kg	1090	494	10500	5700	2170
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	23	25	19	26	28
Arsenic	7440-38-2	5	mg/kg	<5	<5	12	6	6
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	13	15	9	12	15
Copper	7440-50-8	5	mg/kg	16	17	11	14	13
Lead	7439-92-1	5	mg/kg	12	11	7	12	14
Nickel	7440-02-0	2	mg/kg	10	13	25	26	20
Zinc	7440-66-6	5	mg/kg	52	45	81	99	74

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	4.54	2.85	5.52	4.94	8.26
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Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				CM2 - R1	CM2 - R2	CM2 - R3	MCDOUT - R1	MCDOUT - R2
Client sampling date / time				13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-016	EB1809356-017	EB1809356-018	EB1809356-019	EB1809356-020
				Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals								
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg	7.7	26.3	13.9	8.8	9.8
EA038 / EG005: Simultaneously Extracted Metals								
Aluminium	7429-90-5	50	mg/kg	1930	2130	2670	1240	1060
Arsenic	7440-38-2	1.0	mg/kg	4.6	2.4	6.1	7.4	13.8
Cadmium	7440-43-9	0.1	mg/kg	1.0	0.6	1.7	<0.1	0.2
Cobalt	7440-48-4	0.5	mg/kg	525	111	454	9.0	23.8
Chromium	7440-47-3	1.0	mg/kg	3.9	5.9	5.3	3.9	13.5
Copper	7440-50-8	1.0	mg/kg	27.9	22.4	37.7	38.5	36.9
Iron	7439-89-6	50	mg/kg	29900	18100	21800	6060	10000
Lead	7439-92-1	1.0	mg/kg	22.1	27.4	30.2	12.0	11.1
Manganese	7439-96-5	10	mg/kg	16100	2500	22900	3070	10800
Nickel	7440-02-0	1.0	mg/kg	156	58.7	246	10.0	26.7
Vanadium	7440-62-2	2.0	mg/kg	18.0	29.0	23.6	59.4	50.6
Zinc	7440-66-6	1.0	mg/kg	1110	516	1990	44.9	136
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	49.9	55.8	61.8	45.5	46.0
EA150: Particle Sizing								
+75µm	----	1	%	5	7	5	26	53
+150µm	----	1	%	4	5	4	25	44
+300µm	----	1	%	3	4	3	25	24
+425µm	----	1	%	3	4	3	23	15
+600µm	----	1	%	2	3	2	20	9
+1180µm	----	1	%	2	2	2	10	4
+2.36mm	----	1	%	<1	1	<1	3	2
+4.75mm	----	1	%	<1	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	95	93	95	74	47
Sand (>75 µm)	----	1	%	4	6	4	21	50
Gravel (>2mm)	----	1	%	1	1	1	5	3
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				CM2 - R1	CM2 - R2	CM2 - R3	MCDOUT - R1	MCDOUT - R2
Client sampling date / time				13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-016	EB1809356-017	EB1809356-018	EB1809356-019	EB1809356-020
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	980	980	1150	730	550
Arsenic	7440-38-2	1.0	mg/kg	2.1	1.9	2.4	3.0	6.1
Cadmium	7440-43-9	0.1	mg/kg	0.4	0.2	0.4	<0.1	<0.1
Cobalt	7440-48-4	0.5	mg/kg	218	53.6	254	2.9	12.1
Chromium	7440-47-3	1.0	mg/kg	1.2	1.9	1.3	2.0	6.0
Copper	7440-50-8	1.0	mg/kg	12.4	11.9	14.6	19.4	15.6
Iron	7439-89-6	50	mg/kg	14400	7900	14000	2820	4820
Lead	7439-92-1	1.0	mg/kg	10.9	11.3	12.2	6.2	5.0
Manganese	7439-96-5	10	mg/kg	6230	1060	10300	705	4870
Nickel	7440-02-0	1.0	mg/kg	70.6	26.9	114	4.1	14.1
Vanadium	7440-62-2	2.0	mg/kg	8.9	11.9	9.0	28.1	23.3
Zinc	7440-66-6	1.0	mg/kg	605	225	757	15.8	65.7
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	5860	6790	6100	6770	5030
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	243	49	311	9	26
Iron	7439-89-6	50	mg/kg	23500	17900	21800	10500	14000
Manganese	7439-96-5	5	mg/kg	6220	958	9060	1130	5560
Molybdenum	7439-98-7	2	mg/kg	2	<2	3	5	3
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	25	31	27	46	36
Arsenic	7440-38-2	5	mg/kg	<5	7	5	14	20
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	15	19	16	17	20
Copper	7440-50-8	5	mg/kg	21	26	22	40	32
Lead	7439-92-1	5	mg/kg	16	18	16	11	8
Nickel	7440-02-0	2	mg/kg	88	28	133	12	23
Zinc	7440-66-6	5	mg/kg	575	165	700	37	79

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	4.19	5.30	4.85	3.15	2.22
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Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCDOUT - R3	MC500 - R1	MC500 - R2	MC500 - R3	MCDS2 - R1
Client sampling date / time				11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-021	EB1809356-022	EB1809356-023	EB1809356-024	EB1809356-025
				Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals								
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg	20.1	29.6	48.4	68.0	23.7
EA038 / EG005: Simultaneously Extracted Metals								
Aluminium	7429-90-5	50	mg/kg	2000	2010	1510	2740	1520
Arsenic	7440-38-2	1.0	mg/kg	6.6	25.8	28.9	22.2	3.8
Cadmium	7440-43-9	0.1	mg/kg	0.3	0.3	0.1	0.2	0.6
Cobalt	7440-48-4	0.5	mg/kg	41.2	69.6	85.3	122	36.3
Chromium	7440-47-3	1.0	mg/kg	16.6	24.9	22.9	44.8	9.8
Copper	7440-50-8	1.0	mg/kg	30.2	44.1	38.1	62.9	21.7
Iron	7439-89-6	50	mg/kg	14800	20100	38000	60300	9130
Lead	7439-92-1	1.0	mg/kg	16.2	17.5	14.8	25.7	20.6
Manganese	7439-96-5	10	mg/kg	9310	61600	50900	45900	891
Nickel	7440-02-0	1.0	mg/kg	37.8	73.8	69.6	90.0	43.2
Vanadium	7440-62-2	2.0	mg/kg	62.6	66.8	83.1	127	28.9
Zinc	7440-66-6	1.0	mg/kg	189	228	199	355	594
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	49.2	61.7	66.8	67.7	49.7
EA150: Particle Sizing								
+75µm	----	1	%	44	56	62	46	4
+150µm	----	1	%	35	48	52	38	3
+300µm	----	1	%	13	37	34	28	2
+425µm	----	1	%	8	32	25	24	2
+600µm	----	1	%	7	28	19	21	2
+1180µm	----	1	%	4	21	11	15	<1
+2.36mm	----	1	%	2	12	3	6	<1
+4.75mm	----	1	%	<1	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	56	44	38	54	96
Sand (>75 µm)	----	1	%	41	40	56	38	4
Gravel (>2mm)	----	1	%	3	15	6	8	<1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCDOUT - R3	MC500 - R1	MC500 - R2	MC500 - R3	MCDS2 - R1
Client sampling date / time				11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-021	EB1809356-022	EB1809356-023	EB1809356-024	EB1809356-025
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	840	700	660	810	790
Arsenic	7440-38-2	1.0	mg/kg	3.6	10.4	20.3	8.8	4.5
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	0.3
Cobalt	7440-48-4	0.5	mg/kg	20.0	24.9	35.2	38.3	21.7
Chromium	7440-47-3	1.0	mg/kg	6.4	7.7	8.9	12.2	5.3
Copper	7440-50-8	1.0	mg/kg	15.2	15.1	17.6	19.5	22.2
Iron	7439-89-6	50	mg/kg	6120	6570	14000	17800	3630
Lead	7439-92-1	1.0	mg/kg	6.9	5.7	6.0	7.4	11.3
Manganese	7439-96-5	10	mg/kg	4410	21900	22500	14600	390
Nickel	7440-02-0	1.0	mg/kg	18.0	25.5	28.4	28.8	21.9
Vanadium	7440-62-2	2.0	mg/kg	28.4	23.0	34.6	38.0	16.1
Zinc	7440-66-6	1.0	mg/kg	85.5	81.1	86.6	117	259
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	7280	6080	5450	6440	5610
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	53	38	47	58	46
Iron	7439-89-6	50	mg/kg	18600	14600	20500	25000	14000
Manganese	7439-96-5	5	mg/kg	5800	25200	24400	16400	502
Molybdenum	7439-98-7	2	mg/kg	2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	5	<5
Vanadium	7440-62-2	5	mg/kg	53	38	46	53	32
Arsenic	7440-38-2	5	mg/kg	19	25	38	36	11
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	26	26	25	35	24
Copper	7440-50-8	5	mg/kg	38	29	26	39	33
Lead	7439-92-1	5	mg/kg	12	9	9	14	18
Nickel	7440-02-0	2	mg/kg	39	34	40	39	40
Zinc	7440-66-6	5	mg/kg	126	100	101	138	364

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	0.1	0.1	<0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	1.56	3.98	3.88	4.28	2.91
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Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCDS2 - R2	MCDS2 - R3	MCDS3 - R1	MCDS3 - R2	MCDS3 - R3
Client sampling date / time				11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-026	EB1809356-027	EB1809356-028	EB1809356-029	EB1809356-030
				Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals								
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg	24.5	46.3	8.1	3.8	19.4
EA038 / EG005: Simultaneously Extracted Metals								
Aluminium	7429-90-5	50	mg/kg	1880	2340	500	350	1000
Arsenic	7440-38-2	1.0	mg/kg	4.0	3.9	16.4	5.1	43.6
Cadmium	7440-43-9	0.1	mg/kg	0.8	1.1	0.1	<0.1	0.4
Cobalt	7440-48-4	0.5	mg/kg	36.8	64.3	2.7	1.4	5.4
Chromium	7440-47-3	1.0	mg/kg	10.8	16.6	38.4	14.4	97.7
Copper	7440-50-8	1.0	mg/kg	24.6	19.6	19.7	10.4	41.8
Iron	7439-89-6	50	mg/kg	10600	18400	4970	2750	12900
Lead	7439-92-1	1.0	mg/kg	26.0	26.1	6.8	2.3	7.3
Manganese	7439-96-5	10	mg/kg	920	1470	147	73	435
Nickel	7440-02-0	1.0	mg/kg	46.1	77.5	5.2	2.5	13.2
Vanadium	7440-62-2	2.0	mg/kg	35.1	47.0	14.3	5.9	32.6
Zinc	7440-66-6	1.0	mg/kg	692	1130	36.4	19.8	83.9
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	50.8	54.7	19.0	36.0	49.2
EA150: Particle Sizing								
+75µm	----	1	%	5	7	97	95	86
+150µm	----	1	%	4	6	94	92	85
+300µm	----	1	%	4	6	75	70	82
+425µm	----	1	%	4	6	60	54	78
+600µm	----	1	%	3	5	41	37	71
+1180µm	----	1	%	2	4	13	13	48
+2.36mm	----	1	%	<1	2	2	2	18
+4.75mm	----	1	%	<1	<1	<1	<1	5
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	95	93	3	5	14
Sand (>75 µm)	----	1	%	4	5	92	89	59
Gravel (>2mm)	----	1	%	1	2	5	6	27
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

Client sampling date / time				MCDS2 - R2	MCDS2 - R3	MCDS3 - R1	MCDS3 - R2	MCDS3 - R3
				11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-026	EB1809356-027	EB1809356-028	EB1809356-029	EB1809356-030
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	840	870	130	310	610
Arsenic	7440-38-2	1.0	mg/kg	2.5	5.8	1.9	5.5	24.5
Cadmium	7440-43-9	0.1	mg/kg	0.4	0.4	<0.1	<0.1	0.1
Cobalt	7440-48-4	0.5	mg/kg	22.7	26.9	0.5	1.4	3.7
Chromium	7440-47-3	1.0	mg/kg	3.9	6.0	3.7	13.3	48.8
Copper	7440-50-8	1.0	mg/kg	13.3	25.2	4.5	14.3	31.1
Iron	7439-89-6	50	mg/kg	4660	4650	790	2690	8570
Lead	7439-92-1	1.0	mg/kg	10.1	11.1	<1.0	2.0	3.7
Manganese	7439-96-5	10	mg/kg	450	376	24	74	284
Nickel	7440-02-0	1.0	mg/kg	26.4	30.6	<1.0	2.8	8.8
Vanadium	7440-62-2	2.0	mg/kg	14.8	18.0	<2.0	8.3	21.5
Zinc	7440-66-6	1.0	mg/kg	359	396	6.7	21.4	53.2
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	5390	5550	1470	2840	4220
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	42	71	<2	4	8
Iron	7439-89-6	50	mg/kg	13000	16200	3350	7590	14600
Manganese	7439-96-5	5	mg/kg	362	659	41	106	344
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	29	33	7	16	30
Arsenic	7440-38-2	5	mg/kg	11	13	8	20	56
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	20	24	18	50	136
Copper	7440-50-8	5	mg/kg	29	33	11	36	56
Lead	7439-92-1	5	mg/kg	18	16	<5	<5	7
Nickel	7440-02-0	2	mg/kg	36	60	3	5	14
Zinc	7440-66-6	5	mg/kg	318	524	16	33	77

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	3.14	0.08	3.18	0.37	3.23
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Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCDS4 - R1	MCDS4 - R2	MCDS4 - R3	MCDS5 - R1	MCDS5 - R2
Client sampling date / time				11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-031	EB1809356-032	EB1809356-033	EB1809356-034	EB1809356-035
				Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals								
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg	2.9	17.0	5.8	15.6	17.7
EA038 / EG005: Simultaneously Extracted Metals								
Aluminium	7429-90-5	50	mg/kg	150	1180	380	960	910
Arsenic	7440-38-2	1.0	mg/kg	1.0	7.0	2.6	9.7	11.9
Cadmium	7440-43-9	0.1	mg/kg	<0.1	0.2	<0.1	0.2	0.2
Cobalt	7440-48-4	0.5	mg/kg	<0.5	4.6	1.7	7.3	7.8
Chromium	7440-47-3	1.0	mg/kg	<1.0	11.2	4.1	23.2	23.6
Copper	7440-50-8	1.0	mg/kg	13.6	51.7	23.3	25.4	28.7
Iron	7439-89-6	50	mg/kg	840	7670	2500	6590	6080
Lead	7439-92-1	1.0	mg/kg	3.0	11.9	4.3	13.1	12.1
Manganese	7439-96-5	10	mg/kg	15	120	42	521	346
Nickel	7440-02-0	1.0	mg/kg	1.3	27.3	6.6	17.3	16.6
Vanadium	7440-62-2	2.0	mg/kg	10.9	51.5	16.7	31.4	29.7
Zinc	7440-66-6	1.0	mg/kg	5.7	194	65.2	228	180
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	46.4	71.6	66.6	67.3	67.2
EA150: Particle Sizing								
+75µm	----	1	%	66	27	29	9	28
+150µm	----	1	%	63	25	26	8	27
+300µm	----	1	%	56	22	22	8	26
+425µm	----	1	%	51	20	21	7	26
+600µm	----	1	%	44	19	19	6	25
+1180µm	----	1	%	29	15	16	4	23
+2.36mm	----	1	%	16	10	10	<1	14
+4.75mm	----	1	%	<1	<1	1	<1	2
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	34	73	71	91	72
Sand (>75 µm)	----	1	%	46	16	17	7	11
Gravel (>2mm)	----	1	%	20	11	12	2	17
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCDS4 - R1	MCDS4 - R2	MCDS4 - R3	MCDS5 - R1	MCDS5 - R2
Client sampling date / time				11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00	11-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-031	EB1809356-032	EB1809356-033	EB1809356-034	EB1809356-035
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	220	730	720	1040	860
Arsenic	7440-38-2	1.0	mg/kg	4.0	9.8	7.1	15.0	14.0
Cadmium	7440-43-9	0.1	mg/kg	<0.1	0.2	0.2	0.2	0.2
Cobalt	7440-48-4	0.5	mg/kg	<0.5	6.1	4.9	10.8	7.3
Chromium	7440-47-3	1.0	mg/kg	<1.0	8.1	7.2	24.6	22.0
Copper	7440-50-8	1.0	mg/kg	27.9	59.0	65.8	61.5	51.8
Iron	7439-89-6	50	mg/kg	830	4680	3860	4970	5110
Lead	7439-92-1	1.0	mg/kg	4.9	7.7	8.1	11.9	10.3
Manganese	7439-96-5	10	mg/kg	19	80	75	486	273
Nickel	7440-02-0	1.0	mg/kg	1.6	23.0	15.7	16.4	15.3
Vanadium	7440-62-2	2.0	mg/kg	15.9	30.5	28.2	27.9	24.8
Zinc	7440-66-6	1.0	mg/kg	5.7	146	124	216	148
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	3230	6510	6880	6780	7600
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	<2	23	21	26	27
Iron	7439-89-6	50	mg/kg	3650	17700	15500	14800	15900
Manganese	7439-96-5	5	mg/kg	25	147	152	644	513
Molybdenum	7439-98-7	2	mg/kg	2	3	2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	24	50	47	37	40
Arsenic	7440-38-2	5	mg/kg	8	32	24	35	41
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	24	63	61	78	95
Copper	7440-50-8	5	mg/kg	48	153	149	98	105
Lead	7439-92-1	5	mg/kg	6	14	14	16	17
Nickel	7440-02-0	2	mg/kg	6	49	39	28	33
Zinc	7440-66-6	5	mg/kg	11	217	192	214	217

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	3.98	5.13	3.11	5.10	3.46
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Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	MCDS5 - R3	MC5/W2 - R1	MC5/W2 - R2	MC5/W2 - R3	MC20 - R1
Client sampling date / time					11-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00
Compound	CAS Number	LOR	Unit		EB1809356-036	EB1809356-037	EB1809356-038	EB1809356-039	EB1809356-040
					Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals									
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg		10.5	1.1	3.1	4.6	1.6
EA038 / EG005: Simultaneously Extracted Metals									
Aluminium	7429-90-5	50	mg/kg		590	130	260	160	1970
Arsenic	7440-38-2	1.0	mg/kg		6.2	<1.0	<1.0	<1.0	1.5
Cadmium	7440-43-9	0.1	mg/kg		0.2	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.5	mg/kg		5.9	1.9	1.7	1.6	2.8
Chromium	7440-47-3	1.0	mg/kg		14.2	<1.0	<1.0	<1.0	<1.0
Copper	7440-50-8	1.0	mg/kg		16.5	1.2	2.0	1.2	6.7
Iron	7439-89-6	50	mg/kg		4100	860	980	1600	2520
Lead	7439-92-1	1.0	mg/kg		7.7	<1.0	1.2	<1.0	2.3
Manganese	7439-96-5	10	mg/kg		462	286	71	181	180
Nickel	7440-02-0	1.0	mg/kg		12.3	2.0	2.8	1.8	4.2
Vanadium	7440-62-2	2.0	mg/kg		18.9	2.2	6.4	5.2	15.9
Zinc	7440-66-6	1.0	mg/kg		146	5.6	8.6	5.1	13.7
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	1.0	%		64.5	18.9	18.2	19.5	27.0
EA150: Particle Sizing									
+75µm	----	1	%		15	98	95	95	11
+150µm	----	1	%		14	97	94	94	7
+300µm	----	1	%		12	94	90	90	4
+425µm	----	1	%		12	89	85	84	4
+600µm	----	1	%		11	77	74	73	4
+1180µm	----	1	%		8	38	46	53	3
+2.36mm	----	1	%		3	6	19	30	2
+4.75mm	----	1	%		<1	<1	9	16	<1
+9.5mm	----	1	%		<1	<1	<1	<1	<1
+19.0mm	----	1	%		<1	<1	<1	<1	<1
+37.5mm	----	1	%		<1	<1	<1	<1	<1
+75.0mm	----	1	%		<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size									
Fines (<75 µm)	----	1	%		85	2	5	5	89
Sand (>75 µm)	----	1	%		10	82	68	58	9
Gravel (>2mm)	----	1	%		5	16	27	37	2
Cobbles (>6cm)	----	1	%		<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MCDS5 - R3	MC5/W2 - R1	MC5/W2 - R2	MC5/W2 - R3	MC20 - R1
Client sampling date / time				11-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-036	EB1809356-037	EB1809356-038	EB1809356-039	EB1809356-040
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	1030	120	240	210	2670
Arsenic	7440-38-2	1.0	mg/kg	13.4	<1.0	<1.0	<1.0	1.0
Cadmium	7440-43-9	0.1	mg/kg	0.2	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.5	mg/kg	9.1	0.8	1.3	0.8	4.4
Chromium	7440-47-3	1.0	mg/kg	23.7	<1.0	<1.0	<1.0	1.4
Copper	7440-50-8	1.0	mg/kg	55.4	<1.0	1.9	1.2	7.1
Iron	7439-89-6	50	mg/kg	4880	600	860	970	3840
Lead	7439-92-1	1.0	mg/kg	11.4	<1.0	<1.0	<1.0	2.6
Manganese	7439-96-5	10	mg/kg	539	196	59	115	265
Nickel	7440-02-0	1.0	mg/kg	17.2	1.0	2.7	1.5	5.3
Vanadium	7440-62-2	2.0	mg/kg	25.5	<2.0	4.7	4.4	19.2
Zinc	7440-66-6	1.0	mg/kg	203	3.5	5.8	3.4	16.4
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	7980	1240	1880	1900	18500
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	31	<2	3	3	23
Iron	7439-89-6	50	mg/kg	16400	3790	6090	5550	48800
Manganese	7439-96-5	5	mg/kg	921	339	92	279	1000
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	41	11	18	17	74
Arsenic	7440-38-2	5	mg/kg	38	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	87	7	9	9	25
Copper	7440-50-8	5	mg/kg	111	<5	<5	<5	19
Lead	7439-92-1	5	mg/kg	18	<5	<5	<5	10
Nickel	7440-02-0	2	mg/kg	33	3	6	4	24
Zinc	7440-66-6	5	mg/kg	267	8	12	10	110

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	3.52	0.36	0.16	0.58	1.20
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Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	MC20 - R2	MC20 - R3	BPD1 - R1	BPD1 - R2	BPD1 - R3
Client sampling date / time					12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00
Compound	CAS Number	LOR	Unit		EB1809356-041	EB1809356-042	EB1809356-043	EB1809356-044	EB1809356-045
					Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals									
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg		0.7	0.8	7.9	5.2	5.2
EA038 / EG005: Simultaneously Extracted Metals									
Aluminium	7429-90-5	50	mg/kg		1770	2400	4970	3480	4950
Arsenic	7440-38-2	1.0	mg/kg		1.0	1.7	2.5	1.6	2.3
Cadmium	7440-43-9	0.1	mg/kg		<0.1	<0.1	0.2	0.2	0.2
Cobalt	7440-48-4	0.5	mg/kg		3.3	12.3	21.2	14.2	20.5
Chromium	7440-47-3	1.0	mg/kg		1.1	6.3	7.5	14.5	7.2
Copper	7440-50-8	1.0	mg/kg		5.4	9.0	21.6	11.1	22.0
Iron	7439-89-6	50	mg/kg		2650	5470	22800	13300	21800
Lead	7439-92-1	1.0	mg/kg		1.6	3.1	10.5	6.6	10.3
Manganese	7439-96-5	10	mg/kg		196	571	3320	1350	3640
Nickel	7440-02-0	1.0	mg/kg		3.6	7.2	12.1	8.5	11.7
Vanadium	7440-62-2	2.0	mg/kg		16.4	27.2	71.3	45.6	69.6
Zinc	7440-66-6	1.0	mg/kg		8.5	16.3	34.7	21.2	34.0
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	1.0	%		28.4	34.7	65.4	48.5	65.0
EA150: Particle Sizing									
+75µm	----	1	%		12	12	22	25	32
+150µm	----	1	%		7	6	21	20	32
+300µm	----	1	%		5	3	21	12	31
+425µm	----	1	%		5	2	20	10	31
+600µm	----	1	%		5	2	20	9	31
+1180µm	----	1	%		4	1	19	8	31
+2.36mm	----	1	%		4	<1	14	5	30
+4.75mm	----	1	%		2	<1	<1	<1	24
+9.5mm	----	1	%		<1	<1	<1	<1	<1
+19.0mm	----	1	%		<1	<1	<1	<1	<1
+37.5mm	----	1	%		<1	<1	<1	<1	<1
+75.0mm	----	1	%		<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size									
Fines (<75 µm)	----	1	%		88	88	78	75	68
Sand (>75 µm)	----	1	%		8	12	6	19	2
Gravel (>2mm)	----	1	%		4	<1	16	6	30
Cobbles (>6cm)	----	1	%		<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				MC20 - R2	MC20 - R3	BPD1 - R1	BPD1 - R2	BPD1 - R3
Client sampling date / time				12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-041	EB1809356-042	EB1809356-043	EB1809356-044	EB1809356-045
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	2930	3000	2740	2960	2350
Arsenic	7440-38-2	1.0	mg/kg	1.0	1.2	1.9	1.2	1.5
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.5	mg/kg	5.0	9.9	11.1	9.8	9.2
Chromium	7440-47-3	1.0	mg/kg	1.8	1.9	3.3	3.2	2.9
Copper	7440-50-8	1.0	mg/kg	6.8	8.1	12.2	10.9	10.4
Iron	7439-89-6	50	mg/kg	4660	5820	11500	10100	9510
Lead	7439-92-1	1.0	mg/kg	2.4	3.1	5.6	5.6	4.8
Manganese	7439-96-5	10	mg/kg	279	445	1860	999	1730
Nickel	7440-02-0	1.0	mg/kg	5.3	6.6	6.1	6.3	5.2
Vanadium	7440-62-2	2.0	mg/kg	22.1	25.1	35.6	34.0	29.7
Zinc	7440-66-6	1.0	mg/kg	14.0	18.5	17.7	15.7	17.5
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	21300	21300	19400	15600	18900
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	25	22	19	20	19
Iron	7439-89-6	50	mg/kg	55700	55500	40000	32000	39400
Manganese	7439-96-5	5	mg/kg	984	712	2210	1300	2310
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	84	83	70	63	70
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	5
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	28	29	24	20	24
Copper	7440-50-8	5	mg/kg	20	20	23	20	22
Lead	7439-92-1	5	mg/kg	5	6	9	7	8
Nickel	7440-02-0	2	mg/kg	28	26	19	17	19
Zinc	7440-66-6	5	mg/kg	88	89	55	43	56

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	0.91	1.03	3.89	2.80	3.55
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Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	BPD2 - R1	BPD2 - R2	BPD2 - R3	SW36 - R1	SW36 - R2
Client sampling date / time					12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00
Compound	CAS Number	LOR	Unit		EB1809356-046	EB1809356-047	EB1809356-048	EB1809356-049	EB1809356-050
					Result	Result	Result	Result	Result
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals									
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg		12.6	18.2	11.4	1.3	0.7
EA038 / EG005: Simultaneously Extracted Metals									
Aluminium	7429-90-5	50	mg/kg		3140	2680	2960	530	230
Arsenic	7440-38-2	1.0	mg/kg		2.0	2.4	1.5	<1.0	<1.0
Cadmium	7440-43-9	0.1	mg/kg		0.2	0.2	0.2	<0.1	<0.1
Cobalt	7440-48-4	0.5	mg/kg		18.1	15.4	17.2	4.7	1.3
Chromium	7440-47-3	1.0	mg/kg		4.8	4.5	5.0	1.8	2.4
Copper	7440-50-8	1.0	mg/kg		18.8	16.6	17.3	2.9	<1.0
Iron	7439-89-6	50	mg/kg		16700	14800	16400	3150	1260
Lead	7439-92-1	1.0	mg/kg		11.0	11.3	12.2	2.4	1.5
Manganese	7439-96-5	10	mg/kg		1450	1170	1440	269	64
Nickel	7440-02-0	1.0	mg/kg		10.8	9.4	10.3	2.7	<1.0
Vanadium	7440-62-2	2.0	mg/kg		50.8	44.1	50.3	8.8	3.6
Zinc	7440-66-6	1.0	mg/kg		40.1	34.0	38.6	5.9	3.4
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	1.0	%		63.6	59.2	62.2	18.2	15.4
EA150: Particle Sizing									
+75µm	----	1	%		18	18	23	84	95
+150µm	----	1	%		18	17	22	75	95
+300µm	----	1	%		17	16	20	47	94
+425µm	----	1	%		17	16	19	30	91
+600µm	----	1	%		17	15	18	17	85
+1180µm	----	1	%		16	14	16	8	65
+2.36mm	----	1	%		13	10	12	5	43
+4.75mm	----	1	%		<1	<1	2	2	26
+9.5mm	----	1	%		<1	<1	<1	<1	10
+19.0mm	----	1	%		<1	<1	<1	<1	<1
+37.5mm	----	1	%		<1	<1	<1	<1	<1
+75.0mm	----	1	%		<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size									
Fines (<75 µm)	----	1	%		82	82	77	16	5
Sand (>75 µm)	----	1	%		4	7	10	78	45
Gravel (>2mm)	----	1	%		14	11	13	6	50
Cobbles (>6cm)	----	1	%		<1	<1	<1	<1	<1



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				BPD2 - R1	BPD2 - R2	BPD2 - R3	SW36 - R1	SW36 - R2
Client sampling date / time				12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00	12-Apr-2018 00:00
Compound	CAS Number	LOR	Unit	EB1809356-046	EB1809356-047	EB1809356-048	EB1809356-049	EB1809356-050
				Result	Result	Result	Result	Result

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	2130	1750	1980	550	440
Arsenic	7440-38-2	1.0	mg/kg	1.2	<1.0	1.3	<1.0	<1.0
Cadmium	7440-43-9	0.1	mg/kg	0.1	<0.1	<0.1	<0.1	0.1
Cobalt	7440-48-4	0.5	mg/kg	9.4	11.0	10.2	3.6	2.0
Chromium	7440-47-3	1.0	mg/kg	3.0	2.7	3.1	1.8	1.8
Copper	7440-50-8	1.0	mg/kg	11.5	11.0	12.1	2.4	1.3
Iron	7439-89-6	50	mg/kg	8960	9210	9610	2530	1900
Lead	7439-92-1	1.0	mg/kg	6.2	6.7	7.2	2.3	1.8
Manganese	7439-96-5	10	mg/kg	731	737	829	197	84
Nickel	7440-02-0	1.0	mg/kg	6.1	6.3	6.6	2.2	1.4
Vanadium	7440-62-2	2.0	mg/kg	27.8	26.8	28.9	7.3	4.6
Zinc	7440-66-6	1.0	mg/kg	21.7	22.9	22.4	4.6	5.8
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	<5

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	15100	11400	13900	3740	2730
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	19	22	21	6	6
Iron	7439-89-6	50	mg/kg	35000	29400	31900	15400	20100
Manganese	7439-96-5	5	mg/kg	1210	1070	1010	253	198
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	57	50	56	29	25
Arsenic	7440-38-2	5	mg/kg	5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	21	18	21	21	22
Copper	7440-50-8	5	mg/kg	24	22	24	6	<5
Lead	7439-92-1	5	mg/kg	9	10	10	<5	<5
Nickel	7440-02-0	2	mg/kg	19	18	19	8	7
Zinc	7440-66-6	5	mg/kg	59	52	58	17	20

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	4.50	4.18	4.52	1.25	0.20
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Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	SW36 - R3	C1 - R1	C1 - R2	C1 - R3	----
Client sampling date / time					12-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	----
Compound	CAS Number	LOR	Unit		EB1809356-051	EB1809356-052	EB1809356-053	EB1809356-054	-----
					Result	Result	Result	Result	----
EA038 / EG005: Acid Volatile Sulphides & Simultaneously Extracted Metals									
Acid Volatile Sulphides (mmol/kg)	----	0.3	mmol/kg		0.9	0.9	2.6	2.8	----
EA038 / EG005: Simultaneously Extracted Metals									
Aluminium	7429-90-5	50	mg/kg		280	1240	1010	1110	----
Arsenic	7440-38-2	1.0	mg/kg		<1.0	<1.0	<1.0	<1.0	----
Cadmium	7440-43-9	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	----
Cobalt	7440-48-4	0.5	mg/kg		3.4	5.3	3.5	3.6	----
Chromium	7440-47-3	1.0	mg/kg		1.5	1.0	<1.0	<1.0	----
Copper	7440-50-8	1.0	mg/kg		1.4	3.4	3.3	2.9	----
Iron	7439-89-6	50	mg/kg		2010	3790	3280	3110	----
Lead	7439-92-1	1.0	mg/kg		1.9	1.3	1.1	1.0	----
Manganese	7439-96-5	10	mg/kg		122	116	91	91	----
Nickel	7440-02-0	1.0	mg/kg		1.9	3.0	3.0	2.9	----
Vanadium	7440-62-2	2.0	mg/kg		4.9	10.6	7.6	7.5	----
Zinc	7440-66-6	1.0	mg/kg		5.7	10.4	12.9	11.0	----
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	1.0	%		18.4	23.7	39.1	34.7	----
EA150: Particle Sizing									
+75µm	----	1	%		92	74	81	79	----
+150µm	----	1	%		92	66	78	73	----
+300µm	----	1	%		90	54	61	56	----
+425µm	----	1	%		88	49	49	50	----
+600µm	----	1	%		80	44	41	45	----
+1180µm	----	1	%		41	30	28	36	----
+2.36mm	----	1	%		14	16	15	28	----
+4.75mm	----	1	%		5	9	9	21	----
+9.5mm	----	1	%		<1	4	5	8	----
+19.0mm	----	1	%		<1	<1	<1	<1	----
+37.5mm	----	1	%		<1	<1	<1	<1	----
+75.0mm	----	1	%		<1	<1	<1	<1	----
EA150: Soil Classification based on Particle Size									
Fines (<75 µm)	----	1	%		8	26	19	21	----
Sand (>75 µm)	----	1	%		70	53	62	48	----
Gravel (>2mm)	----	1	%		22	21	19	31	----
Cobbles (>6cm)	----	1	%		<1	<1	<1	<1	----



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				SW36 - R3	C1 - R1	C1 - R2	C1 - R3	----
Client sampling date / time				12-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	13-Apr-2018 00:00	----
Compound	CAS Number	LOR	Unit	EB1809356-051	EB1809356-052	EB1809356-053	EB1809356-054	-----
				Result	Result	Result	Result	----

EG005-SDH: 1M HCl-Extractable Metals by ICPAES

Aluminium	7429-90-5	50	mg/kg	330	2100	1420	2000	----
Arsenic	7440-38-2	1.0	mg/kg	<1.0	<1.0	<1.0	<1.0	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----
Cobalt	7440-48-4	0.5	mg/kg	2.2	6.9	3.5	4.8	----
Chromium	7440-47-3	1.0	mg/kg	2.6	1.4	1.0	1.6	----
Copper	7440-50-8	1.0	mg/kg	1.2	4.8	3.0	3.4	----
Iron	7439-89-6	50	mg/kg	2290	5670	3310	4120	----
Lead	7439-92-1	1.0	mg/kg	2.2	1.7	1.2	1.2	----
Manganese	7439-96-5	10	mg/kg	101	140	68	88	----
Nickel	7440-02-0	1.0	mg/kg	1.6	4.4	2.8	3.8	----
Vanadium	7440-62-2	2.0	mg/kg	5.3	13.3	6.5	8.2	----
Zinc	7440-66-6	1.0	mg/kg	5.6	13.5	10.6	13.3	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	----
Molybdenum	7439-98-7	5	mg/kg	<5	<5	<5	<5	----

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	3740	8260	7330	6820	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	----
Cobalt	7440-48-4	2	mg/kg	7	11	9	9	----
Iron	7439-89-6	50	mg/kg	15000	28100	23100	20600	----
Manganese	7439-96-5	5	mg/kg	149	212	171	156	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	----
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	----
Vanadium	7440-62-2	5	mg/kg	45	43	34	33	----
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	----
Chromium	7440-47-3	2	mg/kg	18	14	12	12	----
Copper	7440-50-8	5	mg/kg	7	9	9	8	----
Lead	7439-92-1	5	mg/kg	6	<5	<5	<5	----
Nickel	7440-02-0	2	mg/kg	9	12	10	10	----
Zinc	7440-66-6	5	mg/kg	19	49	46	40	----

EG035T: Total Recoverable Mercury by FIMS

Mercury	7439-97-6	0.1	mg/kg	0.1	0.1	0.2	<0.1	----
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EP003: Total Organic Carbon (TOC) in Soil

Total Organic Carbon	----	0.02	%	0.46	1.18	6.20	8.31	----
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Attachment C Historical Water Quality Graphs



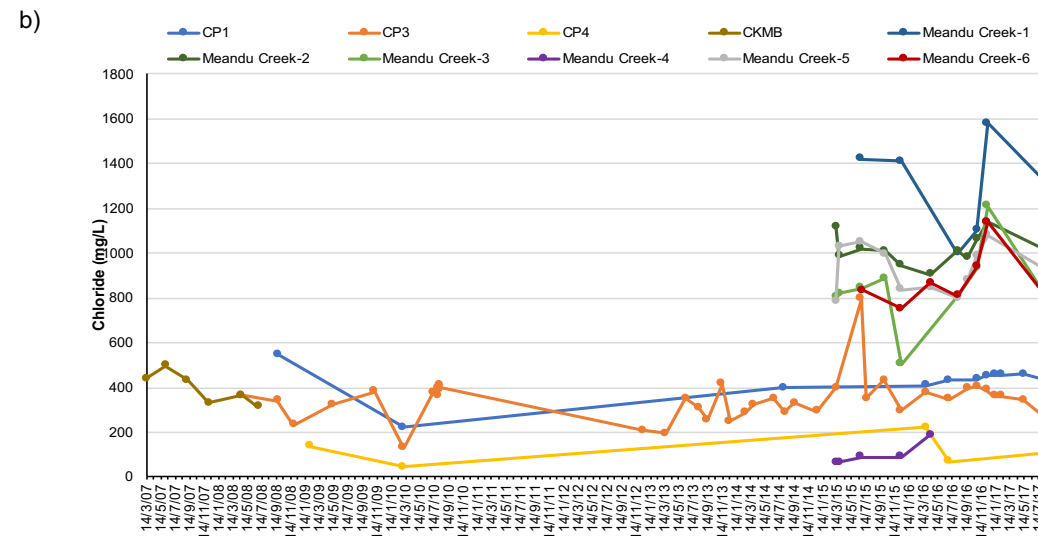
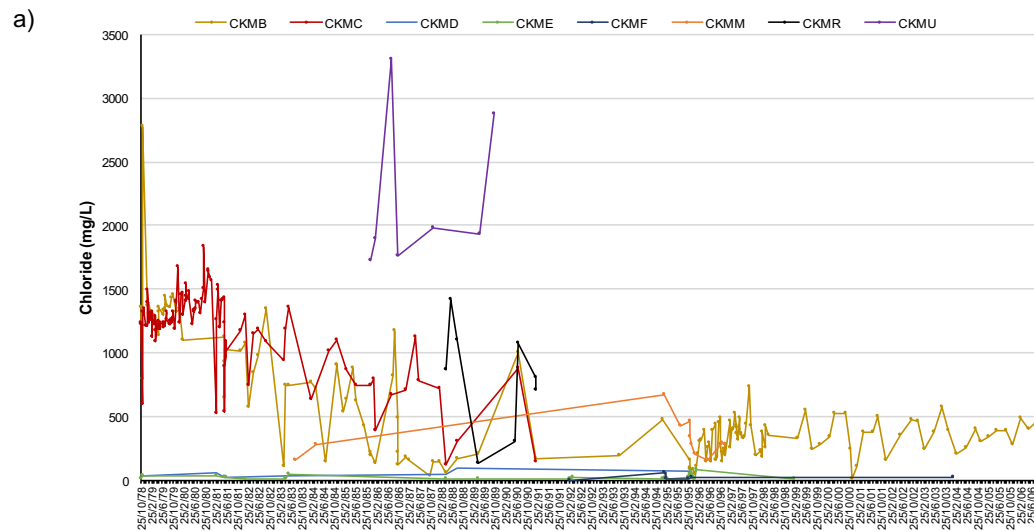


Figure C.1 Chloride concentrations in water at sites on Meandu Creek from a) 1984 to 2006 and b) 2007 to 2017

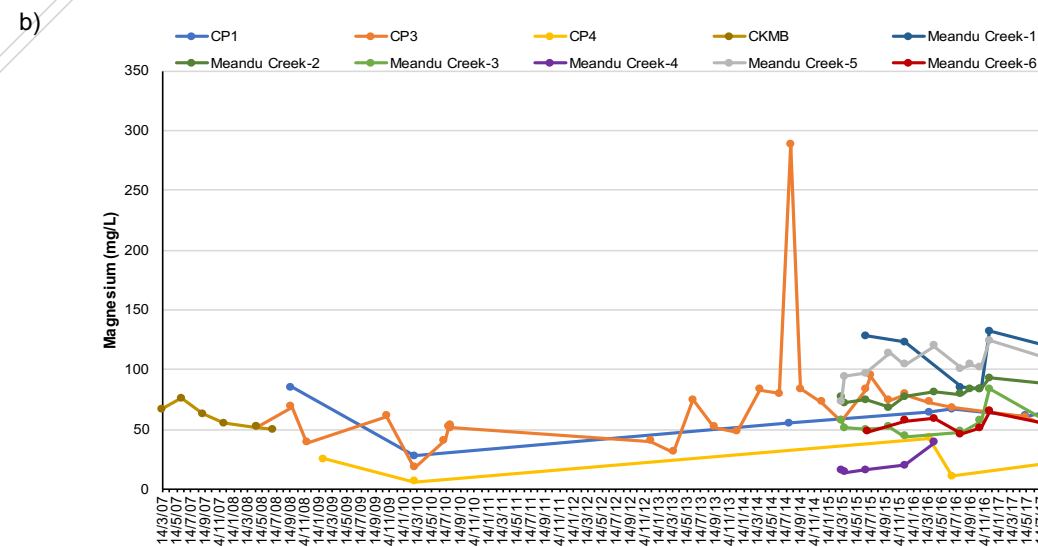
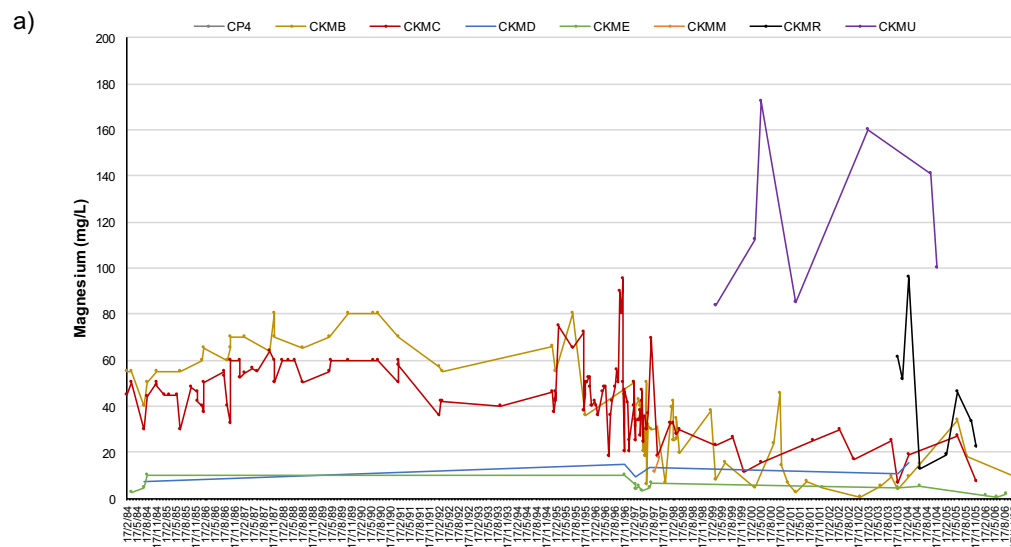


Figure C.2 Magnesium concentrations in water at sites on Meandu Creek from a) 1984 to 2006 and b) 2007 to 2017



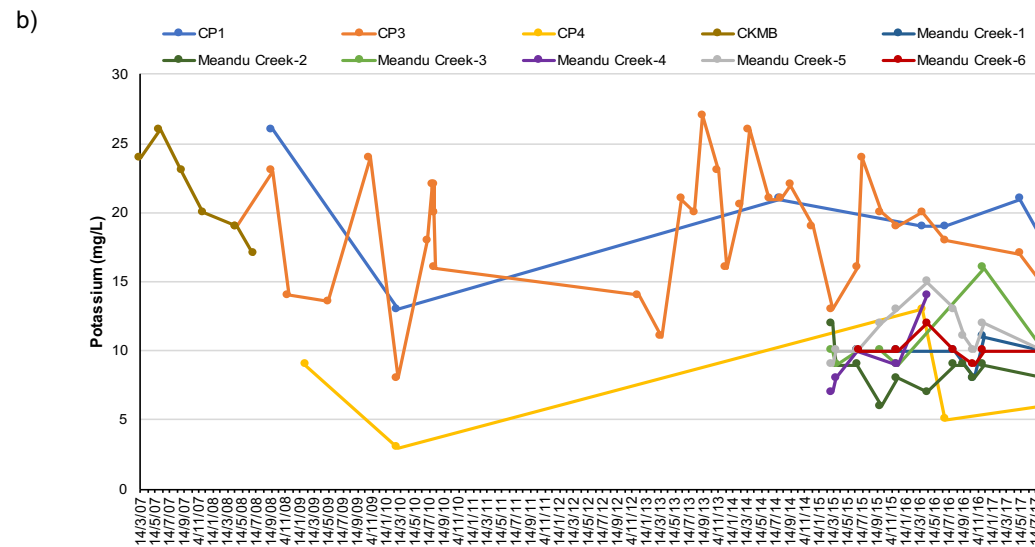
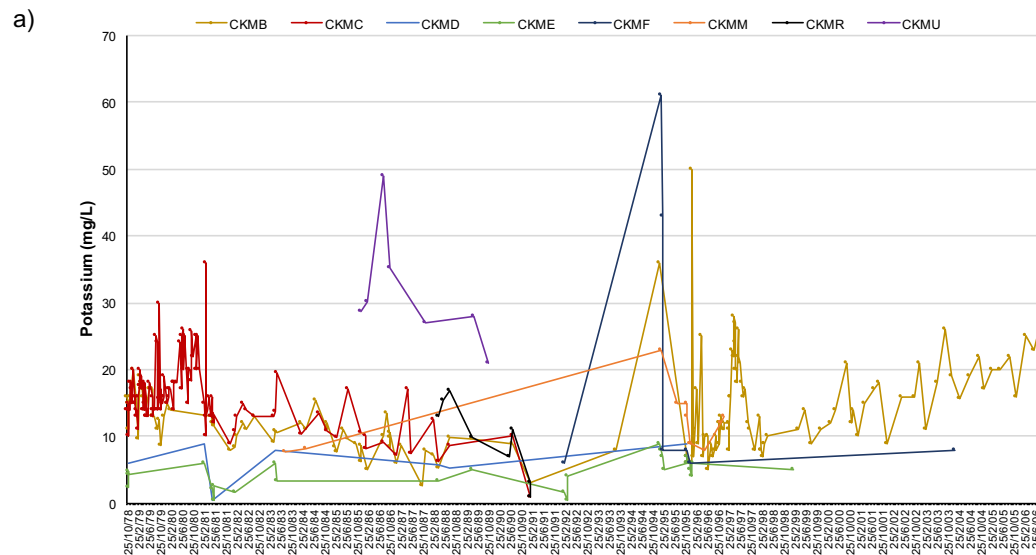


Figure C.3 Potassium concentrations in water at sites on Meandu Creek from a) 1984 to 2006 and b) 2007 to 2017

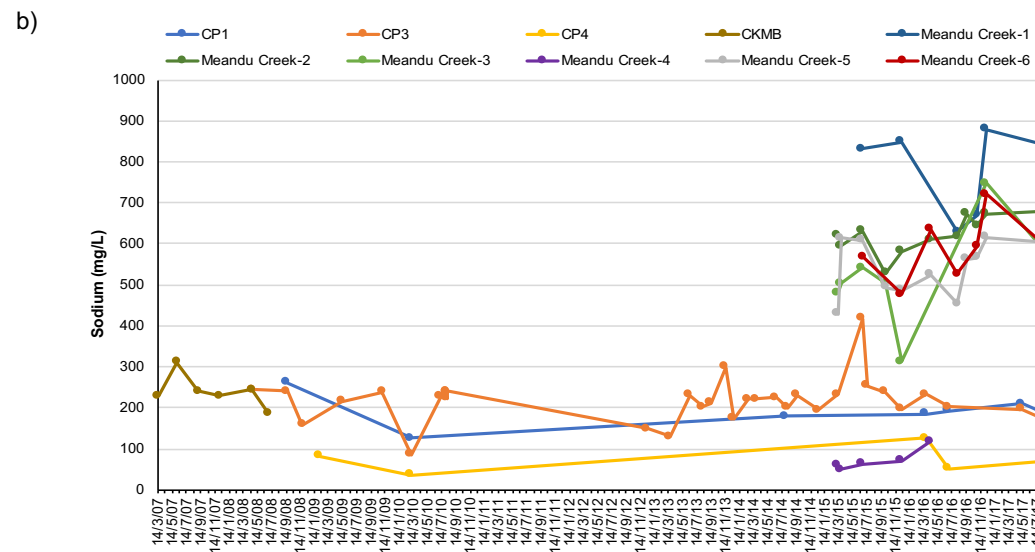
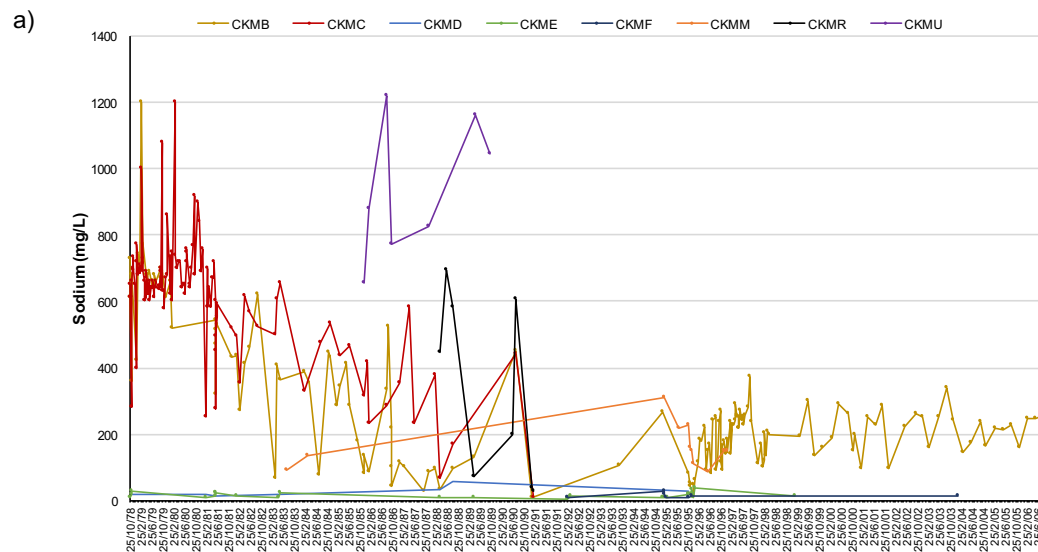


Figure 13.4 Sodium concentrations in water at sites on Meandu Creek from a) 1984 to 2006 and b) 2007 to 2017



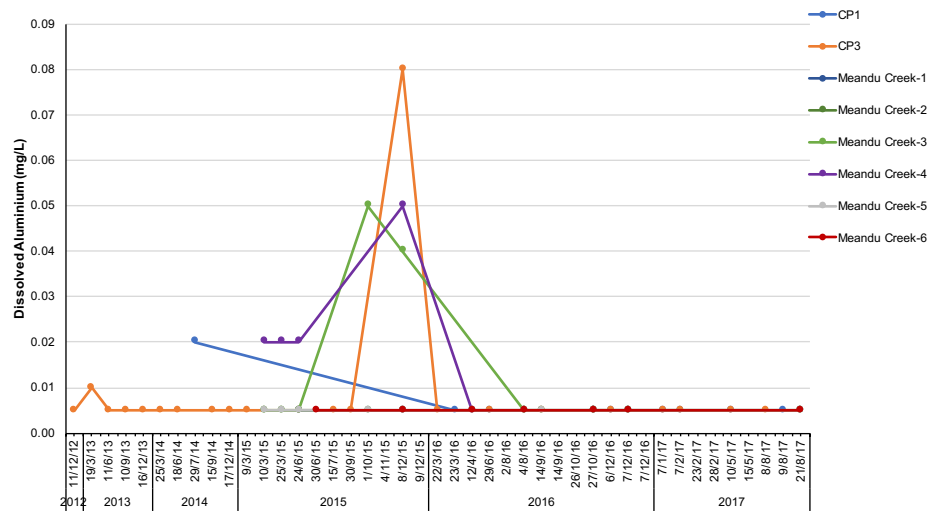


Figure C13.5 Dissolved aluminium concentrations in water at sites on Meandu Creek from 2007 to 2017

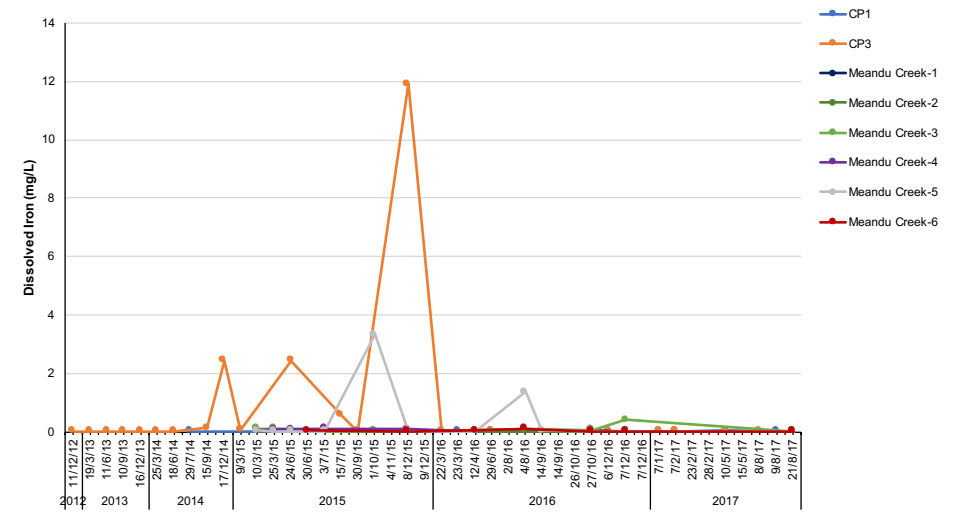


Figure C.6 Dissolved iron concentrations in water at sites on Meandu Creek from 2007 to 2017

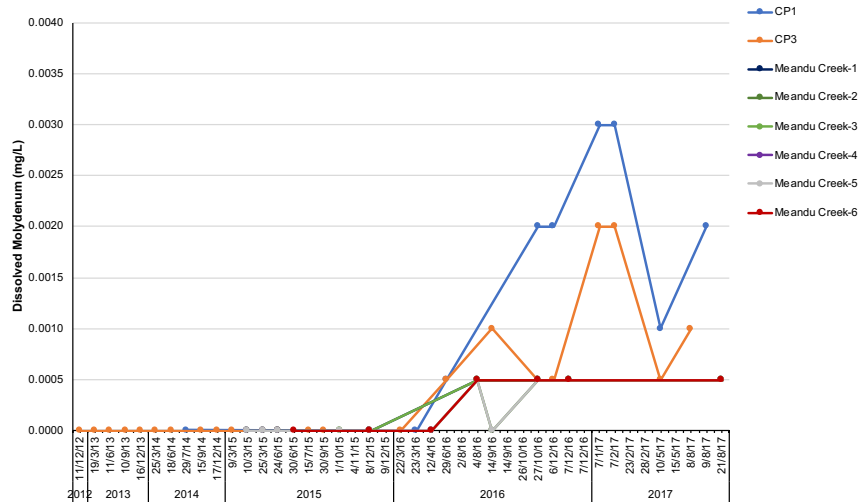


Figure C.7 Dissolved molybdenum concentrations in water at sites on Meandu Creek from 2007 to 2017



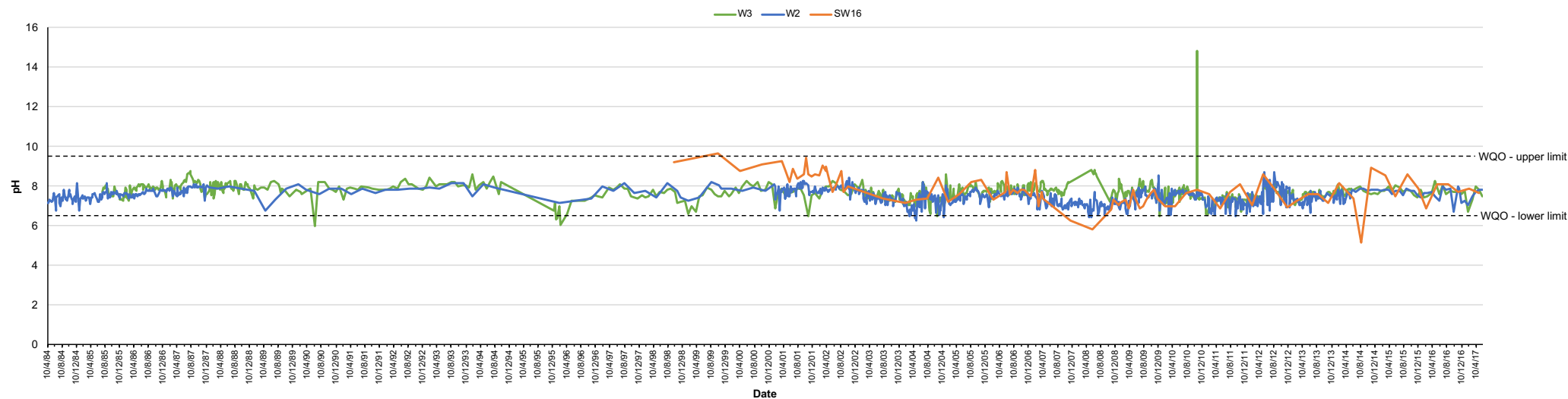


Figure C.8 pH of water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017

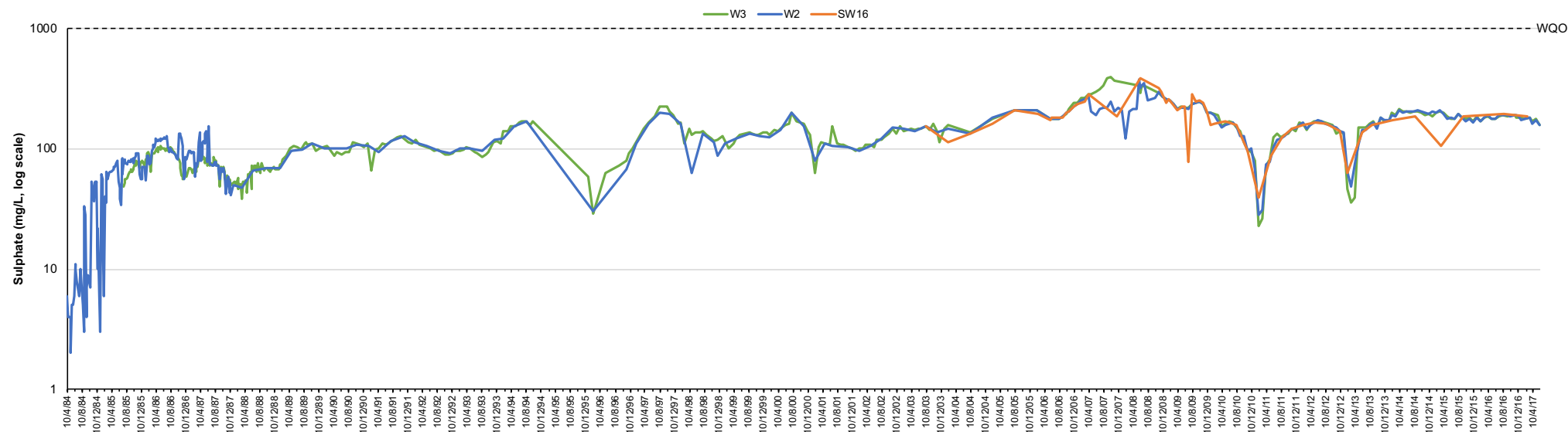


Figure C.9 Sulphate in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017



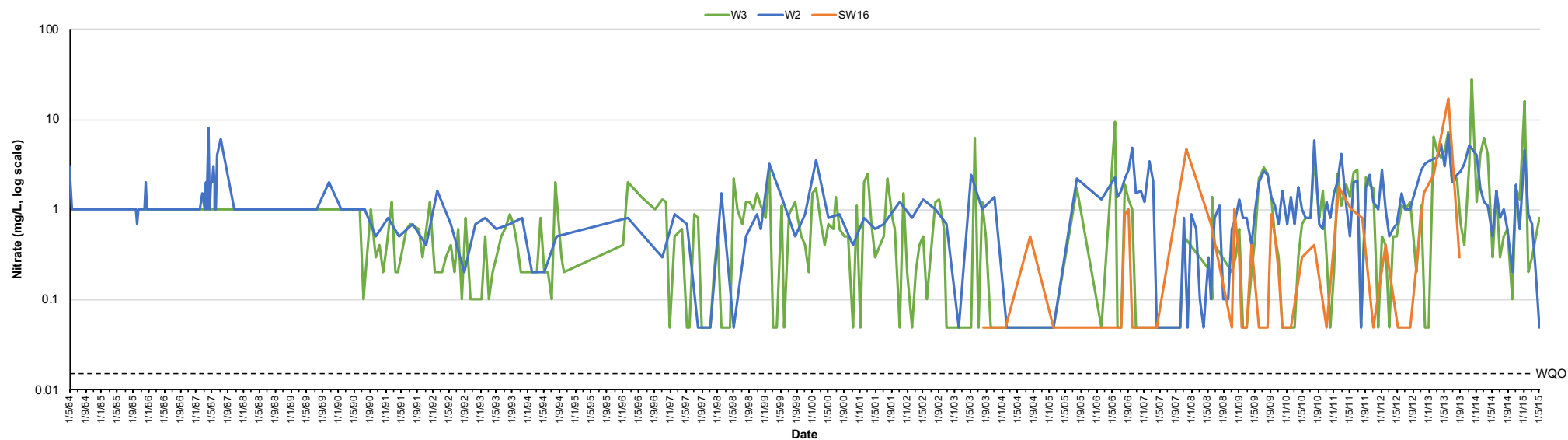


Figure C.10 Nitrate in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017

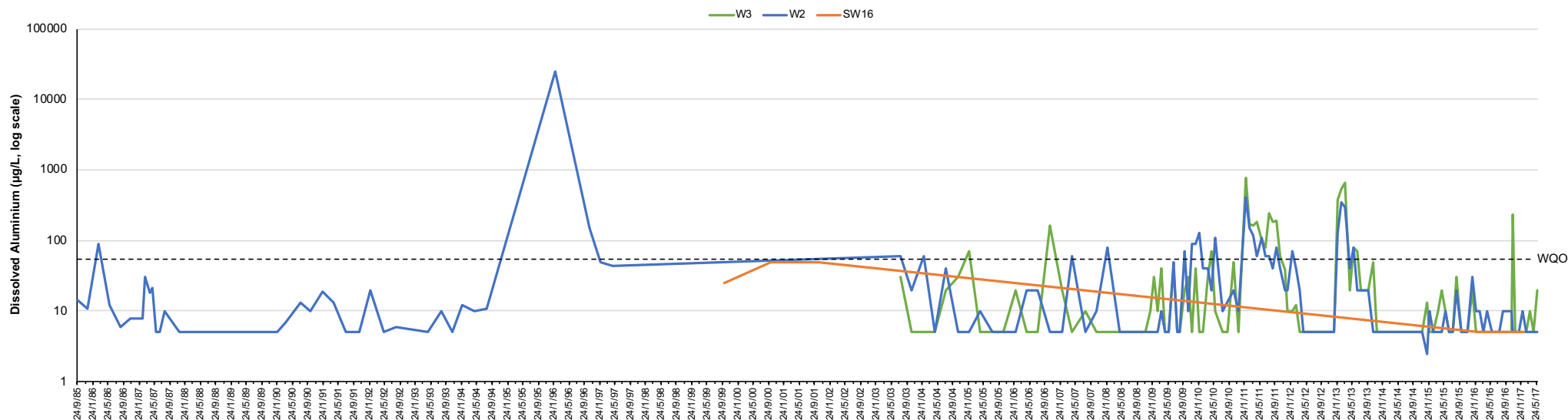


Figure C.11 Dissolved aluminium in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017



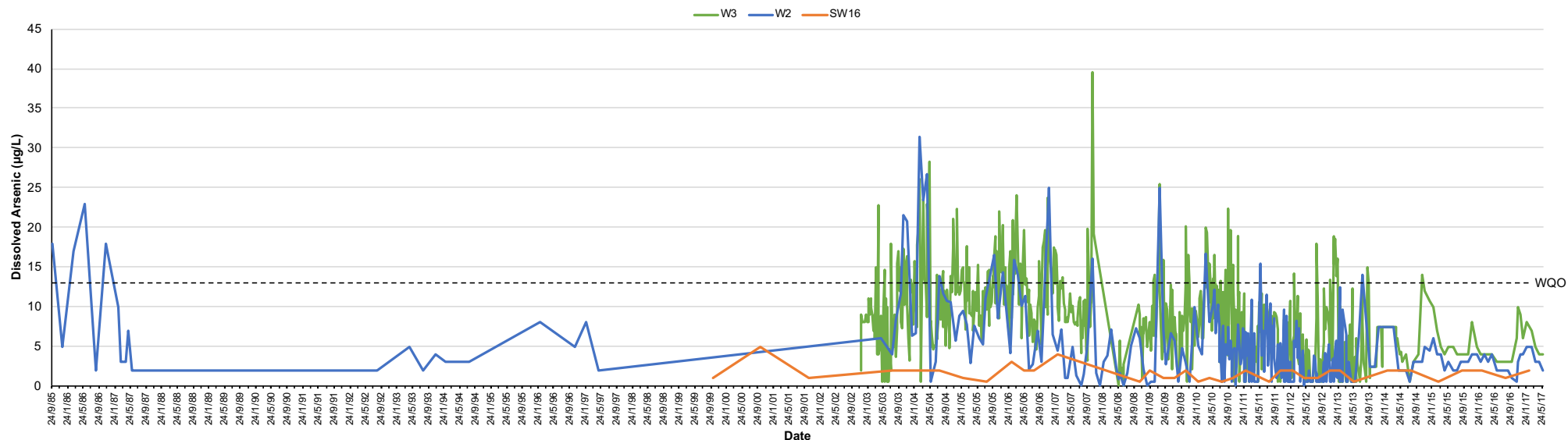


Figure C.12 Dissolved arsenic in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017

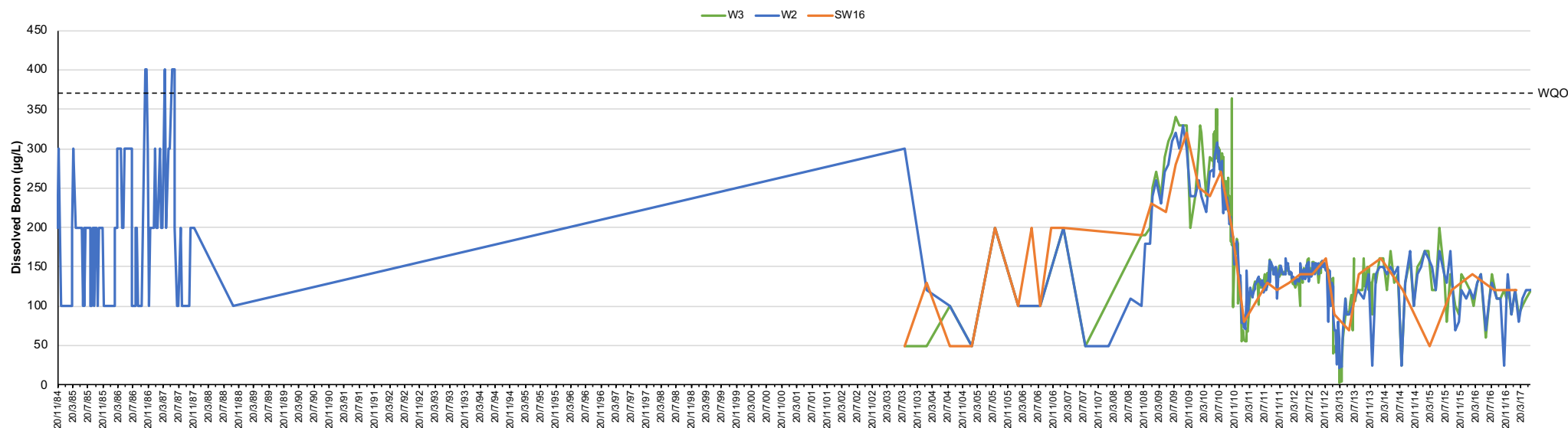


Figure C.13 Dissolved boron in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017



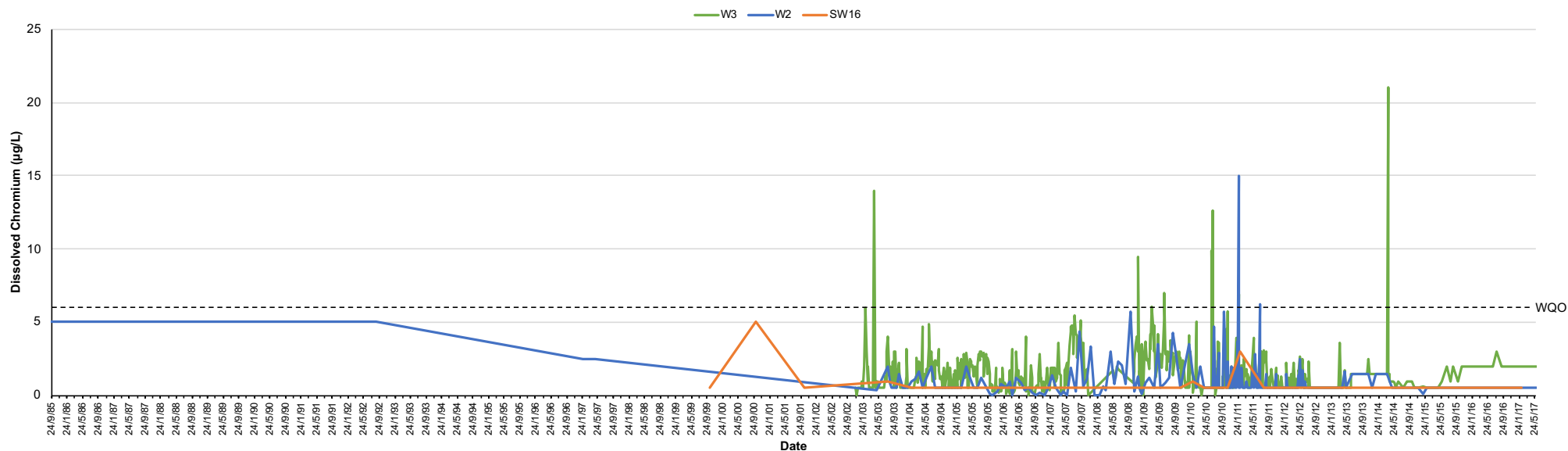


Figure C.14 Dissolved chromium in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017

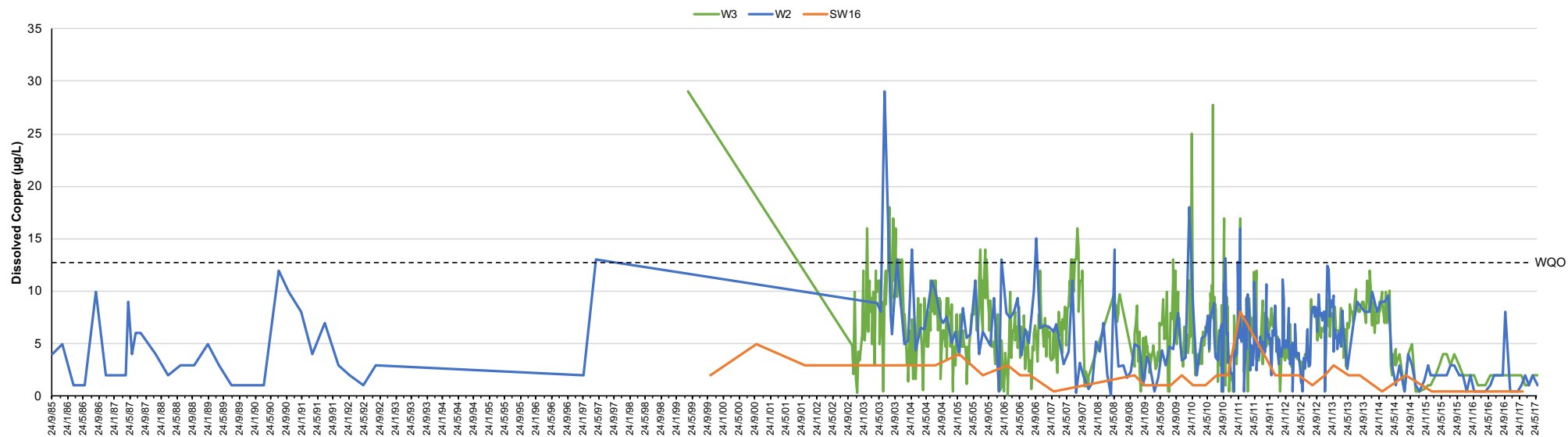


Figure C.15 Dissolved copper in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017



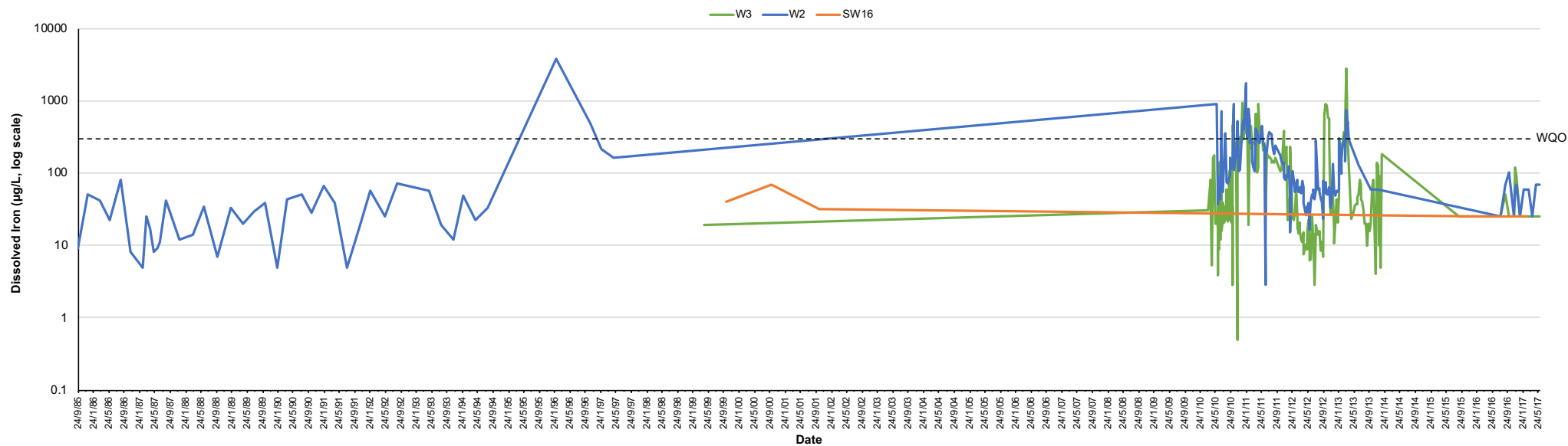


Figure C.16 Dissolved iron in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017

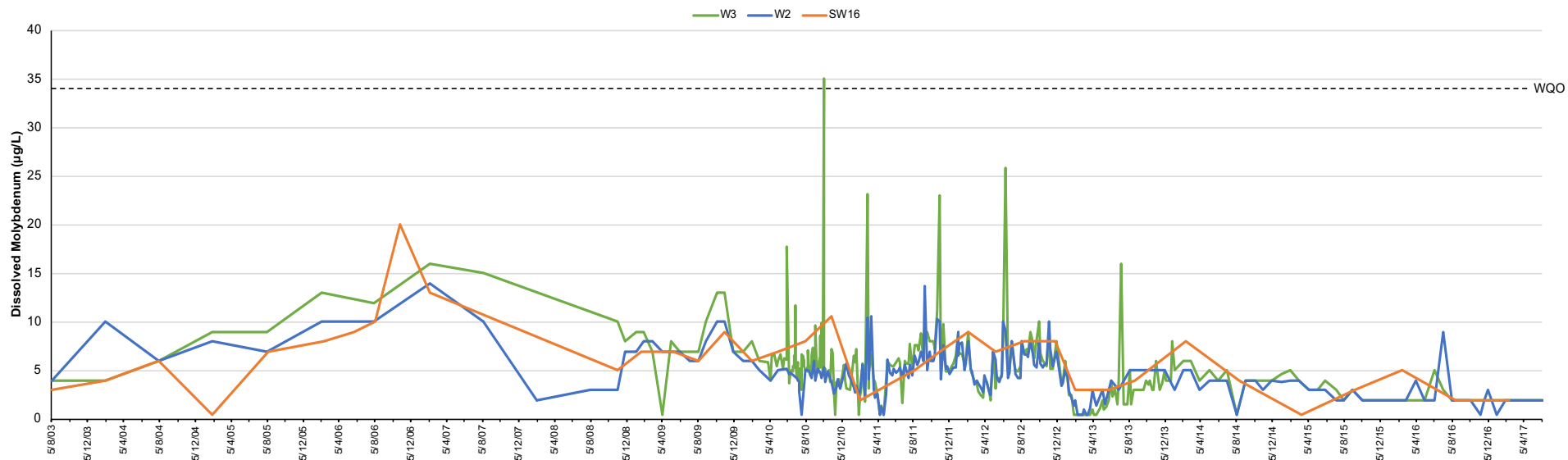


Figure C.17 Dissolved molybdenum in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017





Figure C.18 Dissolved nickel in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017

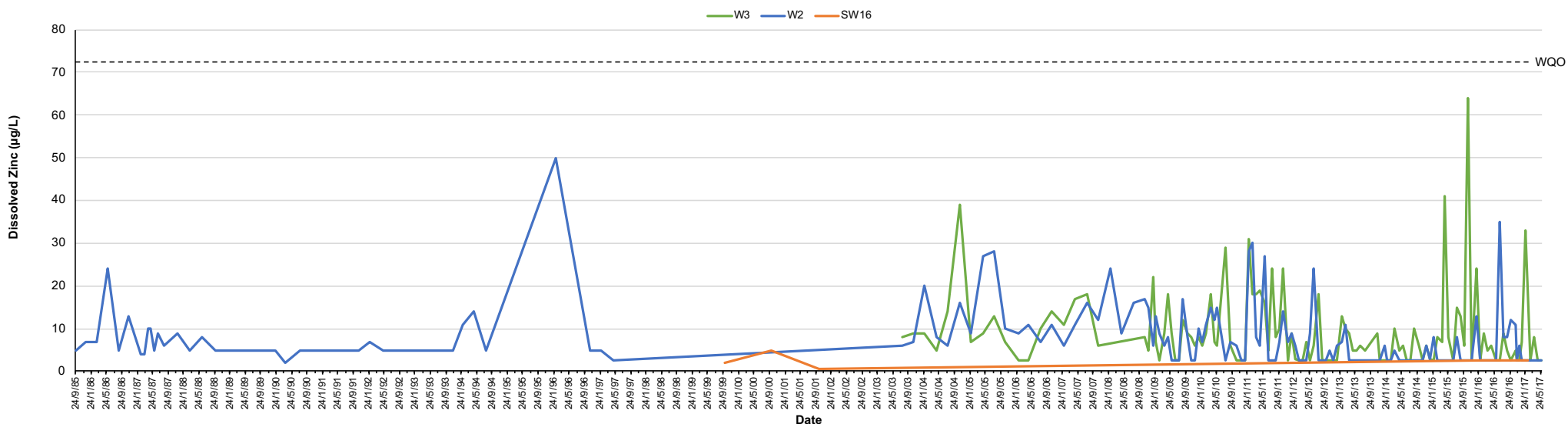


Figure C.19 Dissolved zinc in water at sites on Meandu Creek Dam (W3) and on Meandu Creek downstream of Meandu Creek Dam (W2 and SW16) from 1984–2017



Attachment D Sediment Quality Graphs: April 2018



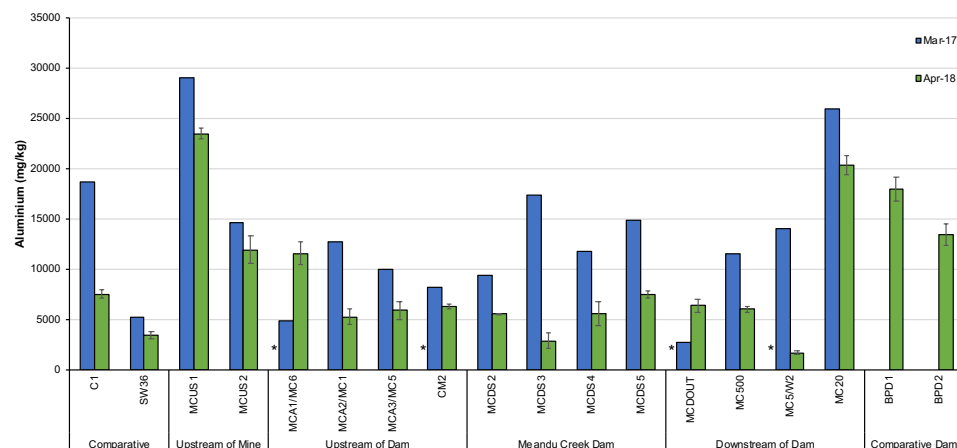


Figure D.1 Total aluminium concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)

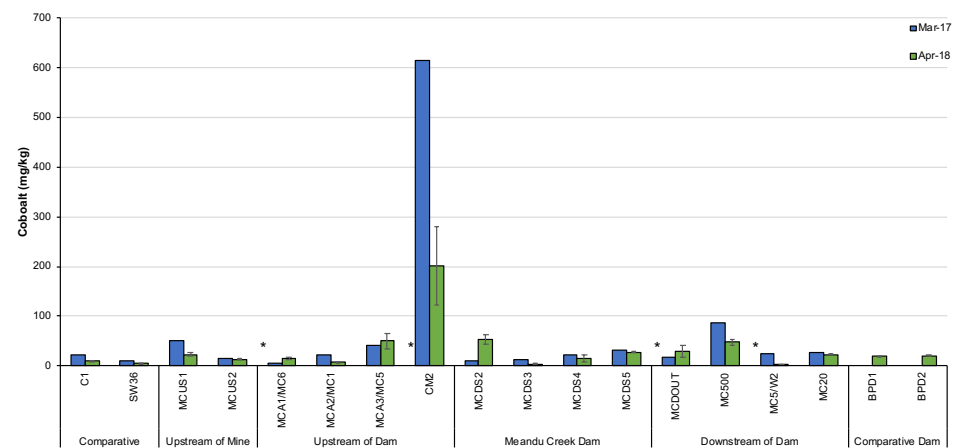


Figure D.2 Total cobalt concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)

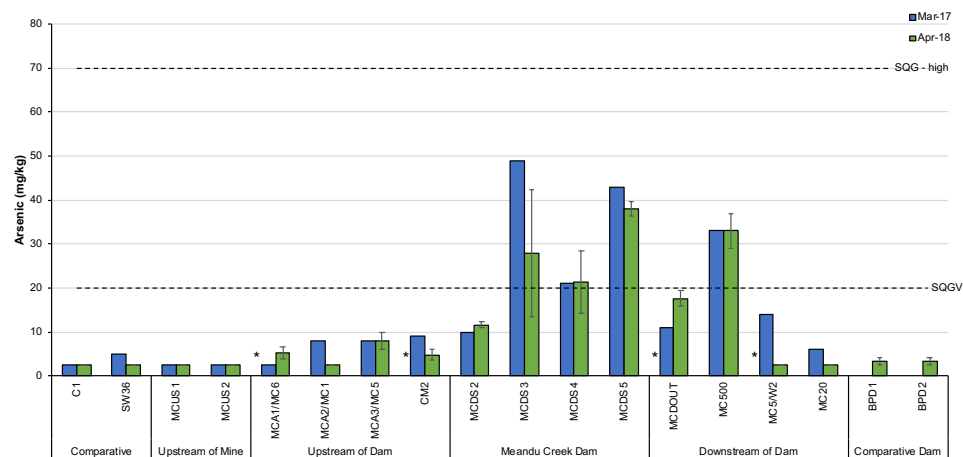


Figure D.3 Total arsenic concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)

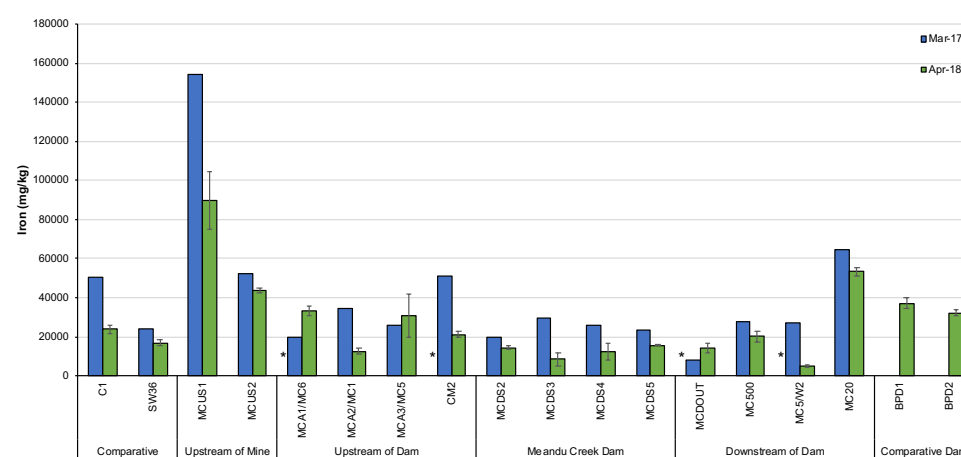


Figure D.4 Total iron concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)



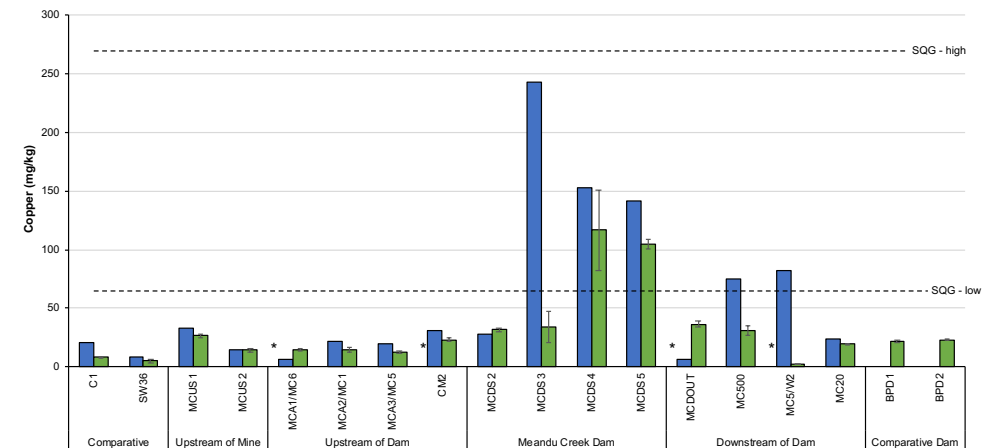
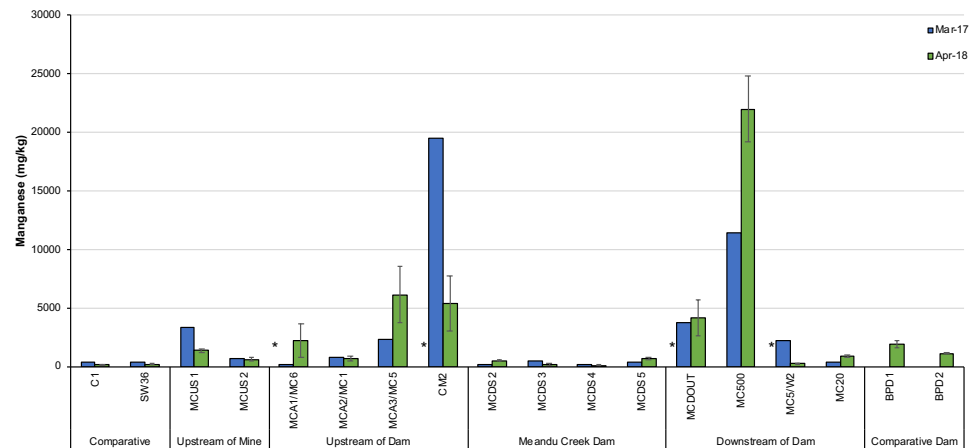


Figure D.5 Total manganese concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)

Figure D.6 Total copper concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)

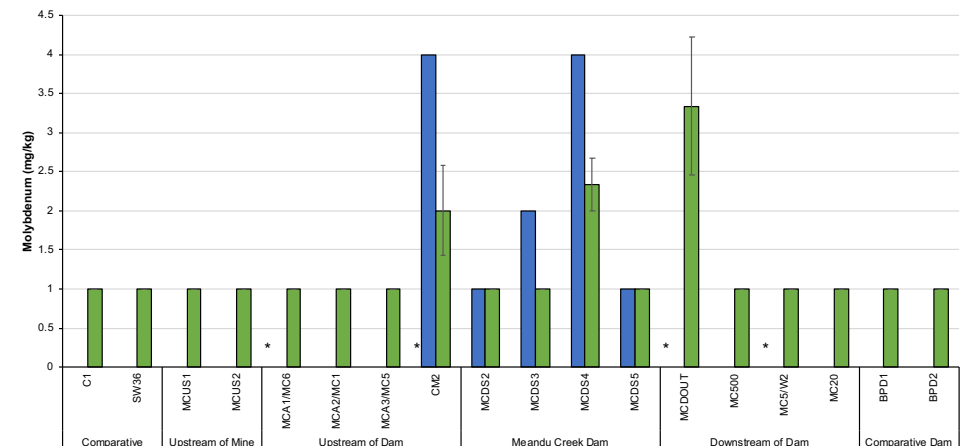
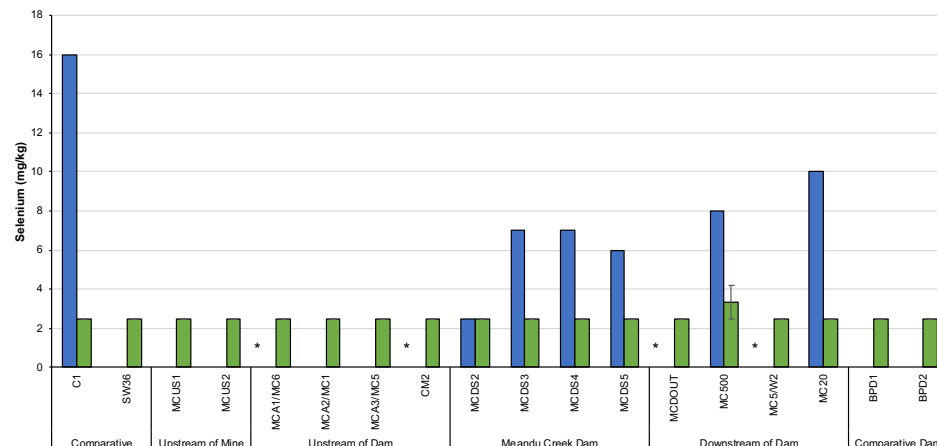


Figure D.7 Total selenium concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)

Figure D.8 Total molybdenum concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)



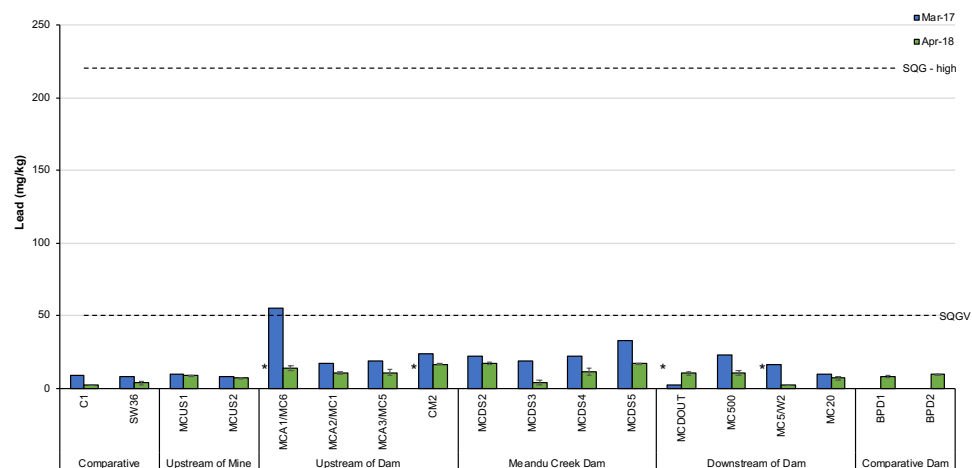


Figure D.9 Total lead concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)

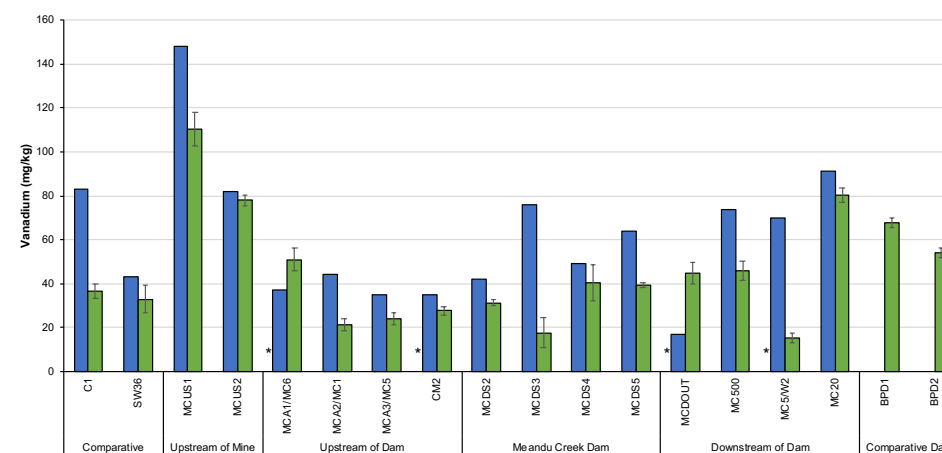


Figure D.10 Total vanadium concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)



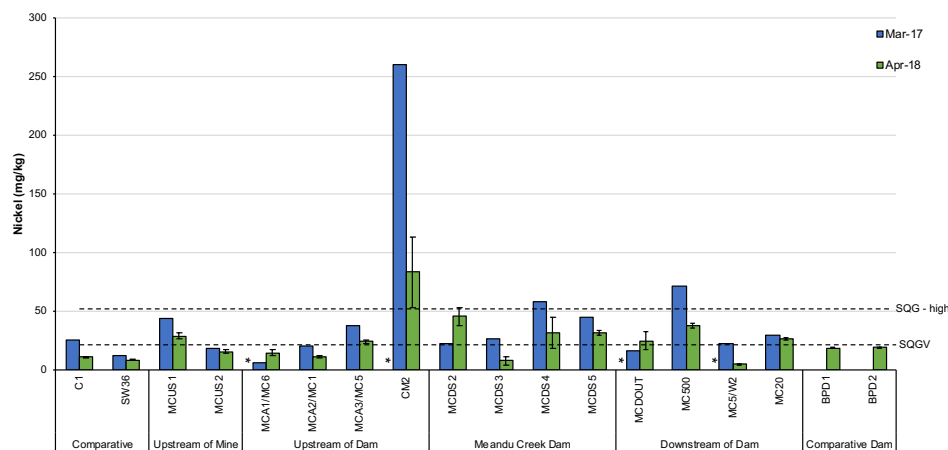


Figure D.11 Total nickel concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)

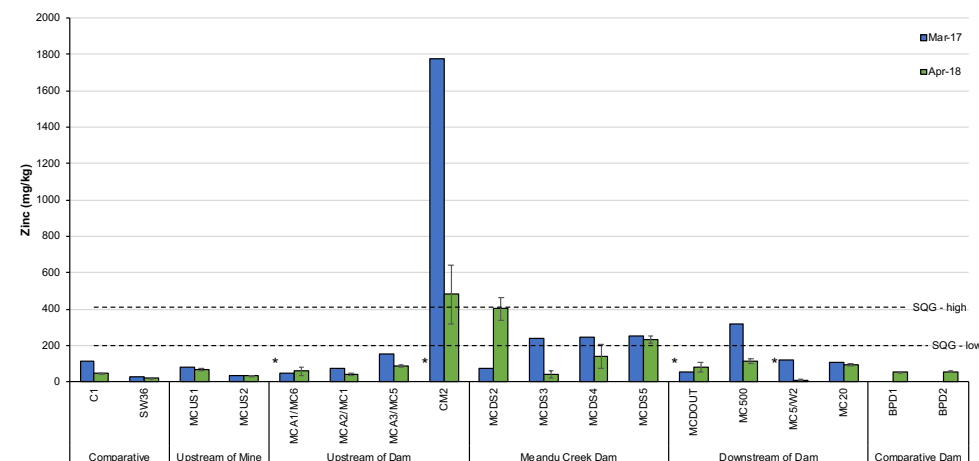


Figure D.12 Total zinc concentrations in sediment at sites on Meandu Creek in March 2017 and April 2018 ($\pm$ standard error)



Attachment E Aquatic Habitat Site Tables



Table E1 Aquatic habitat descriptions from each site during the field survey

Aquatic Habitat Description			
C1			
Upstream:	Downstream:	Left Bank:	Right Bank:
			
Site C1 was located on Barker Creek upstream of the Barker Creek and Meandu Creek confluence. This site consisted of a wide, deep pool (approximately 15 m wide and 1.2 m deep) that was not flowing and disconnected from waterways upstream and downstream.			
Riparian condition: poor	In-stream condition: fair	Substrate:	External impacts: high
Riparian vegetation consisted of a zone of vegetation approximately 5 m wide on the left bank and 4 m wide on the right bank with some mature trees providing shading but mostly grasses providing the majority of ground cover. Adjacent land was cleared and utilised for cropping and grazing. Banks were high and steep with areas of erosion.	The in-stream aquatic habitat condition was fair. The site was an isolated pool, significantly impacted by the surrounding land use activities but the following key habitat features were present, providing structural complexity and shelter for aquatic fauna: • overhanging vegetation • trailing bank vegetation • in-stream aquatic plants, and • woody debris. A significant amount of filamentous algae was present.	Substrate composition was predominately silt overlaying gravel, pebble and cobble substrate with some sand also present. An anoxic odour was apparent in the substrate.	The most apparent impact at the site was the surrounding land clearing that has significantly altered the landscape and caused a reduction in the presence and continuity of riparian vegetation. Stock access impacts were also evident at the site. Lack of connectivity to upstream and downstream reaches was another apparent impact but this is mostly due to the nature of the waterway (i.e. Barker Creek is an ephemeral waterway).



Aquatic Habitat Description

C1B

Upstream:



Downstream:



Left bank:



Right bank:



Site C1B was located on Barker Creek upstream of the Barker Creek and Meandu Creek confluence. This site consisted of a wide, deep pool (approximately 15 m wide and 1 m deep) that was not flowing and disconnected from waterways upstream and downstream.

Riparian condition: poor

Riparian vegetation consisted of a zone of vegetation approximately 5 m wide on the left bank and 7 m wide on the right bank with some mature trees providing shading but mostly grasses providing the majority of ground cover. Adjacent land was cleared and utilised for cropping and grazing. Banks were high and steep with areas of erosion.

In-stream condition: fair

The in-stream aquatic habitat condition was fair. The site was an isolated pool, significantly impacted by the surrounding land use activities but the following key habitat features were present, providing structural complexity and shelter for aquatic fauna:

- trailing bank vegetation
- in-stream aquatic plants, and
- woody debris.

Some filamentous algae was present and a significant amount of floating vegetation was present.

Substrate:

Substrate composition was a mixture of sand, gravel, pebble and cobble substrate with blanketing silt

An anoxic odour was apparent in the substrate.

External impacts: high

The most apparent impact at the site was the surrounding land clearing that has significantly altered the landscape and caused a reduction in the presence and continuity of riparian vegetation.

Stock access impacts were also evident at the site.

Lack of connectivity to upstream and downstream reaches was another apparent impact but this is mostly due to the nature of the waterway (i.e. Barker Creek is an ephemeral waterway).



Aquatic Habitat Description

C2 / SW19

Upstream:



Downstream (with road crossing):



Left bank:



Exotic weed (scotch thistle):



Site C2/SW19 was located on Barker Creek upstream of the Barker Creek and Meandu Creek confluence. This site consisted of a dry channel approximately 8 m wide and disconnected from waterways upstream and downstream. A road crossed over the waterway in the middle of the site.

Riparian condition: fair

Riparian vegetation consisted of a zone of vegetation approximately 3 m wide on both banks with mature trees and grasses providing shading and ground cover. Exotic weeds were also prevalent in the ground cover. Adjacent land had been cleared and was being utilised for cropping. Banks were high and steep.

In-stream condition: N/A

Dry site; unlikely to hold water for long periods after rainfall.

Substrate:

Substrate composition was predominantly sand, gravel, pebble and cobble with finer silt / clay also present.

External impacts: low

The most apparent impact at the site was the adjacent land clearing, which has caused a reduction in the presence and continuity of riparian vegetation and the subsequent shading and protection it would normally provide.

The abundance of exotic weeds (namely the scotch thistle) was another apparent impact.



Aquatic Habitat Description

C3

Upstream:



Downstream:



Left bank:



Right bank:



Site C3 was located on Barker Creek upstream of the Barker Creek and Meandu Creek confluence. This site consisted of a dry channel approximately 12 m wide and disconnected from waterways upstream and downstream.

Riparian condition: good

Riparian vegetation consisted of a zone of vegetation approximately 3 m wide on the left bank and 4 m wide on the right with mature trees and grasses providing shading and ground cover. Exotic weeds were also prevalent in the ground cover. Adjacent land had been cleared and was being utilised for cropping. Banks were high and steep.

In-stream condition: N/A

Dry site; unlikely to hold water for long periods after rainfall.

Substrate:

Substrate composition was predominantly sand, gravel, pebble and cobble with finer silt / clay also present.

External impacts: low

The most apparent impact at the site was the adjacent land clearing, which has caused a reduction in the presence and continuity of riparian vegetation and the subsequent shading and protection it would normally provide.

The abundance of exotic weeds (namely the scotch thistle) was another apparent impact.



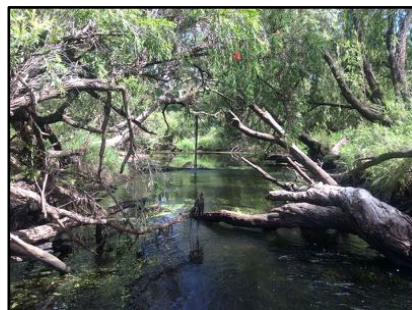
Aquatic Habitat Description

SW36

Upstream:



Downstream:



In-stream habitat (woody debris):



Bare Riparian Zone:



Site SW36 was located on Barambah Creek downstream of Bjelke-Petersen Dam. This site consisted of a large, connected pool approximately 8 m wide with slow to moderate flow (average 0.2 m/s). An old road bridge crossed over the waterway through the middle of the site. The site was well connected to waterways further upstream and downstream.

Riparian condition: fair

Riparian vegetation consisted of a zone of vegetation approximately 5 m wide on both banks with mature trees and grass providing shading and ground cover. Adjacent land-use consisted of an old road corridor and cleared land for grazing and crops. Banks were high and gently sloping with some erosion but mostly stable.

In-stream condition: excellent

The in-stream aquatic habitat condition was excellent with the following key habitat features present, providing structural complexity and shelter for aquatic fauna:

- overhanging vegetation
- trailing bank vegetation
- undercut banks
- in-stream aquatic plants
- a variety of flow regimes (shallow pools, deep pools, runs and riffles)
- a variety of channel sinuosity (straight, bends and bars), and
- woody debris.

A little filamentous algae was present.

Substrate:

Substrate composition was a mixture of pebble, gravel and sand.

External impacts: low

The most apparent impact at the site was the old road bridge crossing over the site and the adjacent vehicle track, which has caused some disturbance to the riparian vegetation continuity and changes to the natural flow regime. There was also evidence of recreation camping on the left bank.



Aquatic Habitat Description

MCUS1

Upstream:



Downstream:



Left bank:



Right bank:



Site MCUS1 was located on Meandu Creek upstream of Meandu Mine and the Tarong power stations. This site consisted of a dry undefined channel disconnected from waterways upstream and downstream.

Riparian condition: excellent

In-stream condition: N/A

Substrate:

External impacts: low

Riparian vegetation consisted of a zone of vegetation approximately 15 m wide on both banks with mature trees and grasses providing shading and ground cover. Adjacent land was intact native forest (Yarraman State Forest Reserve). Banks were low and poorly defined within the landscape.

Dry site; unlikely to hold water after rainfall.

Substrate composition was predominantly sand with some gravel and finer silty / clay; there was little difference between the substrate within the channel and adjacent land.

The most apparent impact at the site was human access in the State Forest, which is utilised for four wheel driving and camping.



Aquatic Habitat Description

MCUS2

Upstream:



Downstream:



Left bank (vehicle track):



Right bank (vehicle track):



Site MCUS2 was located on Meandu Creek upstream of Meandu Mine and the Tarong power stations. This site consisted of a dry channel disconnected from waterways upstream and downstream.

Riparian condition: excellent

In-stream condition: N/A

Substrate:

External impacts: low

Riparian vegetation consisted of a zone of vegetation approximately 15 m wide on both banks with mature trees and grasses providing shading and ground cover. Adjacent land was intact native forest (Yarraman State Forest Reserve). Banks were low and steep.

Dry site; unlikely to hold water after rainfall.

Substrate composition was predominantly sand with some gravel and finer silty / clay; there was little difference between the substrate within the channel and adjacent land.

The most apparent impact at the site was human access in the State Forest, which is utilised for four-wheel driving and camping.



Aquatic Habitat Description

MCA1 / MC6

Upstream:



Downstream:



Left Bank:



Right Bank:



Site MCA1/MC6 was located on a diverted section of Meandu Creek upstream of Meandu Creek Dam and the main Meandu Mine discharge point (RD2) and the Tarong power stations. This site consisted of a wide, deep pool (approximately 5 m wide and 1.4 m deep) that was not flowing and disconnected from waterways upstream and downstream.

Riparian condition: poor

Riparian vegetation consisted of a zone of vegetation approximately 8 m wide on the left bank and 3 m wide on the right bank with some mature trees providing shading but mostly grasses providing the majority of ground cover. Adjacent land was within the Meandu Mine lease. Land adjacent to the right bank is utilised for one of the Mine's retention dams (RD10), which (through underground leeching) is potentially the main source of the water at the site. Land adjacent to the left bank is utilised as a vehicle track corridor but is mostly intact native forest. Banks were high and steep.

In-stream condition: fair

The in-stream aquatic habitat condition was fair. The site was an isolated pool, significantly impacted by the surrounding industrial activities but the following key habitat features were present, providing structural complexity and shelter for aquatic fauna:

- overhanging vegetation
- trailing bank vegetation
- in-stream aquatic plants, and
- woody debris.

No filamentous algae was present.

Substrate:

Substrate composition was predominately sand and gravel with blanketing silt.

An anoxic odour was apparent in the substrate.

External impacts: high

The most apparent impact at the site was the surrounding industrial activity that has significantly altered the landscape and is likely the main source of water at the site. The site is also regularly pumped when water levels are high.

Lack of connectivity to upstream and downstream reaches was another apparent impact but this is mostly due to the natural nature of the waterway.



Aquatic Habitat Description

MCA2 / MC1

Upstream:



Downstream:



Left Bank:



Right Bank:



Site MCA2/MC1 was located on a natural (un-diverted) section of Meandu Creek upstream of Meandu Creek Dam and of the main Meandu Mine discharge point (RD2) and the Tarong power stations. This site consisted of a narrow, pool (approximately 2 m wide and 1 m deep) that was not flowing and disconnected from waterways upstream and downstream.

Riparian condition: poor

Riparian vegetation consisted of a zone of vegetation approximately 8 m wide on the left bank and 3 m wide on the right bank with some mature trees providing shading but mostly grasses providing the majority of ground cover. Exotic weed species were also present (lantana and prickly pear). Adjacent land was within the Meandu Mine lease. Land adjacent to the right bank is utilised for the Mine's retention dams (RD9 and RD10). Land adjacent to the left bank is utilised as a vehicle track corridor but is mostly intact native forest. Banks were high and steep.

In-stream condition: fair

The in-stream aquatic habitat condition was fair. The site was an isolated pool, significantly impacted by the surrounding industrial activities and the in stream aquatic habitat was dominated by extreme growth of aquatic plants (predominantly Cumbungi) that were choking the waterway and causing a build-up of sedimentation. No filamentous algae was present.

Substrate:

Substrate composition was predominately sand and gravel with blanketing silt.

An anoxic odour was apparent in the substrate.

External impacts: high

The most apparent impact at the site was the surrounding industrial activity that has significantly altered the landscape and is likely the main source of water at the site. The abundant growth of in stream vegetation was another apparent impact at the site; cumbungi is an invasive weed that can interfere with water flow, increase sediment deposition and reduce water quality. Lack of connectivity was another apparent impact but this is mostly due to the natural nature of the waterway.



Aquatic Habitat Description

MCA3 / MC5

Upstream:



Downstream:



Left Bank:



Right Bank:



Site MCA3/MC5 was located on a diverted section of Meandu Creek upstream of Meandu Creek Dam and of the main Meandu Mine discharge point (RD2) and the Tarong power stations. This site consisted of a wide (6 m) and deep (1.6 m) pool that was not flowing and disconnected from waterways upstream and downstream.

Riparian condition: poor

Riparian vegetation consisted of a zone of vegetation approximately 4 m wide on the left bank and 2 m wide on the right bank with some mature trees providing shading but mostly grasses providing the majority of ground cover. Adjacent land was within the Meandu Mine lease. Land adjacent to the right bank is utilised for two of the Mine's retention dams (RD7 and RD8), which (through underground leaching) are potentially the main source of the water at the site. Land adjacent to the left bank is utilised as a vehicle track corridor but is mostly intact native forest. Banks were moderate and steep.

In-stream condition: fair

The in-stream aquatic habitat condition was fair. The site was an isolated pool, significantly impacted by the surrounding industrial activities but the following key habitat features were present, providing structural complexity and shelter for aquatic fauna:

- overhanging vegetation
- trailing bank vegetation
- in-stream aquatic plants, and
- woody debris.

No filamentous algae was present.

Substrate:

Substrate composition was predominately silt overlaying larger cobble-sized substrate with some pebble, gravel and sand also present.

An anoxic odour was apparent in the substrate.

External impacts: high

The most apparent impact at the site was the surrounding industrial activity that has significantly altered the landscape and is likely the main source of water at the site. The site is also regularly pumped when water levels are high.

Lack of connectivity to upstream and downstream reaches was another apparent impact but this is mostly due to the natural nature of the waterway.



Aquatic Habitat Description

CM2

Upstream:



Downstream:



Left Bank:



Dominating in stream aquatic plants:



Site CM2 was located on Meandu Creek at the Meandu Mine inlet to Meandu Creek Dam and downstream of the main Meandu Mine discharge point (RD2). This site consisted of a narrow (2 m) and shallow (0.2 m) pool. While there was no flow at the time of the survey, the site appeared connected to waterways further upstream and downstream.

Riparian condition: poor

Riparian vegetation had been completely cleared on both banks. Adjacent land was within the Meandu Mine lease and has been cleared but is not utilised for direct industrial activities. Banks were low and steep.

In-stream condition: poor

The in-stream aquatic habitat condition was poor. Water levels were low and the in-stream aquatic habitat was dominated by significant growth of aquatic plants (predominantly Cumbungi) that were choking the waterway and causing a build-up of sedimentation.

A little filamentous algae was present.

Substrate:

Substrate composition was silt.

An anoxic odour was apparent in the substrate.

External impacts: extreme

The most apparent impact at the site was the surrounding industrial activity that has significantly altered the landscape. The abundant growth of in stream vegetation was another apparent impact at the site; cumbungi is an invasive weed that can interfere with water flow, increase sediment deposition and reduce water quality.



Aquatic Habitat Description

BC1

Dam (north facing):



Dam (south facing):



Black Creek Dam inlet:



Aquatic plants:



Site BC1 was located on Black Creek Dam; an on-stream storage dam for Meandu Mine stormwater drainages (discharged from RD17B) as well as stormwater discharge from the Tarong power stations. This site consisted of a large pool of water within the Black Creek Valley not connected to waterways upstream or downstream.

Riparian condition: poor

Riparian vegetation was completely cleared from around the extent of the dam. Adjacent land is within the lease area for the Tarong power stations and the land adjacent to the dam is utilised for various activities associated with the power stations. Banks were low and moderately sloped.

In-stream condition: fair

The in-stream aquatic habitat condition was fair. The site was an isolated pool, significantly impacted by the surrounding land use activities with little bank vegetation (except for some scattered aquatic plants around the water's edge) or in stream habitat features providing structural complexity and shelter for aquatic fauna. Filamentous algae was present.

Substrate:

Substrate composition was predominately fine silt.

External impacts: high

The most apparent impact at the site was the surrounding industrial activity that has significantly altered the natural structure and function of the channel and caused a reduction in the presence and continuity of riparian vegetation. Lack of connectivity to upstream and downstream waterways was another apparent impact.



Aquatic Habitat Description

BC2

Upstream:



Downstream:



Left bank:



Right bank:



Site BC2 was located at the most downstream point of the diverted section of Black Creek before the Black Creek and Meandu Creek confluence. This site consisted of a large artificial wetland (wetted width approximately 70 m) downstream of several sedimentation ponds that was not connected to waterways upstream or downstream.

Riparian condition: poor

Riparian vegetation was completely cleared from the banks of the site, most likely during construction of the artificial channel. Adjacent land is within the lease area for the Tarong power stations, however the land directly adjacent to the site was not impacted by industrial activities and was predominantly intact native forest. Banks were high and steep and artificially re-enforced.

In-stream condition: fair

The in-stream aquatic habitat condition was fair. The site was an isolated pool, significantly impacted by the surrounding land use activities with little bank vegetation or in stream vegetation. In-stream substrates provided the majority of the available habitat features providing some structural complexity and shelter for aquatic fauna. Filamentous algae was present.

Substrate:

Substrate composition was predominately rocky substrates, including boulder, cobble, pebble and gravel with sand and some finer silt also.

External impacts: high

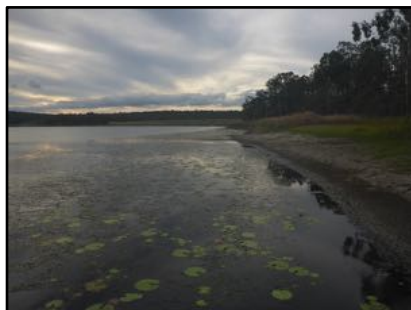
The most apparent impact at the site was the surrounding industrial activity that has significantly altered the natural structure and function of the channel. Lack of connectivity to upstream and downstream waterways was another apparent impact.



Aquatic Habitat Description

Meandu Creek Dam

Dam:



Dam:



Inlet channel from Meandu Mine:



Potential iron oxide sheen on water:



Meandu Creek Dam is a constructed waterbody located at the site of the Tarong power stations and receives licensed process waters from the Tarong Power Station, Tarong North Power Station and Meandu Mine as well as stormwater drainage from the power stations and Meandu Mine. The dam was a large pool of water connected to waterways further upstream and downstream via various inlets, outlets and waterway channels.

Riparian condition: good

Riparian vegetation varied at different points around the dam with the majority of the dam having a continuous zone of vegetation approximately 15 m wide, while other sections were impacted by vegetation clearing. Adjacent land is within the lease area for the Tarong power stations, however the directly adjacent land has not been cleared or utilised for industrial activities and is mostly intact native forest. Banks were low and steep.

In-stream condition: good

The in-stream aquatic habitat condition was good. The dam contained extensive beds of submerged, emergent and floating aquatic vegetation as well as large woody debris, which were providing structural complexity and shelter for aquatic fauna. Water levels were low so bank vegetation (providing shading and overhanging / trailing-bank habitat) was minimal.

Some filamentous algae was present, along with a red/brown colouration of the sediment in places and a red-brown sheen on the water surface particularly around the edges of the dam.

Substrate:

Substrate composition was predominately silt with some sand.

External impacts: high

The most apparent impact at the site was point source impacts from the various inlets and drainage channels that introduce waste water from various sources.



Aquatic Habitat Description

MCDOUT

Upstream:



Downstream:



Bank vegetation:



Riffle habitat:



Site MCDOUT was located on Meandu Creek at the confluence of Meandu Creek and the W3 Meandu Creek Dam outlet channel. This site consisted of a narrow pool approximately 3 m wide with fast flow (average 0.2 m/s). The site was connected to waterways downstream but upstream of the site was dry (i.e. the water at site was purely discharge water).

Riparian condition: good

Riparian vegetation consisted of a zone of vegetation approximately 15 m wide on the left bank and 10 m wide on the right bank with mature trees and grass providing shading and ground cover. Adjacent land is within the lease area for the Tarong power stations, however the directly adjacent land has not been cleared or utilised for industrial activities and is mostly intact native forest. Banks were low and steep.

In-stream condition: fair

The in-stream aquatic habitat condition was fair. The site was predominately a narrow fast-flowing pool and the following key habitat features were present, providing structural complexity and shelter for aquatic fauna:

- overhanging vegetation
- trailing bank vegetation
- in-stream aquatic plants
- a variety of flow regimes (shallow riffles runs), and
- woody debris.

No filamentous algae were present.

Substrate:

Substrate composition was predominately sand with gravel and pebble, however silt, cobble and boulder were also present.

External impacts: high

The most apparent impact at the site was point source impact from the W3 outlet pipe that has changed the natural flow regime of the site from a [likely] dry stretch of Meandu Creek to a permanently flowing waterway. Lack of connectivity to the upstream reaches of Meandu Creek was another apparent impact.



Aquatic Habitat Description

MC500

Upstream:



Downstream:



Bank vegetation:



In-stream emergent vegetation:



Site MC500 was located on Meandu Creek approximately 0.5 km downstream of the W3 Meandu Creek Dam outlet in Meandu Creek. This site consisted of a pool between 2.5 m wide (downstream section) and 10 m wide (upstream section) with slow to moderate flow (average 0.2 m/s). A road bridge crossed above the waterway at the upstream end of the site. The site was well connected to waterways further upstream and downstream.

Riparian condition: good

Riparian vegetation consisted of a zone of vegetation approximately 10 m wide on the left bank and 15 m wide on the right bank with mature trees and grass providing shading and ground cover. Some exotic plant species were present. On the right bank the adjacent land is within the lease area for the Tarong power stations and the directly adjacent land has been cleared but is not utilised for industrial activities. On the left bank the land has been cleared for a road corridor but further afield is state forest. Banks were high and steep but mostly stable and well vegetated.

In-stream condition: good

The in-stream aquatic habitat condition was good with the following key habitat features present, providing structural complexity and shelter for aquatic fauna:

- overhanging vegetation
- trailing bank vegetation
- undercut banks
- in-stream aquatic plants
- a variety of flow regimes (shallow pools, deep pools and runs)
- a variety of channel sinuosity (straight, bends and bars), and
- woody debris.

No filamentous algae was present.

Substrate:

Substrate composition was predominately sand and gravel, however silt, pebble, cobble and boulder were also present. An anoxic odour was apparent in the substrate.

External impacts: moderate

The most apparent impact at the site was the road bridge crossing at the upstream end of the site, which was impacting the natural flow regime downstream.



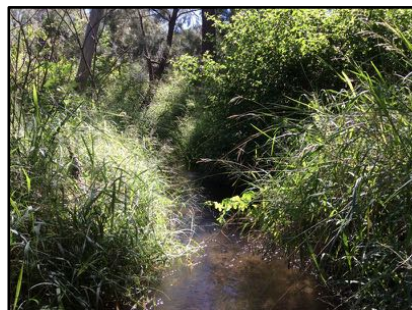
Aquatic Habitat Description

MC2

Upstream:



Downstream:



Left bank:



Right bank erosion:



Site MC2 was located on Meandu Creek approximately 2 km downstream of the W3 Meandu Creek Dam outlet into Meandu Creek. This site consisted of a narrow pool approximately 3 m wide with moderate to fast flow (average 0.2 m/s). The site was well connected to waterways further upstream and downstream.

Riparian condition: good

Riparian vegetation consisted of a zone of vegetation approximately 3 m wide on the left bank and 15 m wide on the right bank with mature trees and grass providing shading and ground cover. Some exotic plant species were present. On the left bank the land had been cleared and was utilised for a road corridor. On the right bank the adjacent land was predominantly intact native forest. Banks were low and steep.

In-stream condition: fair

The in-stream aquatic habitat condition was fair. The site was predominately a straight shallow pool with moderate flow and the following key habitat features present, providing structural complexity and shelter for aquatic fauna:

- overhanging vegetation
- trailing bank vegetation
- undercut banks
- in-stream aquatic plants, and
- woody debris.

No filamentous algae was present.

Substrate:

Substrate composition was predominantly sand with some gravel and pebble and blanketing silt.

External impacts: moderate

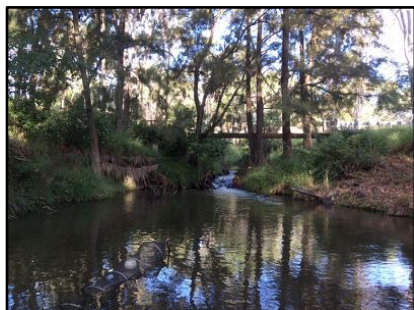
The most apparent impact at the site was the land clearing adjacent to the left bank, which has caused a reduction in the presence and continuity of riparian vegetation.



Aquatic Habitat Description

MC5 / W2

Upstream:



Downstream:



Left bank:



Right bank erosion:



Site MC5/W2 was located on Meandu Creek approximately 5 km downstream of the W3 Meandu Creek Dam outlet into Meandu Creek. This site consisted of a pool between 3 m and 9 m wide with moderate flow (average 0.2 m/s). A road bridge crossed the waterway at the downstream end of the site. The site was well connected to waterways further upstream and downstream.

Riparian condition: fair

Riparian vegetation consisted of a zone of vegetation approximately 5 m wide on both banks with mature trees and grass providing shading and ground cover. Adjacent land-use consisted of cleared land utilised for grazing. Banks were moderate to steep with some areas of severe erosion apparent (likely due to cleared riparian vegetation and high flows around creek bends).

In-stream condition: good

The in-stream aquatic habitat condition was good with the following key habitat features present, providing structural complexity and shelter for aquatic fauna:

- overhanging/trailing vegetation
- undercut banks
- in-stream aquatic plants
- different flow regimes (deep pools, shallow pools, glides, runs and riffles)
- a variety of channel sinuosity (bends, bars and straight sections), and
- woody debris.

Some filamentous algae present.

Substrate:

Substrate composition was predominantly sand, gravel, pebble and cobble with some blanketing silt.

External impacts: moderate

The most apparent impact at the site was the adjacent land clearing, which has caused a reduction in the presence and continuity of riparian vegetation and reduced bank stability leading to large areas of severe erosion. Stock access was also an evident impact.



Aquatic Habitat Description

MC15

Upstream:



Downstream:



In-stream habitat (plants and trees):



Riparian zone at downstream end:



Site MC15 was located on Meandu Creek approximately 15 km downstream of the W3 Meandu Creek Dam outlet into Meandu Creek. This site consisted of a narrow pool approximately 4 m wide with moderate flow (average 0.2 m/s). A road crossing was located at the downstream end of the site. The site was well connected to waterways further upstream and downstream.

Riparian condition: poor to fair

Riparian vegetation consisted of a zone of vegetation approximately 2 m wide on both banks. At the upstream end of the site riparian vegetation included mature trees and grasses providing shading and ground cover, while the downstream end had similar vegetation assemblage but sparser density and coverage. Adjacent land-use consisted of cleared land utilised for grazing. Banks were low and steep but stable.

In-stream condition: fair

The in-stream aquatic habitat condition was fair. The site was predominately a straight shallow pool with moderate flow and the following key habitat features were present, providing structural complexity and shelter for aquatic fauna:

- overhanging vegetation
- trailing bank vegetation
- undercut banks
- in-stream aquatic plants, and
- woody debris.

A little filamentous algae was present.

Substrate:

Substrate composition was predominantly blanketing silt with some sand.

External impacts: high

The most apparent impact at the site was the adjacent land clearing, which has caused a reduction in the presence and continuity of riparian vegetation and the subsequent shading and protection it would normally provide. Stock access was also an evident impact.

An outlet pipe was present but reportedly not in use.



Aquatic Habitat Description

MC20 / SW16

Upstream:



Downstream:



Left bank:



Right bank:



Site MC20 was located on Meandu Creek approximately 20 km downstream of the W3 Meandu Creek Dam outlet into Meandu Creek. This site consisted of a connected pool approximately 10 m wide with slow flow (average 0.1 m/s). A road bridge crossed above the waterway in the middle of the site. The site was well connected to waterways further upstream and downstream.

Riparian condition: poor

Riparian vegetation had been completely cleared on both banks. Grasses and shrubs (including some exotic plant species) provided the only ground cover on both banks. Adjacent land-use consisted of cleared land utilised for cropping and grazing. Banks were high and steep.

In-stream condition: poor

The in-stream aquatic habitat condition was poor. The site was predominately a straight shallow pool with slow flow and the following key habitat features were present, providing structural complexity and shelter for aquatic fauna:

- undercut banks
- in-stream aquatic plants, and
- some woody debris.

A moderate amount of filamentous algae was present.

Substrate:

Substrate composition was predominantly blanketing silt with some sand.

External impacts: high

The most apparent impact at the site was the adjacent land clearing, which has caused a reduction in the presence and continuity of riparian vegetation and the subsequent shading and protection it would normally provide. The road bridge crossing above that site has also impacted the bank stability and the natural flow regime of the waterway. Rubbish present at the site is indicative of recreational human impacts.



Aquatic Habitat Description

MC25

Upstream:



Downstream:



In-stream habitat (floating plants):



Road crossing through site:



Site MC25 was located on Barker Creek approximately 3 km downstream of the Barker Creek and Meandu Creek confluence and approximately 25 km downstream of the W3 Meandu Creek Dam outlet into Meandu Creek. This site consisted of a large, connected pool approximately 11 m wide with slow flow (average 0.1 m/s). A road crossed through the middle of the site. The site was well connected to waterways further upstream and downstream.

Riparian condition: fair

Riparian vegetation consisted of a zone of vegetation approximately 7 m wide on both banks with mature trees and grass providing shading and ground cover. Adjacent land-use consisted of a road corridor and cleared land utilised for grazing. Banks were moderate to steep with some areas of erosion apparent.

In-stream condition: fair

The in-stream aquatic habitat condition was fair with the following key habitat features were present, providing structural complexity and shelter for aquatic fauna:

- overhanging vegetation
- trailing bank vegetation
- undercut banks
- in-stream aquatic plants
- different flow regimes (deep pools and shallow flow)
- a variety of channel sinuosity (straight, bends and bars), and
- woody debris.

A little filamentous algae was present.

Substrate:

Substrate composition was predominantly fine silt and sand with some gravel, pebble and cobble.

External impacts: moderate

The most apparent impact at the site was the road crossing through the site and the adjacent vehicle track, which has caused some disturbance to the riparian vegetation continuity, lowered bank stability and changed the natural flow regime. The in-stream culvert under the road seems to provide sufficient connectivity to allow flow. There was also evidence of recreation swimming at the site. An inlet from an unknown source was also present and flowing at the time.



Attachment F Macroinvertebrate Statistical Outputs

Table F.1 SIMPER results for Meandu Creek downstream of Meandu Creek Dam and comparative locations for **edge** habitat

Average dissimilarity = 77.28						
Taxa	Downstream of Dam Av.Abund	Comparative Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
s-f Chironominae	30.06	26.33	8.61	0.89	11.14	11.14
Tateidae	35.34	9.67	8.52	0.77	11.02	22.16
Ostracoda	47.06	4.67	8.01	0.59	10.37	32.53
s-f Tanypodinae	19.26	20.53	6.34	1.13	8.2	40.73
Oligochaeta	8.8	11.93	4.38	0.89	5.67	46.4
Baetidae	6.57	12.07	3.39	0.49	4.39	50.79
Atyidae	2.2	10.2	3.15	0.86	4.07	54.86
Leptoceridae	11.69	0.67	2.62	0.86	3.39	58.25
s-f Orthocladiinae	12.97	2.47	2.55	0.74	3.3	61.55
Caenidae	4.11	5.4	2.14	0.76	2.77	64.32
Libellulidae	10	2.47	2.08	1.03	2.7	67.01
Thiaridae	3.89	3.47	2.04	0.58	2.64	69.66
Ceratopogonidae	5.23	3.27	1.97	0.68	2.54	72.2
Dytiscidae	1.4	3.2	1.83	0.56	2.37	74.57
Simuliidae	9.71	1.2	1.68	0.47	2.17	76.74
Hydridae	6.29	0.2	1.42	0.4	1.83	78.57
Corbiculidae	4.71	0.13	1.18	0.33	1.53	80.1
Gomphidae	4.03	0.27	1.05	0.54	1.36	81.46
Palaemonidae	1.46	2.53	1	0.68	1.29	82.76
Pleidae	1.29	1.13	0.92	0.46	1.19	83.95
Micronectidae	0.31	3.4	0.87	0.43	1.13	85.08
Nematoda	0.09	1.73	0.68	0.44	0.88	85.96
Noteridae	0.03	1.47	0.67	0.41	0.86	86.82
Planorbidae	1.09	1.13	0.67	0.52	0.86	87.68
Calamoceratidae	2.29	0.07	0.6	0.71	0.78	88.46
Coenagrionidae	1.71	1	0.59	0.68	0.77	89.23
Cladocera	0.97	0.93	0.53	0.78	0.68	89.91
Acarina	1.17	0.87	0.51	0.73	0.66	90.57



Table F.2 SIMPER results for comparative and Meandu Creek upstream of Meandu Creek Dam locations for **edge** habitat

Average dissimilarity = 78.28						
Taxa	Comparative Av.Abund	Upstream of Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tateidae	9.67	29	11.45	0.84	14.63	14.63
s-f Chironominae	26.33	11.55	9.21	1.06	11.76	26.39
s-f Tanypodinae	20.53	5.75	7.02	1.2	8.97	35.37
Oligochaeta	11.93	4.95	5.57	0.87	7.11	42.48
Ostracoda	4.67	13.15	5.22	0.84	6.67	49.15
Nematoda	1.73	25.95	4.9	0.39	6.25	55.41
Atyidae	10.2	1	4.54	0.88	5.8	61.21
Baetidae	12.07	0.4	3.39	0.41	4.33	65.55
Ceratopogonidae	3.27	3.2	2.02	0.81	2.58	68.13
Caenidae	5.4	0	1.94	0.67	2.48	70.61
Dytiscidae	3.2	1.5	1.9	0.69	2.43	73.04
Thiaridae	3.47	2.15	1.79	0.7	2.29	75.33
Copepoda	0.67	3.75	1.49	0.59	1.91	77.24
Palaemonidae	2.53	0.9	1.08	0.84	1.39	78.62
Noteridae	1.47	0.15	1.01	0.48	1.29	79.91
Libellulidae	2.47	0.45	0.99	1.08	1.26	81.17
s-f Orthocladiinae	2.47	0.55	0.99	0.78	1.26	82.43
Micronectidae	3.4	0	0.96	0.4	1.22	83.65
Gastropoda	0	2.8	0.84	0.39	1.08	84.73
Acarina	0.87	0.85	0.79	0.59	1.01	85.74
Hydridae	0.2	2.6	0.67	0.34	0.86	86.6
Planorbidae	1.13	1.05	0.63	0.91	0.81	87.4
Culicidae	0.93	1.6	0.63	0.62	0.8	88.21
Coenagrionidae	1	1	0.59	0.67	0.75	88.96
Pleidae	1.13	0.1	0.5	0.62	0.64	89.6
Sphaeriidae	1.27	0	0.5	0.71	0.63	90.23

Table F.3 SIMPER results for Meandu Creek downstream and upstream of Meandu Creek Dam locations for **edge** habitat

Average dissimilarity = 80.37						
Taxa	Downstream of Dam Av.Abund	Upstream of Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tateidae	35.34	29	13.1	0.92	16.3	16.3
Ostracoda	47.06	13.15	9.79	0.71	12.19	28.49
s-f Chironominae	30.06	11.55	7.87	0.78	9.79	38.28



Average dissimilarity = 80.37						
Taxa	Downstream of Dam Av.Abund	Upstream of Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
s-f Tanypodinae	19.26	5.75	5.36	0.98	6.67	44.94
Nematoda	0.09	25.95	3.7	0.31	4.6	49.54
Oligochaeta	8.8	4.95	2.91	0.78	3.62	53.16
Leptoceridae	11.69	0.35	2.84	0.88	3.54	56.7
s-f Orthocladiinae	12.97	0.55	2.62	0.72	3.26	59.96
Libellulidae	10	0.45	2.3	1.01	2.86	62.83
Thiaridae	3.89	2.15	2.15	0.54	2.68	65.51
Hydridae	6.29	2.6	1.9	0.49	2.37	67.87
Ceratopogonidae	5.23	3.2	1.83	0.61	2.28	70.15
Baetidae	6.57	0.4	1.65	0.87	2.05	72.21
Caenidae	4.11	0	1.58	0.55	1.97	74.18
Simuliidae	9.71	0	1.57	0.43	1.96	76.14
Atyidae	2.2	1	1.4	0.58	1.74	77.88
Dytiscidae	1.4	1.5	1.3	0.39	1.61	79.49
Copepoda	0.4	3.75	1.28	0.55	1.59	81.08
Corbiculidae	4.71	0	1.25	0.33	1.55	82.63
Gomphidae	4.03	0	1.13	0.51	1.41	84.03
Palaemonidae	1.46	0.9	0.91	0.55	1.14	85.17
Pleidae	1.29	0.1	0.84	0.36	1.05	86.22
Planorbidae	1.09	1.05	0.75	0.56	0.93	87.15
Gastropoda	0.03	2.8	0.74	0.38	0.92	88.06
Coenagrionidae	1.71	1	0.69	0.66	0.86	88.92
Calamoceratidae	2.29	0	0.65	0.7	0.81	89.73
Acarina	1.17	0.85	0.55	0.52	0.69	90.42

Table F.4 SIMPER results for comparative and Meandu Creek Dam locations for **edge** habitat

Average dissimilarity = 78.66						
Taxa	Comparative Av.Abund	Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
s-f Chironominae	26.33	1.3	9.72	1.16	12.35	12.35
s-f Tanypodinae	20.53	3.8	8.29	1.34	10.54	22.89
Ostracoda	4.67	11.35	7.11	0.79	9.04	31.93
Oligochaeta	11.93	5.85	5.98	0.97	7.61	39.54
Atyidae	10.2	0.85	5.61	0.98	7.13	46.67
Baetidae	12.07	1.75	4.29	0.47	5.46	52.13
Nematoda	1.73	4.95	3.91	0.79	4.97	57.1
Tateidae	9.67	0.5	3.87	0.7	4.93	62.03
Noteridae	1.47	3	2.51	0.69	3.19	65.22



Average dissimilarity = 78.66						
Taxa	Comparative Av.Abund	Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Caenidae	5.4	0.3	2.34	0.73	2.98	68.19
Dytiscidae	3.2	1.05	2.31	0.71	2.94	71.14
Ceratopogonidae	3.27	1.05	2.26	0.85	2.87	74
Cladocera	0.93	3.25	2.13	0.71	2.71	76.72
Thiaridae	3.47	0.15	1.49	0.62	1.89	78.61
Tipulidae	0.27	1.95	1.37	0.5	1.74	80.35
Micronectidae	3.4	0.1	1.15	0.44	1.46	81.81
Libellulidae	2.47	0.2	1.13	1.25	1.44	83.26
Palaemonidae	2.53	0.2	1.13	0.82	1.44	84.69
Copepoda	0.67	1.5	1.01	0.82	1.29	85.98
s-f Orthoclaadiinae	2.47	0	0.85	0.66	1.08	87.06
Acarina	0.87	0.2	0.69	0.65	0.88	87.94
Coenagrionidae	1	0.7	0.69	0.55	0.88	88.81
Planorbidae	1.13	0.65	0.68	0.66	0.87	89.68
Pleidae	1.13	0.25	0.63	0.72	0.81	90.49

Table F.5 SIMPER results for Meandu Creek upstream of Meandu Creek Dam and Meandu Creek Dam locations for **edge** habitat

Average dissimilarity = 80.82						
Taxa	Upstream of Dam Av.Abund	Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tateidae	29	0.5	14.3	0.83	17.69	17.69
Ostracoda	13.15	11.35	9.93	0.97	12.29	29.98
Nematoda	25.95	4.95	9.04	0.64	11.18	41.16
s-f Chironominae	11.55	1.3	7.82	0.83	9.68	50.84
Oligochaeta	4.95	5.85	5.29	1.05	6.55	57.39
s-f Tanypodinae	5.75	3.8	4.99	0.94	6.17	63.56
Noteridae	0.15	3	2.53	0.62	3.13	66.69
Copepoda	3.75	1.5	2.49	0.8	3.08	69.78
Cladocera	0.4	3.25	2.43	0.71	3	72.78
Ceratopogonidae	3.2	1.05	1.75	1.03	2.16	74.94
Tipulidae	0.25	1.95	1.59	0.51	1.97	76.92
Baetidae	0.4	1.75	1.33	0.61	1.64	78.56
Thiaridae	2.15	0.15	1.29	0.5	1.6	80.15
Atyidae	1	0.85	1.21	0.73	1.49	81.65
Dytiscidae	1.5	1.05	1.17	0.9	1.45	83.1
Gastropoda	2.8	0	1.08	0.4	1.33	84.43
Coenagrionidae	1	0.7	0.96	0.62	1.19	85.62



Average dissimilarity = 80.82						
Taxa	Upstream of Dam Av.Abund	Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planorbidae	1.05	0.65	0.84	0.8	1.04	86.66
Hydridae	2.6	0	0.79	0.34	0.98	87.64
Acarina	0.85	0.2	0.79	0.46	0.97	88.61
Palaemonidae	0.9	0.2	0.66	0.62	0.82	89.43
Culicidae	1.6	0.15	0.63	0.53	0.77	90.21

Table F.6 SIMPER results for Meandu Creek downstream of Meandu Creek Dam and Meandu Creek Dam locations for **edge** habitat

Average dissimilarity = 85.32						
Taxa	Downstream of Dam Av.Abund	Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ostracoda	47.06	11.35	11.58	0.77	13.58	13.58
Tateidae	35.34	0.5	9.9	0.74	11.61	25.18
s-f Chironominae	30.06	1.3	7.3	0.72	8.56	33.74
s-f Tanypodinae	19.26	3.8	6.31	1.09	7.39	41.14
Oligochaeta	8.8	5.85	3.73	0.97	4.37	45.51
Leptoceridae	11.69	0	3.23	0.9	3.78	49.29
Nematoda	0.09	4.95	3.07	0.66	3.6	52.9
s-f Orthocladinae	12.97	0	2.93	0.75	3.44	56.33
Libellulidae	10	0.2	2.66	1.08	3.12	59.45
Thiaridae	3.89	0.15	2.19	0.48	2.56	62.01
Baetidae	6.57	1.75	2.17	1	2.55	64.56
Ceratopogonidae	5.23	1.05	1.94	0.56	2.27	66.83
Caenidae	4.11	0.3	1.91	0.6	2.24	69.07
Simuliidae	9.71	0	1.73	0.44	2.03	71.1
Cladocera	0.97	3.25	1.7	0.7	1.99	73.1
Hydridae	6.29	0	1.69	0.42	1.98	75.08
Atyidae	2.2	0.85	1.68	0.61	1.97	77.05
Noteridae	0.03	3	1.68	0.54	1.96	79.01
Dytiscidae	1.4	1.05	1.49	0.39	1.74	80.75
Corbiculidae	4.71	0	1.42	0.34	1.66	82.42
Gomphidae	4.03	0	1.32	0.55	1.54	83.96
Tipulidae	0.17	1.95	1.08	0.44	1.27	85.22
Pleidae	1.29	0.25	1.08	0.4	1.26	86.49
Palaemonidae	1.46	0.2	0.96	0.51	1.13	87.61
Copepoda	0.4	1.5	0.92	0.71	1.07	88.69
Planorbidae	1.09	0.65	0.85	0.51	1	89.69
Coenagrionidae	1.71	0.7	0.85	0.65	0.99	90.68



Table F.7 SIMPER results for Meandu Creek upstream of Meandu Creek Dam and comparative locations for **bed** habitat

Average dissimilarity = 79.80						
Taxa	Comparative Av.Abund	Upstream of Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ostracoda	62.27	24.35	11.24	0.99	14.08	14.08
s-f Chironominae	41.4	20.6	9.93	0.87	12.44	26.52
Nematoda	17.4	7.8	8.79	0.63	11.01	37.53
Tateidae	25.67	25.15	8.74	0.83	10.96	48.48
Atyidae	22.8	2.6	6.43	0.93	8.06	56.55
s-f Tanypodinae	23.27	12.55	4.9	1.16	6.14	62.68
Oligochaeta	18.27	3.85	3.35	0.67	4.2	66.88
Copepoda	4.93	9	2.84	0.95	3.56	70.45
Ceratopogonidae	1.07	12.35	2.38	0.36	2.98	73.42
Thiaridae	8.73	5.6	2.35	0.87	2.95	76.37
Caenidae	14.93	0	2.25	0.57	2.82	79.18
Baetidae	10.8	3	1.96	1.03	2.46	81.64
Culicidae	0	7.25	1.95	0.55	2.44	84.09
Planorbidae	5	0.4	1.34	0.64	1.68	85.76
Cladocera	1.2	5.1	1.29	0.65	1.61	87.38
Coenagrionidae	3.47	2.65	1.12	0.77	1.4	88.78
Hydridae	1.2	3.5	0.84	0.44	1.06	89.83
Leptophlebiidae	4.87	0	0.82	0.45	1.02	90.86

Table F.8 SIMPER results for Meandu Creek downstream of Meandu Creek Dam and comparative locations for **bed** habitat

Average dissimilarity = 82.48						
Taxa	Downstream of Dam Av.Abund	Comparative Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ostracoda	39	62.27	10.56	0.86	12.8	12.8
s-f Chironominae	63.8	41.4	9.85	0.74	11.95	24.75
Nematoda	0.51	17.4	6.36	0.54	7.71	32.46
Tateidae	14.63	25.67	6.1	0.81	7.4	39.86
Oligochaeta	33.86	18.27	5.93	0.8	7.18	47.04
Atyidae	1.29	22.8	5.36	0.87	6.5	53.54
s-f Tanypodinae	23.14	23.27	4.39	1.04	5.32	58.86
Thiaridae	17.29	8.73	4.29	0.63	5.2	64.06
Baetidae	18.43	10.8	4.18	0.58	5.07	69.13
s-f Orthocladiinae	27.54	2.6	3.07	0.72	3.72	72.85



Average dissimilarity = 82.48						
Taxa	Downstream of Dam Av.Abund	Comparative Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Caenidae	8.8	14.93	2.91	0.74	3.53	76.38
Corbiculidae	14.43	0.47	2.35	0.39	2.85	79.22
Simuliidae	11.71	5	2.33	0.55	2.83	82.05
Copepoda	2.69	4.93	1.63	0.65	1.97	84.02
Planorbidae	0.71	5	1.18	0.65	1.43	85.46
Cladocera	4.23	1.2	1.07	0.64	1.3	86.76
Hydridae	4.23	1.2	0.88	0.53	1.07	87.82
Hydropsychidae	4.83	0.53	0.86	0.52	1.04	88.87
Coenagrionidae	1.06	3.47	0.79	0.65	0.96	89.83
Leptophlebiidae	0.03	4.87	0.71	0.44	0.86	90.69

Table F.9 SIMPER results for Meandu Creek downstream and upstream of Meandu Creek Dam locations for **bed** habitat

Average dissimilarity = 82.83						
Taxa	Downstream of Dam Av.Abund	Upstream of Dam Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
s-f Chironominae	63.8	20.6	10.11	0.81	12.21	12.21
Ostracoda	39	24.35	8.56	0.8	10.34	22.55
Tateidae	14.63	25.15	8.25	0.75	9.96	32.51
Oligochaeta	33.86	3.85	5.86	0.7	7.07	39.59
Thiaridae	17.29	5.6	5.47	0.62	6.6	46.18
Baetidae	18.43	3	4.98	0.51	6.01	52.19
s-f Tanypodinae	23.14	12.55	4.86	0.8	5.87	58.06
s-f Orthocladiinae	27.54	0.75	3.65	0.74	4.41	62.46
Corbiculidae	14.43	0	2.82	0.4	3.41	65.87
Copepoda	2.69	9	2.54	0.62	3.06	68.94
Ceratopogonidae	0.66	12.35	2.48	0.35	3	71.93
Simuliidae	11.71	0	2.47	0.49	2.99	74.92
Culicidae	0.03	7.25	2.35	0.51	2.83	77.75
Cladocera	4.23	5.1	2.07	0.79	2.5	80.25
Caenidae	8.8	0	1.87	0.54	2.26	82.5
Nematoda	0.51	7.8	1.58	0.28	1.91	84.41
Hydridae	4.23	3.5	1.43	0.54	1.72	86.13
Hydropsychidae	4.83	0	1.06	0.5	1.28	87.41
Palaemonidae	2.06	2.05	0.88	0.69	1.07	88.48
Atyidae	1.29	2.6	0.87	0.86	1.05	89.53
Leptoceridae	3.57	0.1	0.8	0.83	0.96	90.49



Table F.10 SIMPER results for Meandu Creek downstream of Meandu Creek Dam and Meandu Creek Dam locations for **bed** habitat

Average dissimilarity = 86.19						
Taxa	Downstream of Dam Av.Abund	Dam Av.Abund	Av.Diss	Diss/SD	Contrib %	Cum. %
s-f Chironominae	63.8	9.2	9.15	0.66	10.62	10.62
Oligochaeta	33.86	2	7.7	0.77	8.94	19.56
Baetidae	18.43	0.2	7.13	0.53	8.28	27.83
Thiaridae	17.29	0	6.92	0.59	8.03	35.86
Ostracoda	39	1	6.86	0.58	7.96	43.82
Tateidae	14.63	0	6.31	0.61	7.32	51.14
s-f Orthocladinae	27.54	0	4.77	0.81	5.54	56.68
Cladocera	4.23	8.4	4.57	0.93	5.31	61.99
s-f Tanypodinae	23.14	0	3.97	1.19	4.6	66.59
Corbiculidae	14.43	0	3.57	0.41	4.14	70.73
Simuliidae	11.71	0	3.26	0.54	3.78	74.51
Atyidae	1.29	5.2	2.73	0.8	3.17	77.68
Caenidae	8.8	0	2.54	0.59	2.95	80.63
Copepoda	2.69	1.4	1.48	0.45	1.72	82.35
Hydropsychidae	4.83	0	1.41	0.52	1.64	83.99
Hydridae	4.23	0	1.22	0.49	1.42	85.41
Leptoceridae	3.57	0	1.11	0.93	1.29	86.7
Gomphidae	4.06	0	0.89	0.49	1.04	87.73
Palaemonidae	2.06	0	0.86	0.51	0.99	88.73
Libellulidae	1.77	0.8	0.82	0.93	0.95	89.67
Acarina	1.23	0	0.79	0.41	0.92	90.59

Table F.11 SIMPER results for comparative and Meandu Creek Dam locations for **bed** habitat

Average dissimilarity = 87.65						
Taxa	Comparative Av.Abund	Dam Av.Abund	Av.Diss	Diss/SD	Contrib %	Cum. %
Nematoda	17.4	0.4	12.41	0.65	14.16	14.16
Ostracoda	62.27	1	11.39	0.83	12.99	27.15
s-f Chironominae	41.4	9.2	10.04	0.71	11.45	38.61
s-f Tanypodinae	23.27	0	8.46	1.52	9.66	48.26
Atyidae	22.8	5.2	7.99	1.01	9.11	57.38
Tateidae	25.67	0	6.89	0.68	7.86	65.24
Oligochaeta	18.27	2	4.24	0.66	4.84	70.07
Cladocera	1.2	8.4	3.6	1.29	4.1	74.18



Average dissimilarity = 87.65						
Taxa	Comparative Av.Abund	Dam Av.Abund	Av.Diss	Diss/SD	Contrib %	Cum. %
Caenidae	14.93	0	2.82	0.59	3.22	77.4
Baetidae	10.8	0.2	2.3	0.97	2.63	80.03
Copepoda	4.93	1.4	2.23	0.87	2.54	82.57
Thiaridae	8.73	0	2.18	0.74	2.48	85.05
Planorbidae	5	0	1.79	0.65	2.04	87.09
Coenagrionidae	3.47	0.6	1.21	0.72	1.38	88.47
Leptophlebiidae	4.87	0	1.07	0.46	1.22	89.7
Decapoda	2.4	0	0.93	0.41	1.06	90.75

Table F.12 SIMPER results for Meandu Creek upstream of Meandu Creek Dam and Meandu Creek locations for **bed** habitat

Average dissimilarity = 82.88						
Taxa	Upstream of Dam Av.Abund	Dam Av.Abund	Av.Diss	Diss/SD	Contrib %	Cum. %
s-f Chironominae	20.6	9.2	11.34	1.12	13.69	13.69
s-f Tanypodinae	12.55	0	10.18	1	12.28	25.97
Tateidae	25.15	0	9.34	0.61	11.27	37.24
Ostracoda	24.35	1	9.32	1.01	11.24	48.48
Cladocera	5.1	8.4	6.89	1.39	8.31	56.79
Culicidae	7.25	0	4.91	0.65	5.92	62.71
Atyidae	2.6	5.2	4.09	1.18	4.94	67.65
Ceratopogonidae	12.35	0.4	3.94	0.41	4.75	72.4
Copepoda	9	1.4	3.82	0.8	4.6	77
Nematoda	7.8	0.4	2.38	0.31	2.87	79.87
Oligochaeta	3.85	2	2.22	1.15	2.68	82.55
Thiaridae	5.6	0	2.01	0.56	2.42	84.97
Baetidae	3	0.2	1.47	0.91	1.77	86.74
Libellulidae	1	0.8	1.2	0.44	1.44	88.18
Coenagrionidae	2.65	0.6	1.13	0.81	1.36	89.54
Noteridae	0.05	1.2	1.05	0.77	1.26	90.81



APPENDIX



Integrated Water Model



Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Suitably qualified person

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. This Statutory Declaration must be completed by the person who conducted the environmental evaluation and accompany the environmental report submitted to the Department of Environment and Heritage Protection (the department).

Oaths Act 1867

QUEENSLAND

TO WIT

I

Michael Gowan, employee of Golder Associates Pty Ltd

Insert the name of the person making this declaration

of

147 Coronation Drive,

Insert the street address of the person making this declaration

Milton, Queensland 4064

in the State of Queensland do solemnly and sincerely declare that:

- I am the suitably qualified person and author of an environmental report entitled

Integrated Water Model, Meandu Mine – Environmental Engineering Evaluation Project

Insert title of the environmental report

In accordance with the environmental evaluation issued by the department under the Act to:

TEC Coal Pty Ltd

21 December 2016

Insert name of recipient of the notice

Insert date of the notice

A copy of my report is attached to this statutory declaration and marked "A".

I possess the following qualifications and experience relevant to this environmental evaluation:

Principal Engineer

I have not knowingly included any false, misleading or incomplete information in the report; and

I have not knowingly failed to reveal any relevant information or document to the department.

I certify that:

Statutory Declaration
Suitably qualified person

- The report addresses the relevant matters for the evaluation and is factually correct; and
- The opinions expressed in it are honestly and reasonably held.

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at

147 Coronation Drive, Milton,

Insert location

this

11th

day of

September

in the year

2018

Insert day (e.g. 18th)

Insert month

Insert year



Signed

(Person making this declaration)



Signed

Megan Dowden, Legal Practitioner Qld, Reg.
69680

Printed name and registration number (if
applicable)



REPORT

Integrated Water Model

Meandu Mine - Environmental and Engineering Evaluation Project

Submitted to:

Javier Cabrera
TEC Coal Pty Ltd
GPO Box 800
Brisbane
QLD 4001

Submitted by:

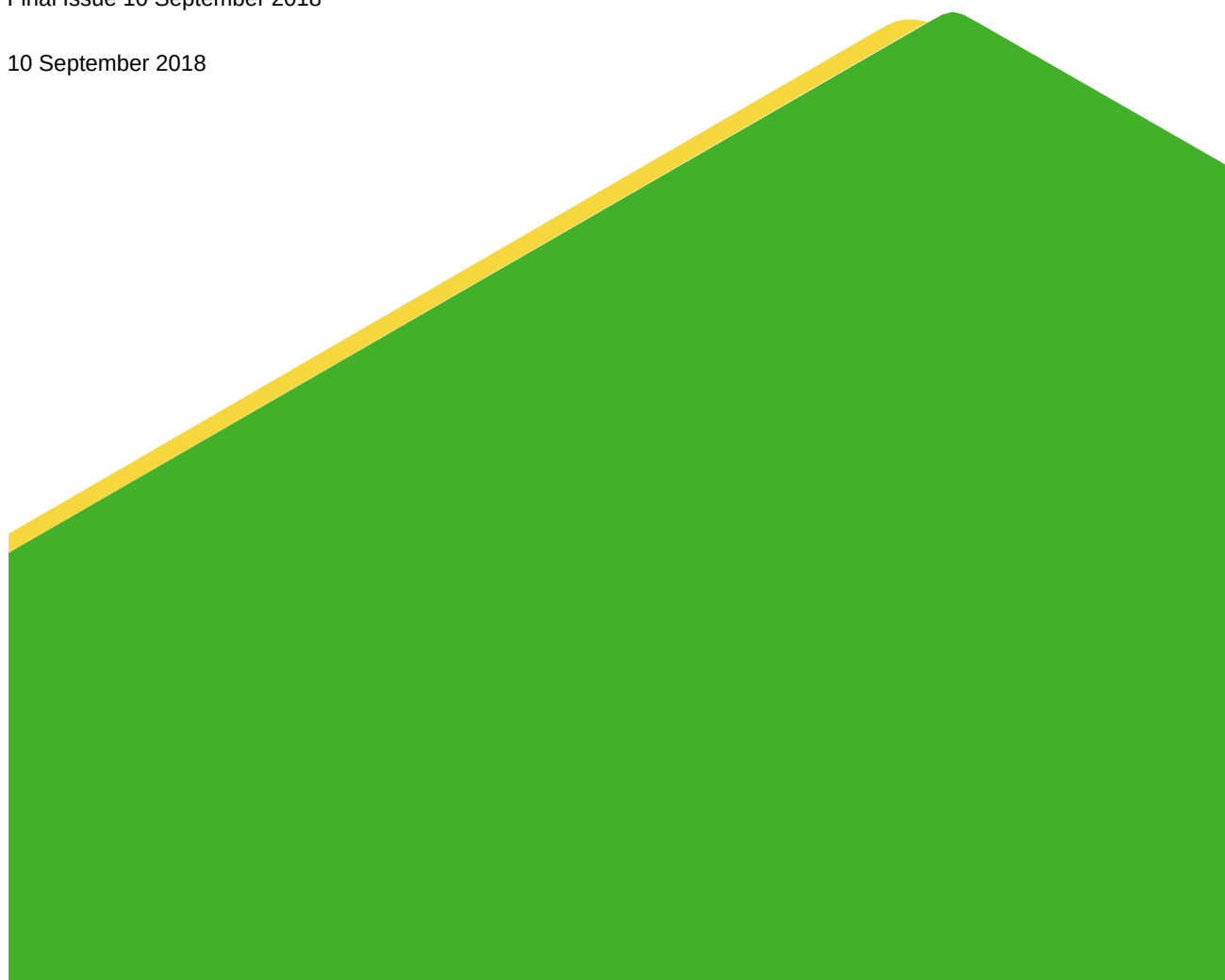
Golder Associates Pty Ltd

147 Coronation Drive Milton, Queensland 4064 Australia

+61 7 3721 5400

Final Issue 10 September 2018

10 September 2018



Distribution List

Amanda O'Kane. Technical Executive, Environment. WSP.

Study Limitations

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APPENDICES

ATTACHMENT A

Important Information Relating to this Report

ATTACHMENT B

Catchment Areas

1.0 INTRODUCTION

Stanwell Corporation Limited (Stanwell) has engaged Golder to develop an integrated numerical water quantity and mass balance water quality model (the model) of Meandu Mine for the Environmental and Engineering Evaluation Project (EEE Project). The purpose of the model is to simulate the environmental performance of the 2017 Life of Mine Plan prepared to inform the water modelling (throughout operations and the post closure monitoring period) in relation to Acid Saline and Metalliferous Drainage (AMD) potential and then use the model to test a series of options for engineered or managed controls.

This report details:

- The model development (Section 3.0).
- Structure, inputs and assumptions (Section 4.0).
- Calibration (Section 5.0).
- Verification against measured data (Section 6.0).
- Baseline results given the existing mine plan during operations and post closure (Section 7.0).
- Conclusions (Section 8.0).
- Recommendations (Section 9.0).

1.1 EEE Project background

Stanwell is the owner of Meandu Mine, located approximately 14 km south-west of Nanango and 150 km north-west of Brisbane. Meandu Mine was commissioned in 1983 and is the sole supplier of coal to the adjacent Tarong and Tarong North power stations. Site features are shown in Figure 1.

On 21 December 2016, the former Department of Environment and Heritage Protection (EHP) (now Department of Environment and Science (DES)) issued TEC Coal Pty Ltd (a subsidiary of Stanwell) with a notice to conduct or commission an environmental evaluation under Section 326B of the *Environmental Protection Act 1994* (EP Act) (the Notice).

The grounds for the environmental evaluation relate to the identification of acid and metalliferous drainage (AMD) at Meandu Mine and the potential for this AMD to cause environmental harm. As the full nature and extent of the AMD was unknown, EHP (now DES) required that an environmental investigation be undertaken to determine whether environmental harm has occurred as a result of AMD at the Meandu Mine. AMD was identified as reporting by overland flow to retention dam 7 (RD7) in the retention dam network on the western side of the mine, where it was mixing with other mine affected water. Water from RD7 flows to RD8 where it is either re-used for site purposes or reports to the Meandu Creek Dam via release (compliance) point CP3. AMD reporting to RD7 is believed to be originating from two closely associated seepage locations:

1. Bullgang Corner, located approximately 600 m south-east of RD7; and
2. A covered (vegetated) coal rejects area between Ramp 7 and the western side of the North-West A tailings void (NWA tailings). This coal rejects area is assumed to be rehabilitated in the current Plan of Operations for Meandu Mine. This area will need to be evaluated to determine if remedial works are necessary in the future.

Specifically, the Notice requires that investigations are undertaken to:

1. Determine whether environmental harm has occurred as a result of AMD at Meandu Mine.

2. Identify and characterise the AMD and material with potential to generate AMD in the North-West (NW) tailings void/ spoil dump and rehabilitated rejects to assess the extent of environmental harm likely to be caused by the AMD; and to determine the effects of AMD ingress to stored historical tailings (e.g. potential dissolution of metal contaminants in the tailings which may be transported to the receiving environment in the seepage).
3. Identify other locations at Meandu Mine where AMD is occurring; and to identify potential AMD source materials at Meandu Mine.
4. Determine the potential for AMD related environmental harm (acute and/or chronic impacts on the aquatic ecosystem and other relevant water quality objectives (WQO's)) that could occur from future (ongoing) activities at Meandu Mine, including potential impacts from:
 - Build-up of metals in sediment downstream of Meandu Creek Dam
 - Elevated metal concentrations in Meandu Creek waters
 - Alteration of the pH of Meandu Creek Dam waters and release of sediment bound contaminants to the downstream environment
 - Elevated salinity levels in Meandu Creek waters.

To address the requirements of the Notice, Stanwell has commissioned an Environmental and Engineering Evaluation into AMD at the Meandu Mine site. This investigation incorporates studies across a range of technical disciplines including:

- Mine planning historical and life of mine (future) (Xenith Consulting)
- Material classification assessments (geochemical) (RGS Environmental Pty Ltd)
- Hydrogeological assessments (JBT Consulting)
- Surface water quality, sediments and aquatic ecology investigations (Ecological Services Professionals Pty Ltd)
- Water modelling and development of engineering solutions (Golders Associates Pty Ltd) (this assessment).

The integrated water model, that is the subject of this report, is a predictive model for Meandu Mine in relation to potential AMD impacts developed to provide information relevant to the development of:

- Mine material management plans
- Mine water management plans
- Landform and rehabilitation management plans
- Closure plans.

The model has been developed with components that represent the following EEE Project requirements:

- *A material model based on geochemical characterisation.*
- *Mine water modelling that includes representation of surface water, groundwater and in pit and in mine spoil water.*
- *Potential contaminant pathways.*

- *Capacity to predictively model acid production at Meandu Mine.*
- *Capacity to predictively model the dissolution and transport of metals to the receiving environment from Meandu Mine.*
- *Capacity to predictively model water quality impacts from AMD on groundwater and Meandu Creek.*

Stanwell is committed to proactive long-term resolution of the AMD issue and development of potential engineering options that may be implemented at Meandu Mine to mitigate any potential environmental impacts associated with AMD. Some initial measures have been made by Stanwell to manage AMD including interim lime dosing and changes to monitoring and operations. Further changes are potentially required to the way mining, mine waste, mine water, landform design and rehabilitation are managed at Meandu Mine.

1.2 Purpose of the Integrated Water Model

The purpose of the model is to:

- Simulate the surface water, groundwater and geochemical components of the Meandu Mine environment to estimate the AMD potential using the 2017 Life of Mine Plan (prepared by Xenith Consulting) which depicts mining from 2016 to a nominal closure date of 2037. This is designated the base case.
- Once the base case AMD potential is estimated using the model, the model will then be used as a tool to trial engineering controls and management measures, where required, to mitigate potential AMD impacts (scenario trials).

1.3 Information sources

The work contained in this report commenced in January 2017 following issuing of the Notice. Data and information for the development of the model has been supplied by Stanwell, sourced directly from Meandu Mine operations or in collaboration with other technical specialist studies. Details of the source data and information for every component are provided in the discussion of model inputs and assumptions in Section 4.0 of this report.

The Base Case scenario described in the model is based on the 2017 Life of Mine plan and includes any control measures that have been implemented by Stanwell prior to 2018 including the construction of RD27 with continuous lime dosing of low flow inflows to RD27; and the change to high density tailings, removing the tailings slurry flow input to NWB tailings and reducing water demand at the CHPP. Additionally, the base case includes anticipated changes to water infrastructure required during the life of mine that will be required to support the 2017 Life of Mine Plan.

Trial scenarios have engineering controls and management measures to mitigate potential AMD impacts applied to the 2017 Life of Mine Plan.

The continuation of control measures and water quality sampling and monitoring beyond these date ranges is acknowledged.

- ★ Compliance Points
- Watercourses
- Mining Lease
- Site Dams**
- Site Features

0 1,000 2,000
METRES
SCALE: 1:30,000
PROJECTION: GDA 1994 MGA Zone 56

CLIENT
STANWELL CORPORATION

CONSULTANT



YYYY-MM-DD	2018-02-23
DESIGNED	BG
PREPARED	BG
REVIEWED	MH
APPROVED	MH

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PROJECT
ENVIRONMENTAL AND ENGINEERING EVALUATION PROJECT
- INTEGRATED WATER MODEL

TITLE

SITE LAYOUT

PROJECT NO.	CONTROL	REV.	FIGURE
1665629	002	0	01

2.0 BACKGROUND

2.1 Hydrologic setting

Meandu Mine is located within a rural area adjacent to the Yarraman State Forest. The Tarong and Tarong North power stations (owned and operated by Stanwell) are located immediately to the north of the mine. Land use regionally is characterised by forestry, grazing and cropping land, mining and power generation, and remnant and regrowth vegetation.

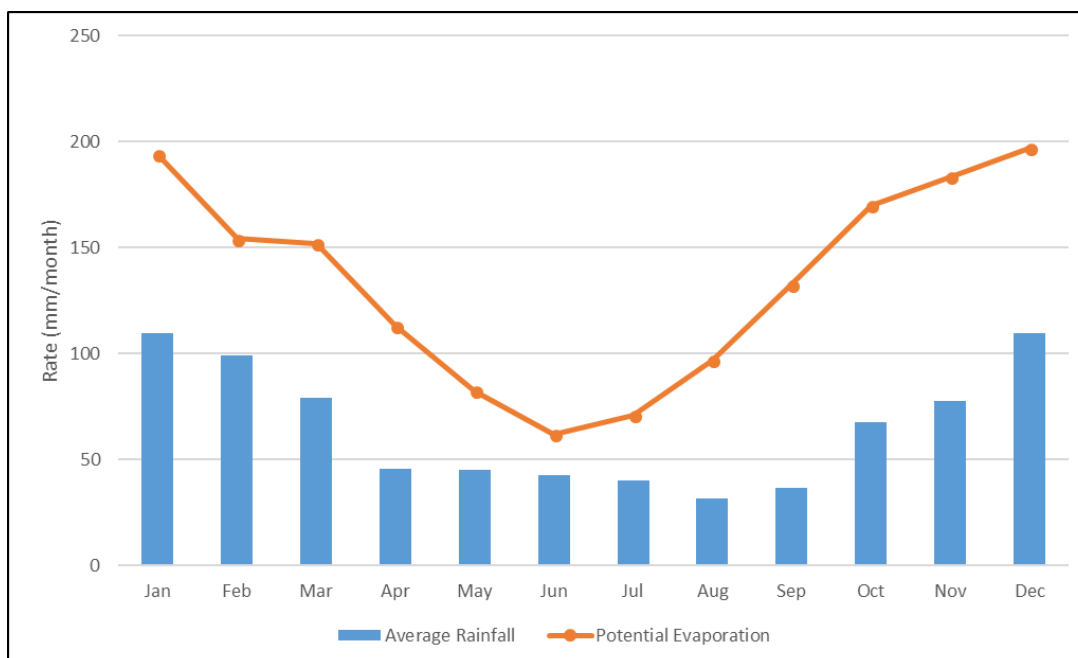
The mine is located within the headwaters of the catchment of Meandu Creek, within the Burnett River Basin. Meandu Creek is an ephemeral watercourse near to the western boundary of the mining lease. The natural landform in the location of the mine slopes gently from the south-east to the north-west towards Meandu Creek.

2.2 Local and regional climate

Meandu Mine lies within the subtropical climate zone, as classified by the Bureau of Meteorology (BoM, 2018a). The Australian subtropical climate is seasonal with the highest rainfall and evaporation occurring during summer months.

Historical rainfall data was obtained from the BoM for Station 040199 Tarong, located approximately 8 km from Meandu Mine. The data record is available for the period September 1920 to present and the metadata indicates records are 99% complete. On average, approximately 60% of rainfall occurs between November and March at Tarong (Figure 2).

Additional climate data was also obtained from the Queensland Government's Scientific Information for Land Owners (SILO) Data Drill (Queensland Government, 2018). The Data Drill accesses grids of data interpolated from point observations by the BoM including evaporation records. The SILO data was obtained for location latitude -26.8, longitude 151.9. Potential evaporation exceeds rainfall in all months (Figure 2).

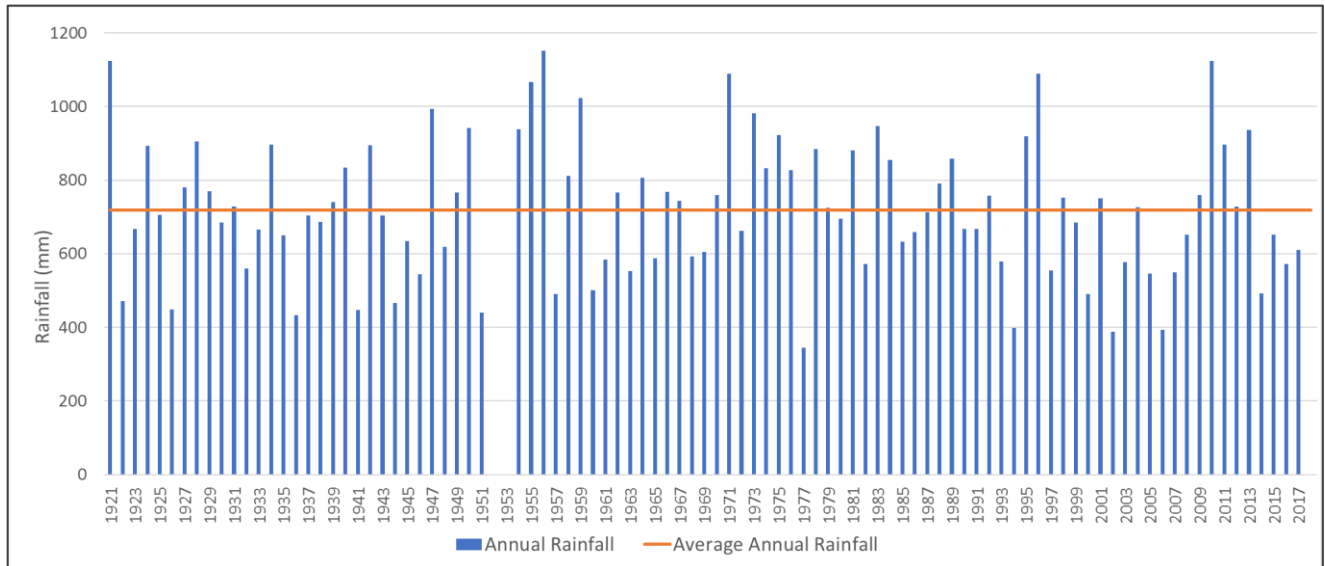


Rainfall: BoM Tarong (Stn. 040199) Average of 98 years of record 1920 – present. 99% data completeness.

Potential Evaporation: SILO data Location Latitude -26.8, Longitude 151.9. Average of 48 years of record 1970 - present

Figure 2: Measured average rainfall and potential evaporation at Tarong

Annual rainfall is variable (Figure 3). On average, measured annual rainfall is 719 mm and historically interannual variability has ranged between 344 mm (in 1977) and 1152 mm (in 1956). Sequential wet or dry years are attributable to the influence of El Nino / Southern Oscillation (ENSO) effects.



Rainfall: BoM Tarong (Stn. 040199) Average of 98 years of record 1920 – present. 99% data completeness. Missing data in 1951 – 1952.

Figure 3: Measured annual rainfall

2.3 Mine water management system

Meandu Mine includes five active mining areas and a tailings storage facility. Coal is processed in the mine Coal Handling and Preparation Plant (CHPP) and transferred to the adjacent Tarong and Tarong North power stations and ash is returned for storage in a remnant pit. Runoff water from disturbed areas as well as pit water is directed to a series of retention dams, from where recycled water is sourced for the CHPP. Runoff in excess of CHPP requirements is discharged into Meandu Creek just upstream of the inlet to Meandu Creek Dam. Meandu Creek has been diverted to allow for the mining of coal and runs the length of the site from south to north where it enters Meandu Creek Dam.

Mining is progressing from west to east and the 2017 Life of Mine Plan indicates mining will continue till 2037. Detail of the current and future mine water management system is provided in Section 4.0.

3.0 MODEL OVERVIEW

3.1 GoldSim software

The model has been developed in GoldSim (Vers.12.0) (GoldSim Technology Group, 2018). GoldSim is used globally to simulate dynamic systems, to understand the factors which control the system and to forecast the future behaviour. Any system that can be quantitatively described using equations and or rules can be modelled using GoldSim.

GoldSim models are composed of containers and functional elements such as inputs, expressions, stocks, events, delays, cell pathways and results. Each functional element forms part of the model structure which is developed specifically for a particular modelled system, such as the Meandu Mine. The calculations within and relationship between functional elements are built by the modeller. Input data is either stored within the model or uploaded from a spreadsheet by the model at the start of each simulation and can come in the form of a scalar value, a vector or a matrix.

Model simulations are run generally on daily time-steps over an identified simulation period with one or multiple realisations. A realisation is defined as a single model run under one set of stochastic inputs. The purpose of using multiple realisations is to test the system under multiple rainfall or other input patterns.

Model dashboards are created to assist the model user with required inputs, running the model and viewing results. It is possible to run a model that has user input and result dashboards using a freeware version of GoldSim, the GoldSim player.

3.2 Spatial extent of the model

The spatial extent of the model, defined in collaboration with Stanwell for the EEE Project, includes all the elements of Meandu Mine bounded by Meandu Creek Dam and CP2 to the north, Meandu Creek to the west, the extent of the mine catchment to the east and the extent of the Meandu Creek catchment to the south.

Model elements represented within the model boundaries include:

- water reservoirs (dams, tailings storage areas, ash storage areas, operating pits, decommissioned pits, back-filled pits)
- inflows (rainfall, catchment runoff, water in tailings, water in ash, pumped water between mine dams, pumped inflows across model boundaries, seepage, groundwater inflow to deep pits, mine impacted water expressed from back-filled pits)
- outflows (evaporation, overflows from water storages, seepage, pumped water between mine dams, pumped outflows across model boundaries, truck-fill water use, mine impacted water expressed from back-filled pits)
- Meandu Creek streamflow.

3.3 Temporal extent of the model

The model simulations use a daily time-step for the period 2016 to 2050 (post closure) for three scenarios using a low rainfall data record, a median rainfall data record and a high rainfall data record (based on SILO data drill 120-year synthetic rainfall data records for the location of Meandu Mine). Rainfall records used for the simulation are described further in Section 4.3.1.

Changes in the model components as a result of progression of the mine development (such as, changes in material placement and related changes in catchments or rehabilitation) are applied according 2017 Life of Mine plan in a step-wise manner in the years 2016, 2018, 2019, 2020, 2022, 2024, 2027, 2029, 2032, and 2037.

3.4 Summary of model development

3.4.1 Conceptual model

Three model conceptualisations (representing surface water, groundwater and materials/ geochemistry) were prepared in collaboration with Stanwell, JBT Consulting and RGS prior to development of the integrated model in GoldSim. Conceptualisations are shown for an arbitrary two-dimensional cross section of the modelled three-dimensional network. Schematics of the inflows and outflows represented in each conceptual model are provided in Figure 4. The integration of the conceptual models provided the framework for subsequent model development.

3.4.1.1 Surface Water Conceptual Model

The surface water module developed within the integrated model includes representation of the surface water features within the model spatial extent (discussed in Section 3.2). The surface water module includes representation of water storages and voids (all features that will retain water) including water storage dams, raw water dams, retention dams, tailings voids, ash voids, active pits, and inactive voids. Inflows to the surface water model include rainfall and runoff, water retained in tailings and ash, and water expressed at the surface from water retained in below-surface voids (discussed in Section 3.4.1.2).

The surface water conceptual model includes the detail and features found in a mine water balance, the balance using the site layout described in Section 4.1. Surface features within the Meandu Mine are dynamic, changing as the mine progresses during operation and closure. Similarly, the model representation of surface water features changes over the life of mine operations and closure.

3.4.1.2 Groundwater Conceptual Model

Water contained within, and inflows to and outflows from, the particle void spaces of materials in historical mining voids (mine impacted water) is modelled in a groundwater module component of the integrated model. The groundwater module includes representation of historical mine voids as shown in Figure 4. Each void has an associated elevation-mine impacted water storage capacity relationship and a spill point from where (when “overflowing”) mine impacted water enters the surface water conceptual model domain as water expressed from below-surface back-filled voids.

Other flows within the groundwater conceptual model include seepage flow into waste deposition areas from surface recharge during rainfall and groundwater inflow to deep mining pits.

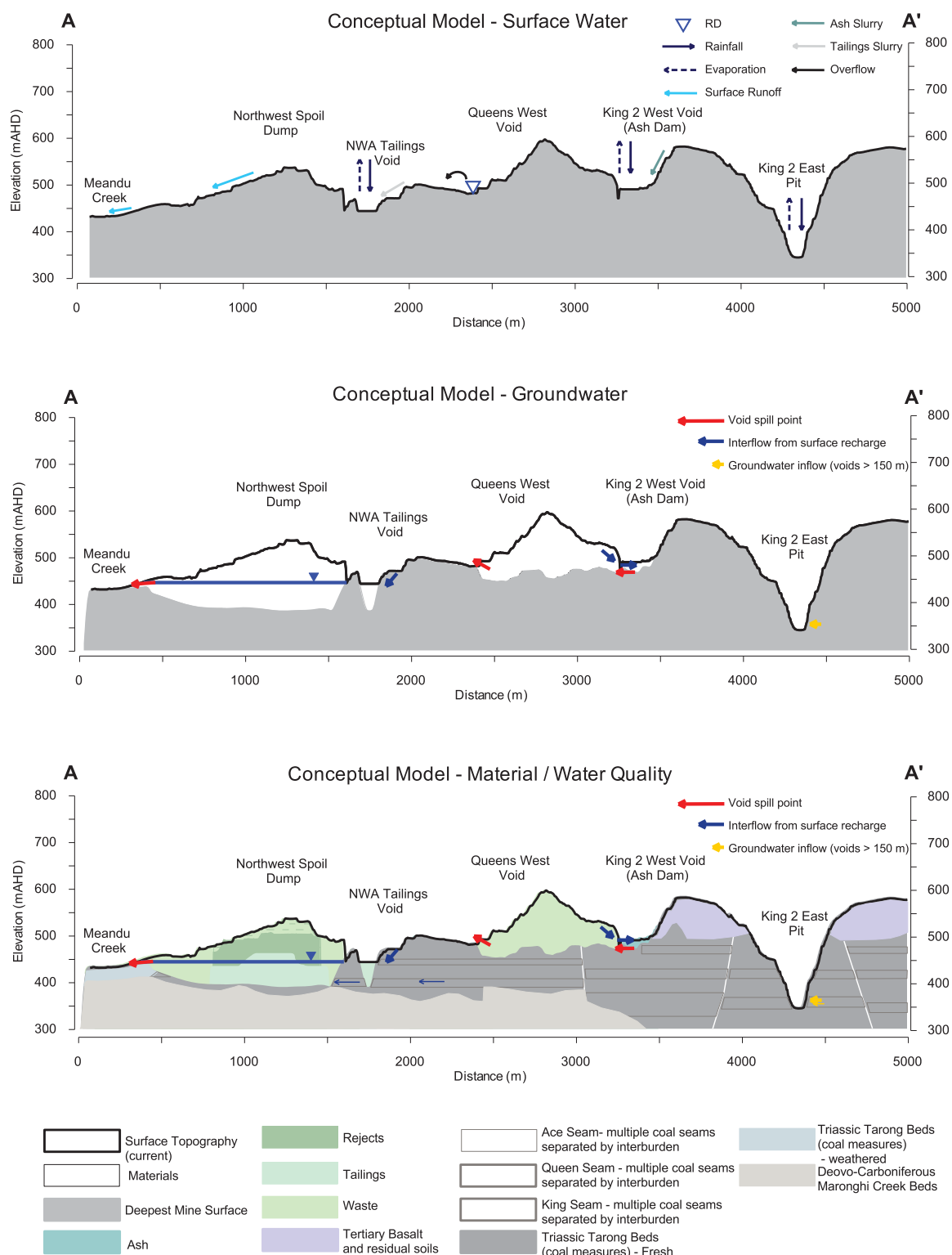
Further detail is provided regarding the groundwater components of the integrated model in Section 4.0.

3.4.1.3 Materials / Water Quality Conceptual Model

The third module within the integrated model represents the water quality components. Each of the materials within the below-surface placed materials and the units in the overburden will have different acid and salinity generating potential in the water associated with them. Additionally, over time the acid and salinity generating potential of a material changes.

AMD drainage potential in the materials and overburden have been modelled as vectors of elements attached to each of the materials, overburden and water flows in the surface and groundwater modules. The material and water quality components of the model are detailed in Section 4.6.

Water quality has been modelled in the integrated model using a mass balance mixing model approach, that is, by dilution or concentration of the modelled elements. At any point in time and from any model component (for example, a model component may be the ash void, or overflow from the North West Back-Filled Pit (NWBFP) or a retention dam) the mixed solution may be retrieved for further assessment of chemical reactivity-.



Material additions occur in a step-wise fashion each month. With each sequential addition of materials an associated step change occurs in quantity and age of materials and the associated water quality.

Material classifications include:

- Ash – fly and bottom ash produced at the Tarong and Tarong North power stations through the burning of product coal from Meandu Mine.
- Rejects – oversized or poor-quality material hauled from the CHPP.
- Tailings – fine fraction washed from the coal in the CHPP that reports to the tailings thickener and is then pumped as a slurry to mined pits (voids) at a solids concentration of 15 to 25%.
- Waste – side cast waste coal, roof and floor and partings, and over or inter-burden.

3.4.2 Modelling method and development

Following confirmation of the conceptual models and model specification the integrated model was developed in GoldSim. Elements representing climate, global parameters and parameters specific to surface water, groundwater and materials/water quality modules have been incorporated, referenced and linked.

Calibration and validation simulations were conducted using measured site data for the period 2016 (calibration) and 2017 (validation). A sensitivity analysis was undertaken for selected results that are influenced by input parameters that are either assumed or uncertain.

The base case model incorporates any control measures that have been implemented by Stanwell prior to 2018 including:

- RD27 and associated infrastructure including lime dosing from the beginning of 2018.
- The change to high density tailings from 2018.

Additionally, the base case includes anticipated changes to water infrastructure required during the life of mine to support the 2017 Life of Mine Plan.

3.5 General capability and use

The model estimates the quantity and quality of water stored, transferred and discharged, over the life of mine up to and including closure. It provides a water balance within the model boundary which is the extent of the catchments reporting to the model components along with an indication of changes in water quality (mass balance of key analytes).

The model has the capacity to forecast:

- Water containment in pits and water storages reported in terms of volume and water level.
- Rates of water transfer and water quantity transferred between storages.
- Quantity of water released at key discharge locations and compliance points.
- Quantity of groundwater intercepted by mining pits.
- Water quality (mass balance of key analytes) of retained water within pits and water storages.
- Water quality (mass balance of key analytes) at compliance points.
- Runoff from catchments in response to rainfall and evaporative losses.
- Changes in flow quantities to the Meandu Mine water infrastructure as a result of operational change and at closure.
- The reliability of water supply to the CHPP.
- Water used at truck fill points.

3.6 Model limitations

The model is a representation of the Meandu Mine water management network simulated on a daily basis using input data from reference sources and calibrated for a period of time to measured site data. It is designed as a decision-support tool for estimating long-term trends and has the following limitations:

- Operational decisions in mine water management made on a day to day basis (such as, turning on/ off of pumps to change dewatering supply to retention dams and the CHPP; or emptying and desilting of a retention dam) are not able to be represented in the model.
- Pumped transfers, such as the dewatering of pits and water supply to the CHPP are calibrated to long-term total flow rates and may not represent the day to day variability in supply that occurs due to process operator inputs and scheduled and unscheduled maintenance.
- Water quality is modelled as a mixing model of a group of analytes as they migrate through the system with the flow of water. Chemical reactions between analytes have not been simulated in the model but may be simulated externally to the model for specific locations if required. Further detail about water quality inputs is provided in Section 4.6.

4.0 BASE CASE MODEL INPUTS AND ASSUMPTIONS

4.1 Model structure

The operational processes of the Meandu Mine are represented in the model and details of the model components are described in the sections below.

A high-level container view showing the site features represented in the model is provided in Figure 5.

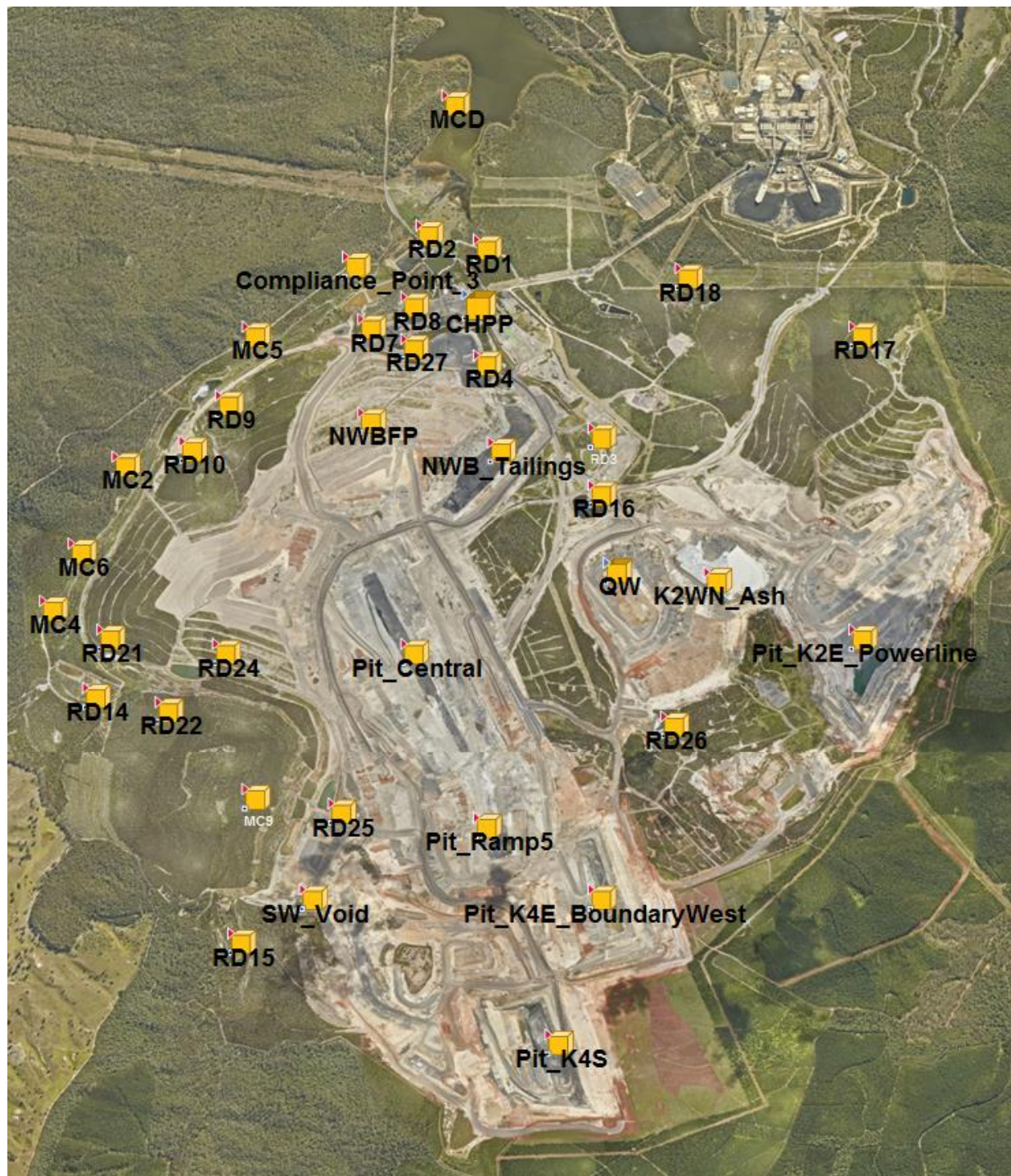


Image: Stanwell December 2017 (in mga56_meandu_merged_1712_100)

Figure 5: High level container view of the model

4.1.1 Process flow

All components represented in the model are shown in the block flow diagrams provided in Figure 6 and Figure 7. The inclusion and connectivity between mine infrastructure will change over time as the mine progresses. As a result, block flow diagrams are provided for two snapshots in time – the first in 2016 at the start of modelling, and at year 2027 once mining has progressed to the east.

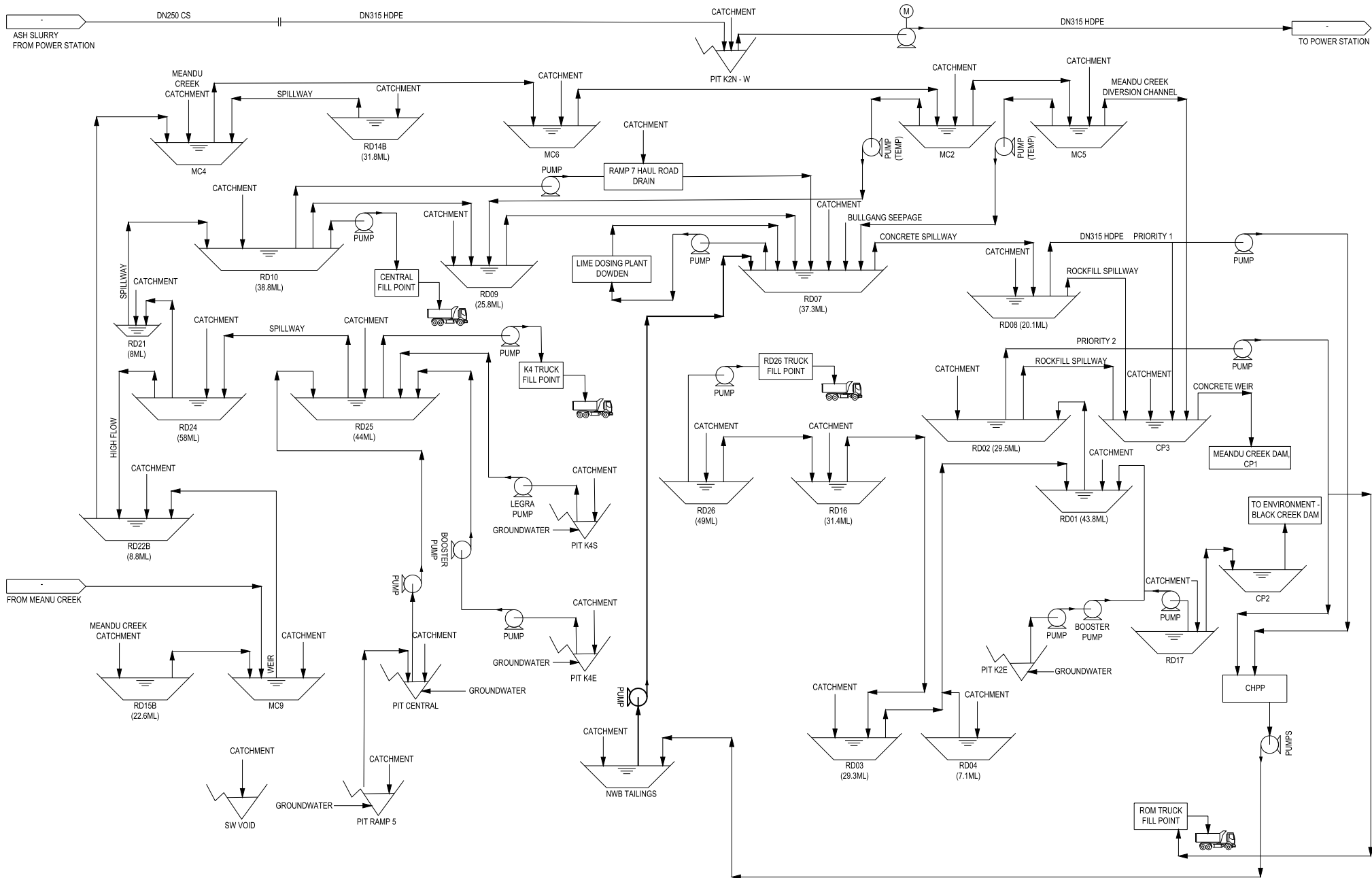
Components of the modelled system as shown in the block flow diagram for 2016 (Figure 6) include:

- Active mining pits – Central, Ramp 5, K4E (Boundary), K4S, K2E.
- Tailings storage facility – NWB-TSF.
- Ash storage facility – K2W-N.
- Retention dams (RDs) – RD1, RD2, RD3, RD4, RD7, RD8, RD9, RD10, RD14A, B and C, RD15B, RD16, RD17A and B, RD18, RD21, RD22B, RD24, RD25, RD26.
- Out of pit dumps – NWBFP, QW.
- Meandu Creek ponds – MC2, MC4, MC5, MC6, MC9
- Meandu Creek Dam.
- Compliance points – CP1, CP2, CP3, CP4.
- Truck fill locations – Central, K4S, Sparrows, ROM.
- CHPP.
- Catchments reporting to pits and retention dams.
- SW void.
- Pumped and piped or spillway connections between pits and retention dams and between retention dams.

As the mine progresses, in accordance with the 2017 Life of Mine Plan, the following changes in infrastructure are anticipated and have been assumed in the model:

- The SW void and K4S fill point will be decommissioned in 2022. The SW void will be filled and rehabilitated. Once rehabilitated the drainage flow path to the SW void will become catchment runoff to Meandu Creek at MC9.
- The recently completed RD27 will be operational from 2018.
- The NWB tailings void would start being decommissioned in 2018 (corresponding to the commissioning of the solid bowl centrifuge that produces dewatered mixed plant rejects); and filled and capped by 2024.
- Central Pit is no longer active after 2025 and from 2026 starts receiving ash from the Tarong and Tarong North power stations. K2W-N will be covered and rehabilitated at this time.
- RD26 will be re-located (that is, replaced by a new RD26) when current RD26 is consumed by K4E (Boundary) Pit.
- K2E is active from 2024. Before this time K2E stores water that is used to top up RD26 or RD2 as required.
- The central fill point will close around 2024 at which time a new fill point of similar capacity will start from the relocated RD26.
- A block flow diagram for a snapshot in time in year 2027 is provided in Figure 7.

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REV.	YYYY-MM-DD	DESCRIPTION				DESIGNED	PREPARED	REVIEWED	APPROVED

CLIENT
STANWELL CORPORATION LIMITED

CONSULTANT



BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
+61 (7) 3721 5400
www.golder.com

PROJECT
MEANDU MINE ENVIRONMENTAL AND ENGINEERING
EVALUATION PROJECT

TITLE
**BASLINE MODELLED WATER MANAGEMENT SYSTEM
BLOCK FLOW DIAGRAM 2016**

PROJECT NO. 1665629 CONTROL 002 REV. A FIGURE 006

4.1.1.1 Pits

Elevation-area-storage curves for pits were developed from life of mine landform data supplied by Xenith (in Pit Shells_FY2018. 00t – Pit Shells_FY2037. 00t). Each of the pits is represented as a “reservoir” element in the model with inflow, outflow and geometry modules. Changes in pit shape and size over the life of mine is represented in the model using 2-dimensional (2-D) lookup tables for the reference years 2016, 2018, 2019, 2020, 2022, 20204, 2027, 2029, 2032, 2037, and 2050. The model linearly interpolates elevation-area-storage information for years not included in the 2-D lookup tables.

Inflows include:

- Catchment runoff including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces, as described in Section 4.1.2, that will report to the pit void.
- Direct rainfall (direct to the surface of retained water in the active pit sump or water held in an inactive pit water storage).
- Surrounds runoff (rainfall that falls within the dynamic area of an active pit).
- Seepage from waste (spoil and rejects).
- Pumped transfers in from other pits (for example, water transferred from Ramp 5 Pit sump to Central Pit sump).
- Groundwater inflow (as described in Section 4.3.3).

Outflows include:

- Evaporation (from the surface of retained water in the active pit sump or water held in an inactive pit water storage). Evaporation is described in Section 4.4.1.
- Seepage (seepage from retained water in the active pit sump or water held in an inactive pit water storage). Seepage is described in Section 4.4.4.
- Dewatering active pits or pumped transfers from water stored in inactive pits, as described in Section 4.5.1.

Relevant changes to the pit geometry over the Life of Mine are provided in Table 1.

Table 1: Life of Mine changes in pit geometry

Parameter	Central	Ramp 5	K4S	Boundary West	K2E
Maximum depth (year)	2018	2018	2024	2029	2037
Maximum depth (m RL)	375	370	403	335	312
Receiving first waste to void (pump off) (year)	2026	2021	2025	-	2029
Filled void	2037	2029	2032	-	-

4.1.1.2 Retention dams

Each of the retention dams within Meandu Mine are represented in the model as a “reservoir” element. The geometry module for retention dams is based on information provided by Stanwell in the dam register (4868-SE-F1062 - Meandu Mine Site Dam Register - 14 October 2016.xls) including capacity, surface area, maximum

water level, and water depth. Elevation-storage-area details of each storage have been calculated at 0.5 m increments from the information provided and assuming a standard square pond geometry.

Inflows to retention dams include:

- Direct rainfall (to the water surface).
- Surrounds runoff (rainfall to the remaining area of the water storage at the crest of the dam).
- Catchment runoff including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces, as described in Section 4.1.2.
- Pumped water transfers received by a retention dam, as shown in the block flow diagrams (Figure 6 and Figure 7).
- Overflow received from other retention dams, as shown in the block flow diagrams (Figure 6 and Figure 7).

Outflows from retention dams include:

- Evaporation (directly from the water storage), as described in Section 4.4.1.
- Seepage (seepage from retained water in the retention dam storage), as described in Section 4.4.4.
- Truck fill points for water for dust suppression, as described in Section 4.4.3.
- Pumped transfers as shown in the block flow diagrams (Figure 6 and Figure 7).
- Overflows as shown in the block flow diagrams (Figure 6 and Figure 7).

4.1.1.3 Meandu Creek Dam

Elevation-area-storage data was supplied by Stanwell (*in Meandu_Dam_2014.xls*) detailing bathymetric survey data at 0.1 m elevation increments measured in February 2014. The spillway invert elevation used in the model is 418.1 m RL.

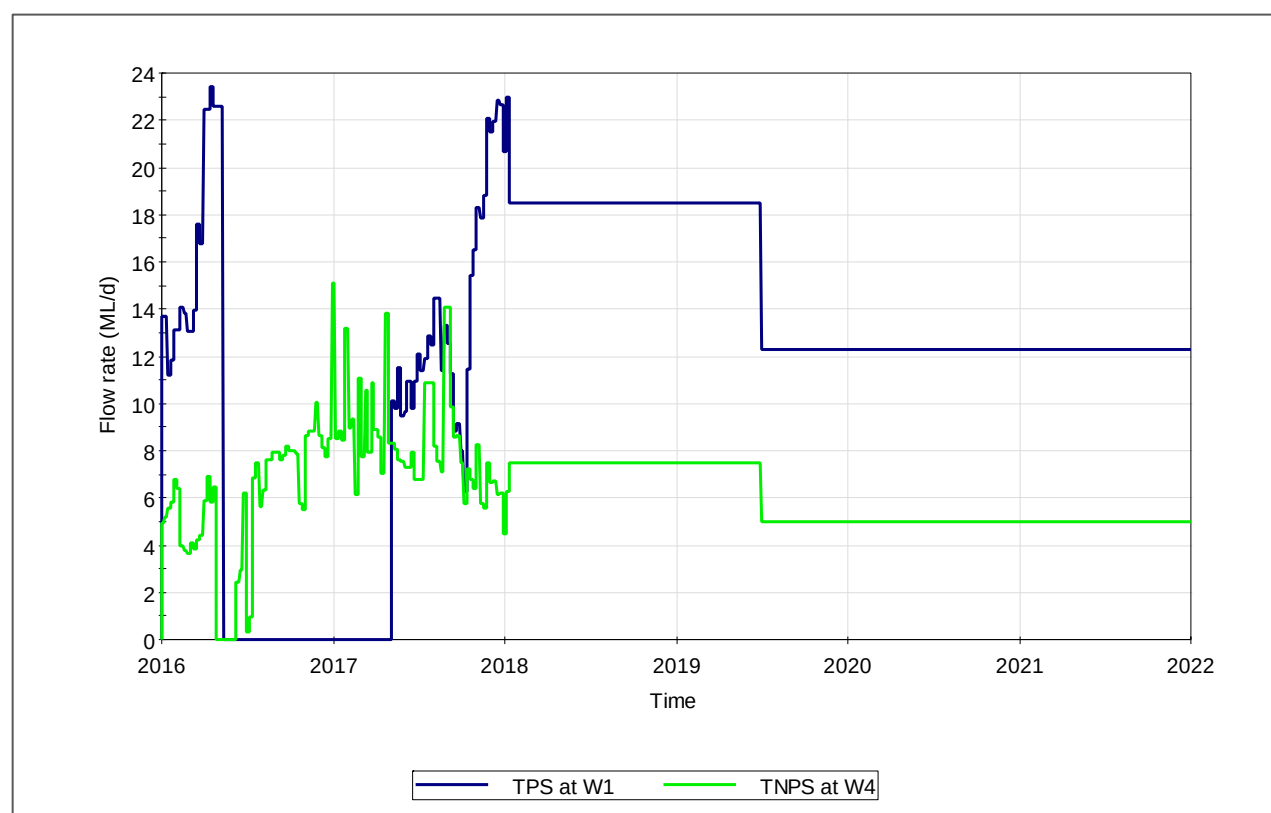
Inflows to Meandu Creek Dam include:

- Direct rainfall (to the water surface).
- Surrounds runoff (rainfall to the remaining area of the water storage at the crest of the dam).
- Catchment runoff (to the catchment including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces, as described in Section 4.3.2).
- Overflow from CP3 (the receiving point for discharge from Meandu Creek and Meandu Mine)
- Cooling water blowdown inflow from Tarong Power Station (W1) and Tarong North Power Station (W4) (measured data received from Stanwell *in Discharges ML per day.xlsx and Updated Discharges ML per day.xlsx*) for the period January 2016 to January 2018. For predictive modelling, the cooling water blowdown inflows and rationale for the assumptions (supplied by Stanwell via email of 12 January 2018) are provided in Table 2.

Table 2: Assumed cooling water blowdown water to Meandu Creek Dam

Years	Tarong Power Station blowdown to Meandu Creek Dam (ML/day)	Tarong North Power Station blowdown to Meandu Creek Dam (ML/day)
January 2016 – January 2018	Input is the weekly measured data at location W1. Average daily flow over the period of record is 7.7 ML/day.	Input is the weekly measured data at location W4. Average daily flow from this data record is 7.0 ML/day.
January 2018 – June 2018	22	6
July 2018 – June 2019	18.5	7.5
July 2019 – January 2038	12.3	5.0
January 2038 – end of simulation	0	0

The measured historical and assumed predictive blowdown water inflow until 2022 is shown in Figure 8. Tarong Power Station and Tarong North Power Station blowdown inputs were lower (and atypical) in 2016 and 2017 than those predicted for later years. In 2016 and 2017, recycling of blowdown water via the Tarong Ash Dam meant that less blowdown water was released to Meandu Creek Dam. From 2018 onwards, it is assumed that the option of recycling the blowdown water through the ash dam will no longer be available.

**Figure 8: Historical and assumed future blowdown water inflow to Meandu Creek Dam (shown up to 2022)**

Outflows from Meandu Creek Dam include:

- Evaporation (directly from the water storage), as described in Section 4.4.1.

- Seepage as described in Section 4.4.4.
- Flow release at location W3 (measured data received from Stanwell in *Discharges ML per day.xlsx* and *Updated Discharges ML per day.xlsx*) for the period January 2016 to January 2018. The assumed future flow release is the monthly average of the two years of historical record (shown in Figure 9).
- Overflow through the spillway.

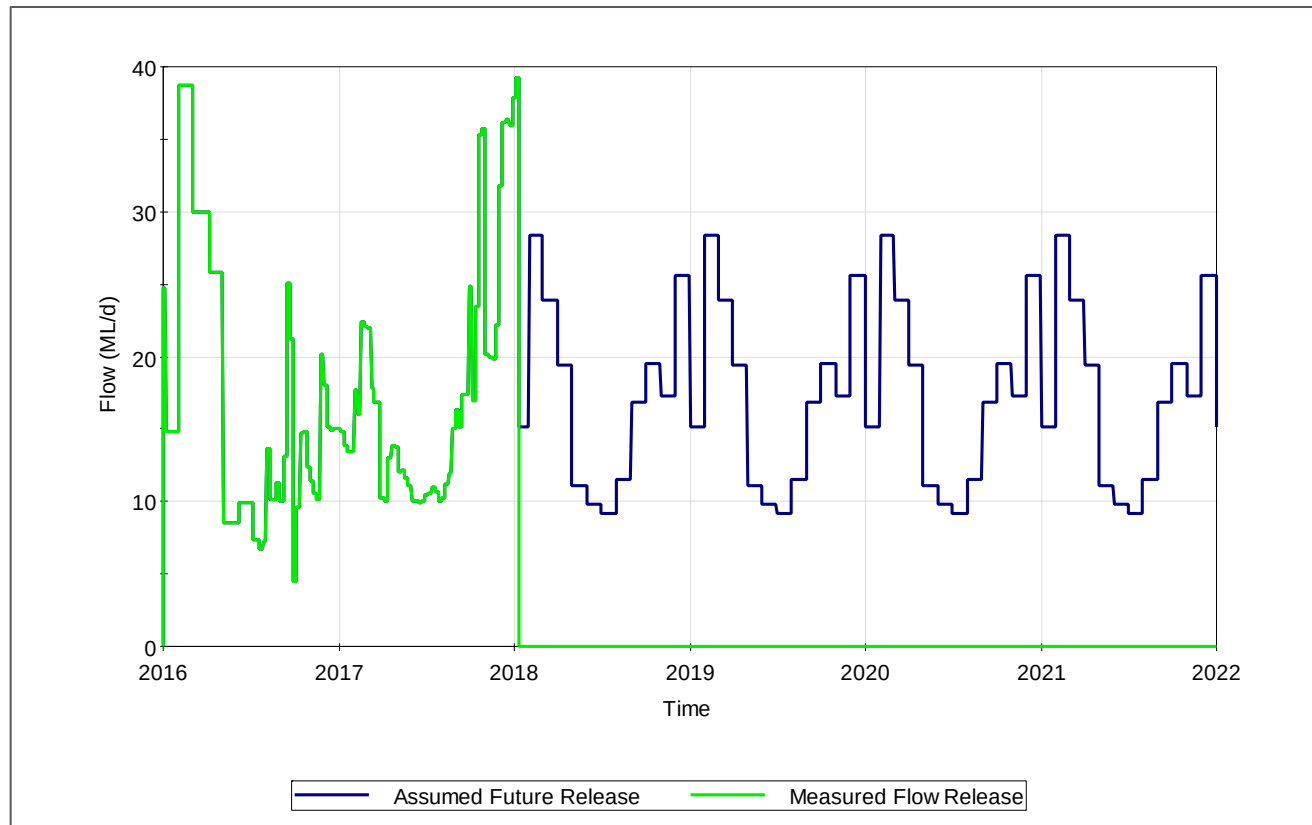


Figure 9: Historical and assumed future flow releases from Meandu Creek Dam (shown up to 2022)

4.1.1.4 North West Back-filled Pit

The North-West Back-filled Pit (NWBFP) is represented in the model as a reservoir with an elevation-area-storage relationship assuming a 30% available pore space for water within the deepest mined surface. Seepage discharge from the NWBFP in the location of Bullgang Corner has been conceptualised as originating from the NWBFP via the following flow sources:

- Infiltration from rainfall on the surface of the NWBFP.
- Seepage of water stored in the NWBFP.
- Seepage of water from the NWB tailings through the NWBFP.

A SEEP/W model has been used to estimate the water level – baseflow (seepage) relationship within the NWBFP. SEEP/W is used to analyse groundwater seepage within porous materials such as soil and rock. The groundwater model domain used for the SEEP/W model is based on the deepest mined surface (as shown in Figure 10). Cross-sections (two-dimensional vertical slices) were generated using historical material deposition data to examine the material distribution within the NWBFP (supplied by Stanwell in *3D Meandu Mine - LoM Ash, Rejects, Tailings and Waste.pdf*).

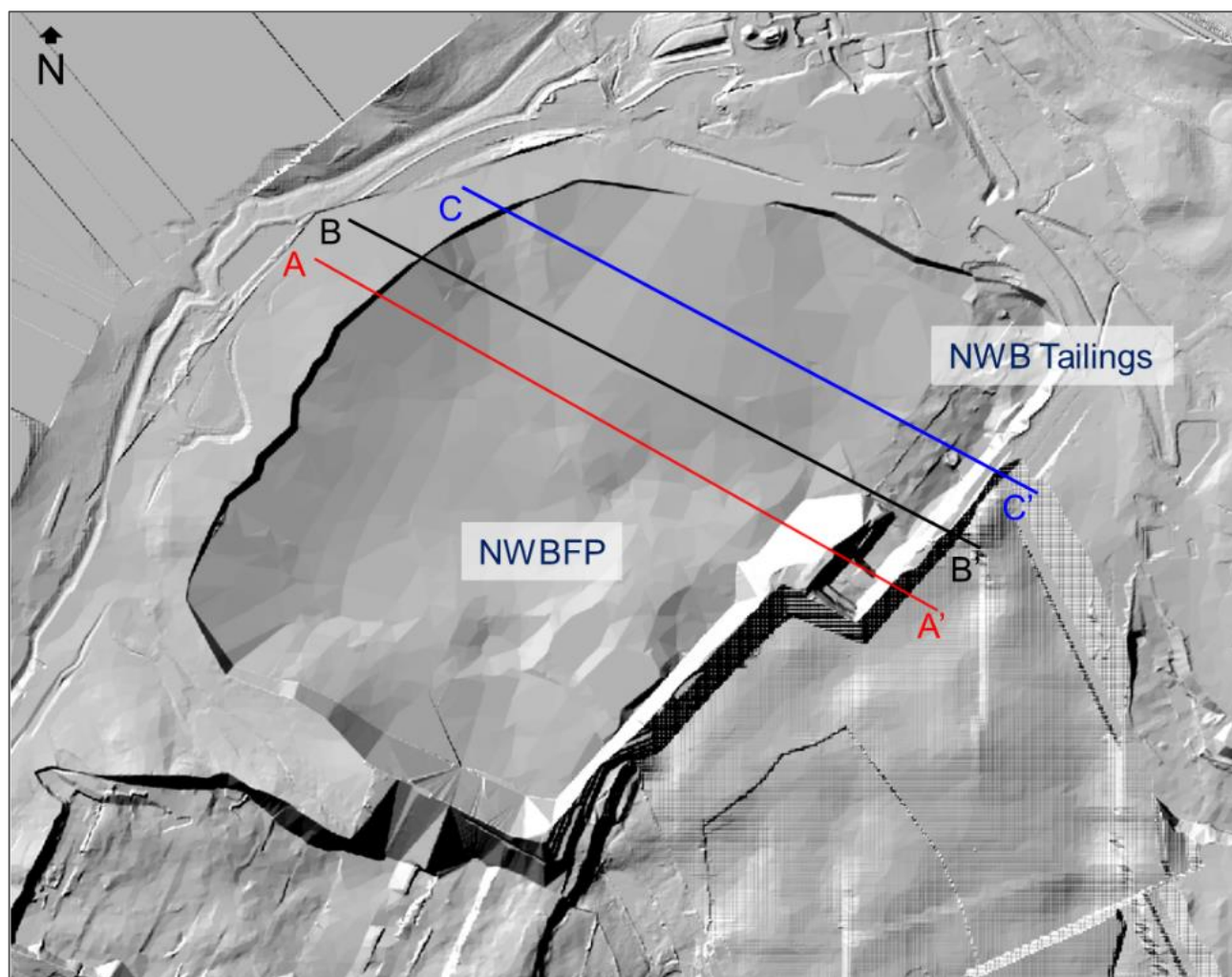


Figure 10: Deepest mined surface at NWBFP and NWB tailings

Cross-section AA' (Figure 11) shows that the deepest mined surface creates a flow barrier (up to 475 m RL) between the NWBFP and the NWB tailings. Cross-section BB' (Figure 12), situated slightly further north, shows how this barrier reduces in height northwards, until it merges with the deepest mined surface (Cross-section CC', Figure 13), allowing potential seepage from the NWB tailings into the NWBFP.

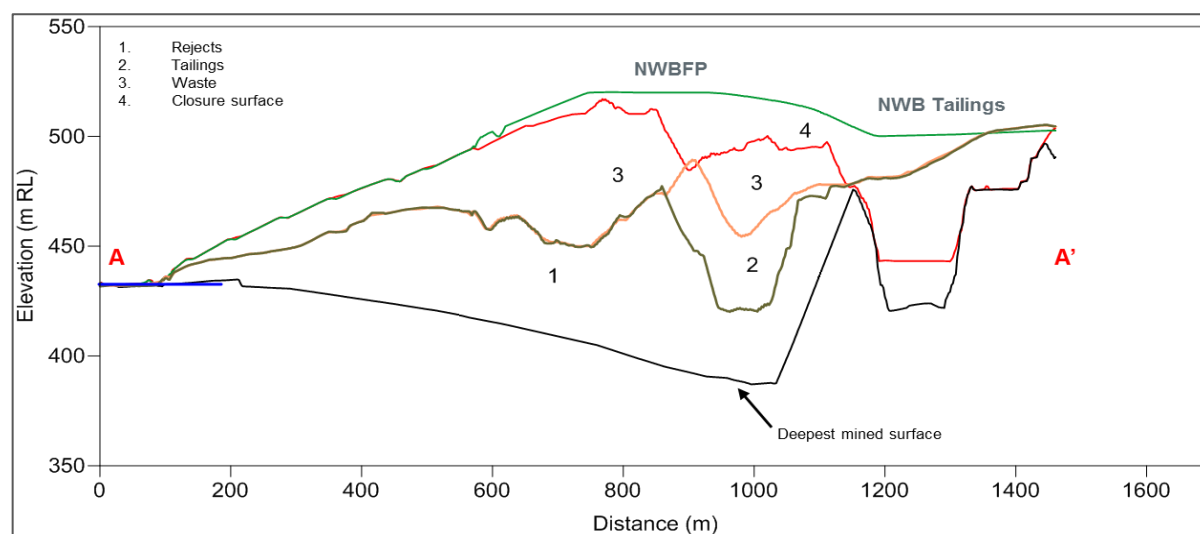


Figure 11: NWBFP cross-section AA'

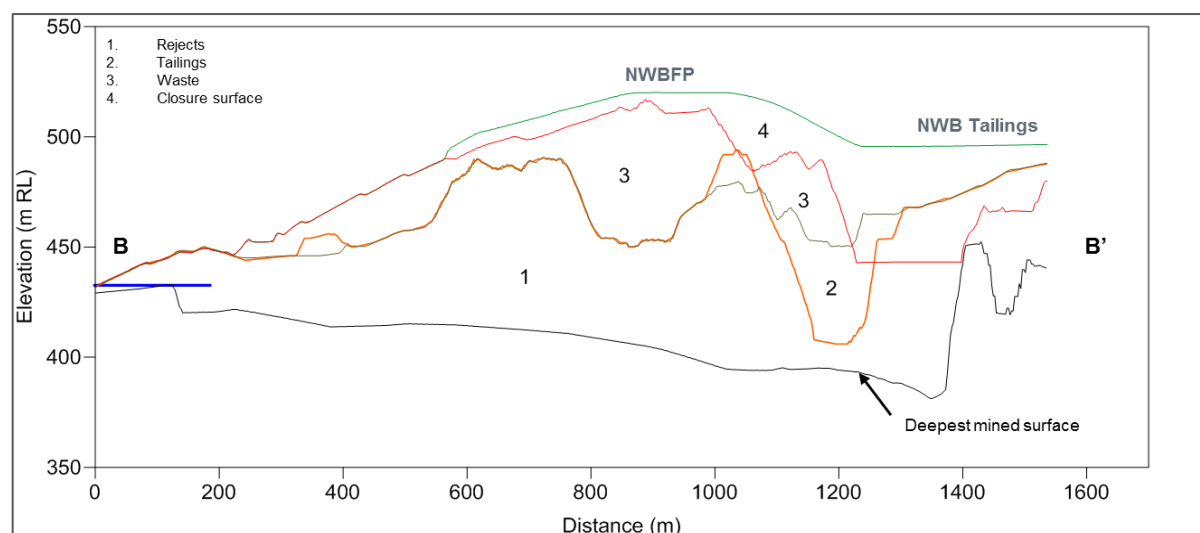


Figure 12: NWBFP cross-section BB'

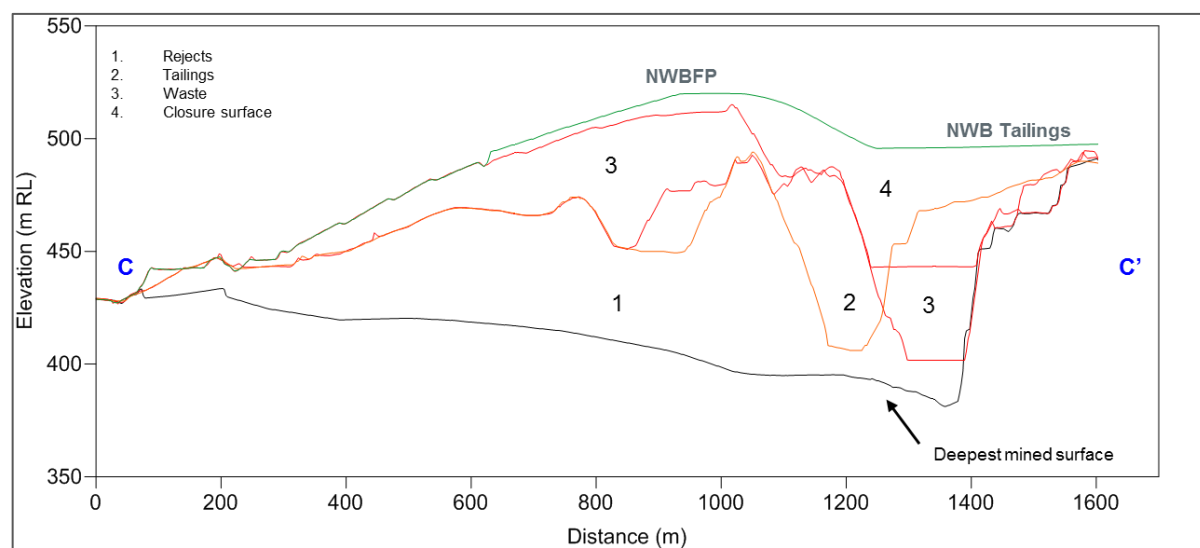


Figure 13: NWBFP cross-section CC'

A conceptualisation of the flow components that comprise seepage to Bullgang Corner is shown in Figure 14 and described as follows:

- The decant water in the NWB tailings specifies a (groundwater level) boundary condition at that end of the cross-sectional model. The boundary condition prescribes a corresponding “base” water level within the NWBFP which determines a baseflow out of the NWBFP. The baseflow is separated into diffuse seepage in the western wall / Ramp 7 area (above a spillpoint of 432 m RL) and seepage to Bullgang Corner (above a spillpoint of 435 m RL). NWB tailings is modelled as receiving tailings slurry until 2018; and is then in the process of rehabilitation until 2022.
- Additionally, rain falling on the surface of the NWBFP separates into surface runoff, interflow, and recharge to the water level within the NWBFP. Recharge to the water level within the NWBFP raises the NWBFP water level and will therefore increase the base flow component at the tipping point.
- Total seepage flow out of the NWBFP is the sum of interflow and base flow components.

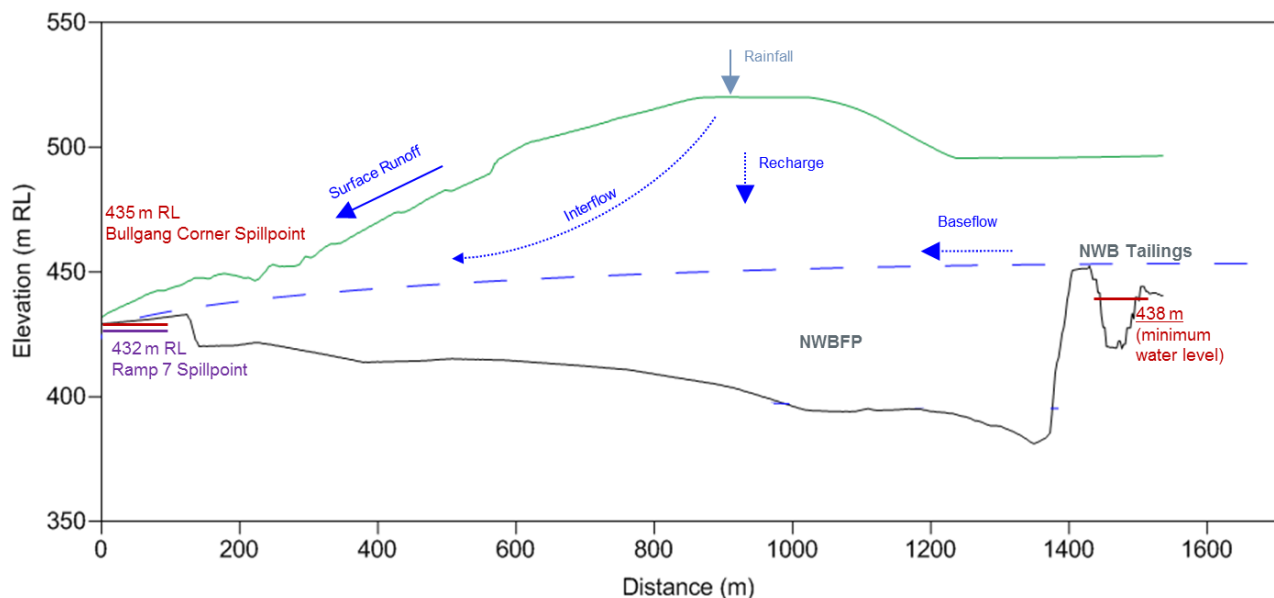


Figure 14: NWBFP water flow conceptualisation

The separation of rainfall into surface runoff, interflow and recharge is accomplished using the rainfall-runoff model AWBM (described in Section 4.3.2). AWBM separates rainfall into surface runoff and water that infiltrates into the NWBFP. Interflow is then set to be 30% of infiltrated water, with the remainder being recharge to the water level within the NWBFP. The relationship between the water level within the NWBFP and the corresponding base flow component has been estimated by two-dimensional (vertical slice) variably-saturated groundwater flow modelling using cross-section BB' (Figure 12) as follows:

- 1) The water level in the NWB tailings is specified as a constant head boundary condition.
- 2) The corresponding water level in the NWBFP (at the mid-point of the cross-section) was recorded.
- 3) The corresponding rate of seepage at the spill points at Ramp 7 and Bullgang Corner were recorded.

The above procedure was repeated using different values for the boundary condition to generate a NWBFP water level – baseflow relationship that could be then used in the water balance model. The groundwater modelling was conducted using industry standard software Seep/W (version 8.16, developed by Geo Slope International Ltd). The material parameter values used in the groundwater model have been taken from previous modelling studies at the site (Sherwood Geotechnical and Research Services, 2018) and are presented in Table

3). The NWBFP water level – baseflow relationship is shown in Figure 15. The relationship between the water level in NWB tailings and the water level in NWBFP is shown in Figure 16.

Table 3: NWBFP hydraulic conductivity

Spoil	Tailings	Rejects	Hard Rock
2.00E-06 m/s	2.0E-09 m/s	2.0E-05 m/s	5.0E-10 m/s

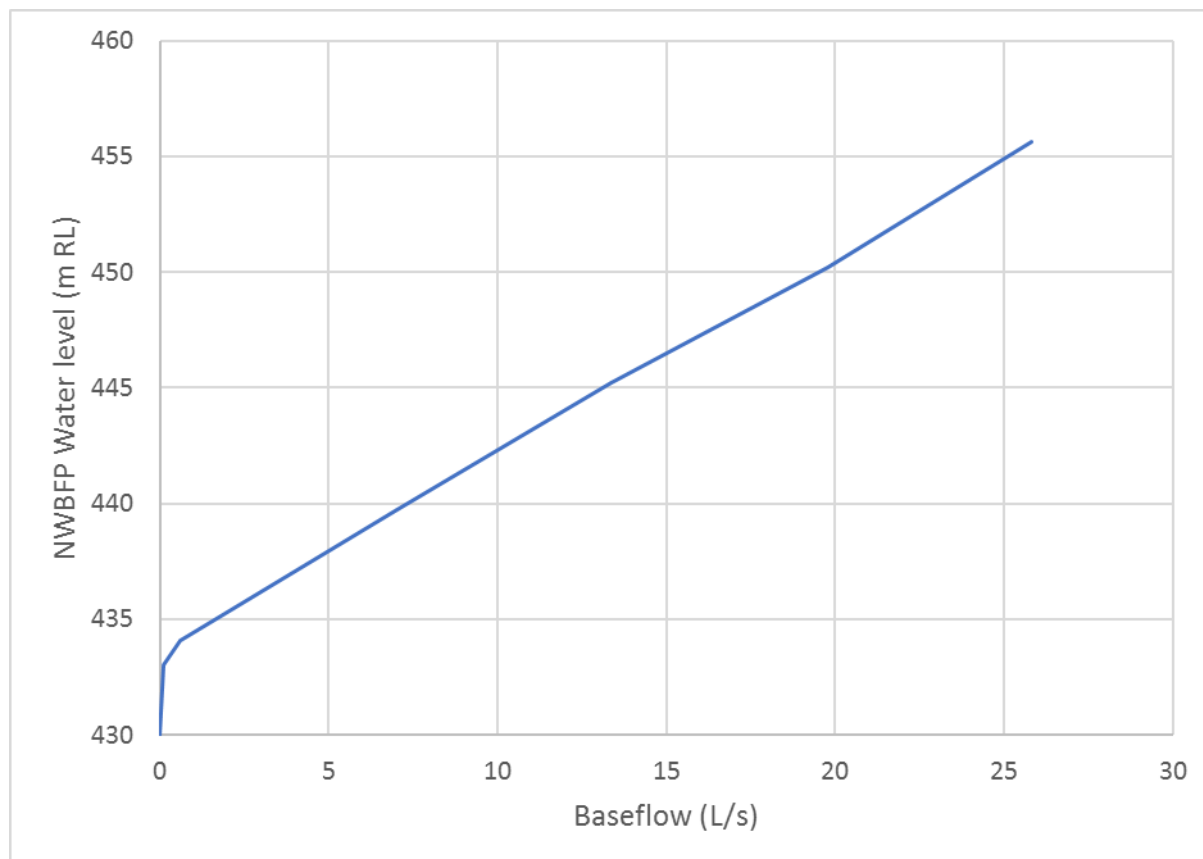


Figure 15: NWBFP Water level - baseflow relationship

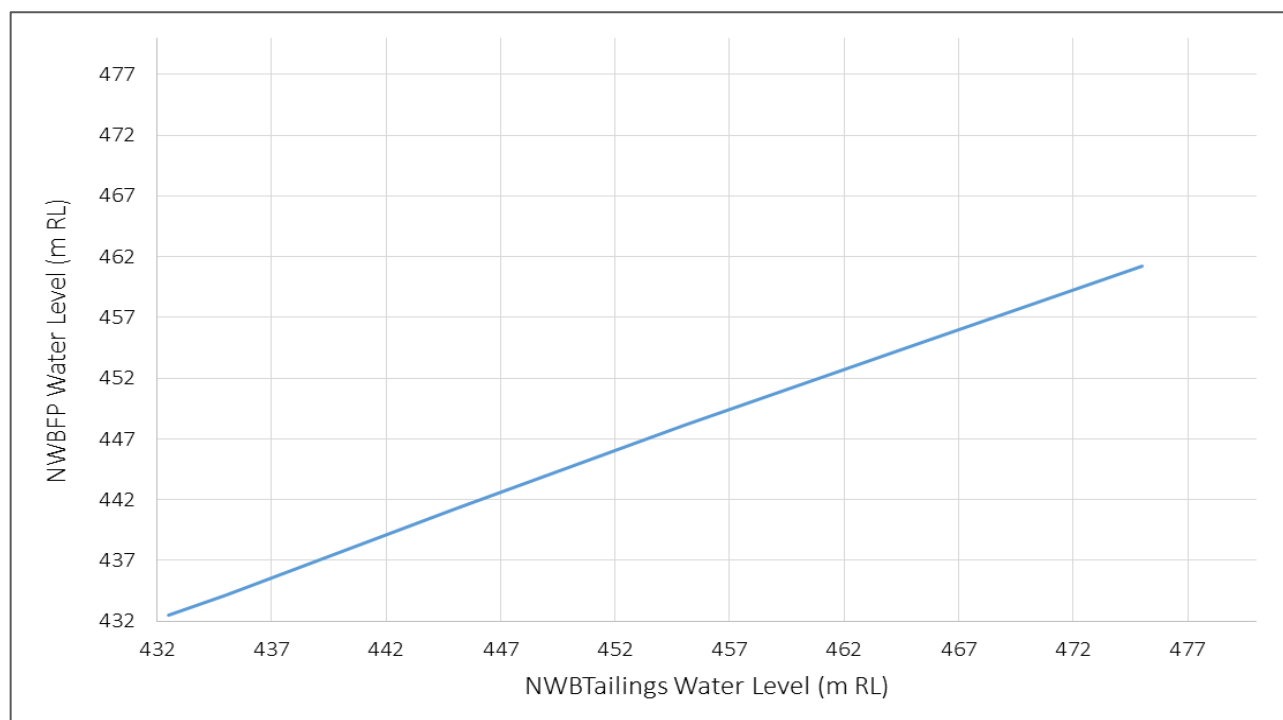


Figure 16: NWB Tailings - NWBFP water level relationship

4.1.1.5 NWB tailings

The NWB tailings is modelled as receiving tailings slurry until 2018 at which stage there is no longer a wet process outflow stream (the solid bowl centrifuge commences operation in 2018). During the process of rehabilitation (up to 2022), a void remains that is subject to rainfall, evaporation and seepage; however, pumping return from the NWB tailings ceases in 2018.

The capacity of the tailings void was obtained from bathymetric survey data provided by Stanwell in *Tailings_Storage_280716.doc*. It has been assumed that 20% of the total area is available for storage of decant water.

Inflow to the tailings decant includes:

- Direct rainfall (to the water surface).
- Surrounds runoff (rainfall to the remaining area of the water storage at the crest of the decant).
- Catchment runoff (including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces of the catchment that reports to the tailings storage).
- Supernatant inflow (calculated based on a slurry inflow of 122 t/hr (from PIMS data records), slurry weight percentage of 45% (from supplied CHPP water balance assumptions provided by Stanwell), and a residue dry density of 0.83 t/m³ (from PIMS data records)).

Outflow from the tailings decant includes:

- Evaporation (from the decant water surface).
- Pump transfer, as shown in the block flow diagrams (Figure 6 and Figure 7).
- Seepage to the NWBFP (based on a head-discharge relationship developed in SEEP/W and described further in Section 4.1.1.4).

4.1.1.6 K2W-N ash void

Ash has previously been deposited into the K2W Pit and is currently being deposited into the K2N Pit. The elevation of the ash in both pits meet at approximately 490 m RL. The void of the combined pit (designated K2W-N) is represented in the model as a reservoir with an elevation-area-storage relationship. The void receives tailings slurry until 2026 after which, rehabilitation commences.

Inflow to the ash void includes:

- Direct rainfall.
- Surrounds runoff (rainfall to the remaining area of the water storage at the crest of the decant).
- Supernatant inflow until 2026, calculated based on provided data:
 - Slurry inflow rate according to *170215.02 MeanduAMDLOM_6MPTE V1.05 New AMDReserves* (typically 120 t/hr).
 - Slurry weight percentage of 40% (Parsons Brinckerhoff, 2016).
 - Residue dry density of 0.83 t/m³ (*170421_RFI's_Xenith.xls*).
- Catchment runoff including runoff from natural, rehabilitated, hardstand, or waste (including spoil and rejects) surfaces of the catchment that reports to the ash void.
 - From 2026 onwards, catchment runoff to the ash void comprises an assumed 20% of baseflow, with the remainder of baseflow and all surface runoff reporting to RD 16.

Outflow from the ash void includes:

- Evaporation.
- Pump transfer to Tarong Power Station.
- Seepage into the basement rock.

4.1.1.7 Queen West dump

Inflow to the Queen West (QW) out of pit dump includes:

- Infiltration (from rainfall) through the waste material.
- Seepage from saturated ash (slurry) deposited in the K2W-N void.

Infiltration from rainfall is the baseflow component determined by the rainfall runoff model AWBM (described in Section 4.3.2). The rate of seepage from K2W-N to QW during and after the deposition of saturated ash has been provided by groundwater modelling (Golder, 2017a) and is shown in Figure 17 as is the corresponding water level elevation.

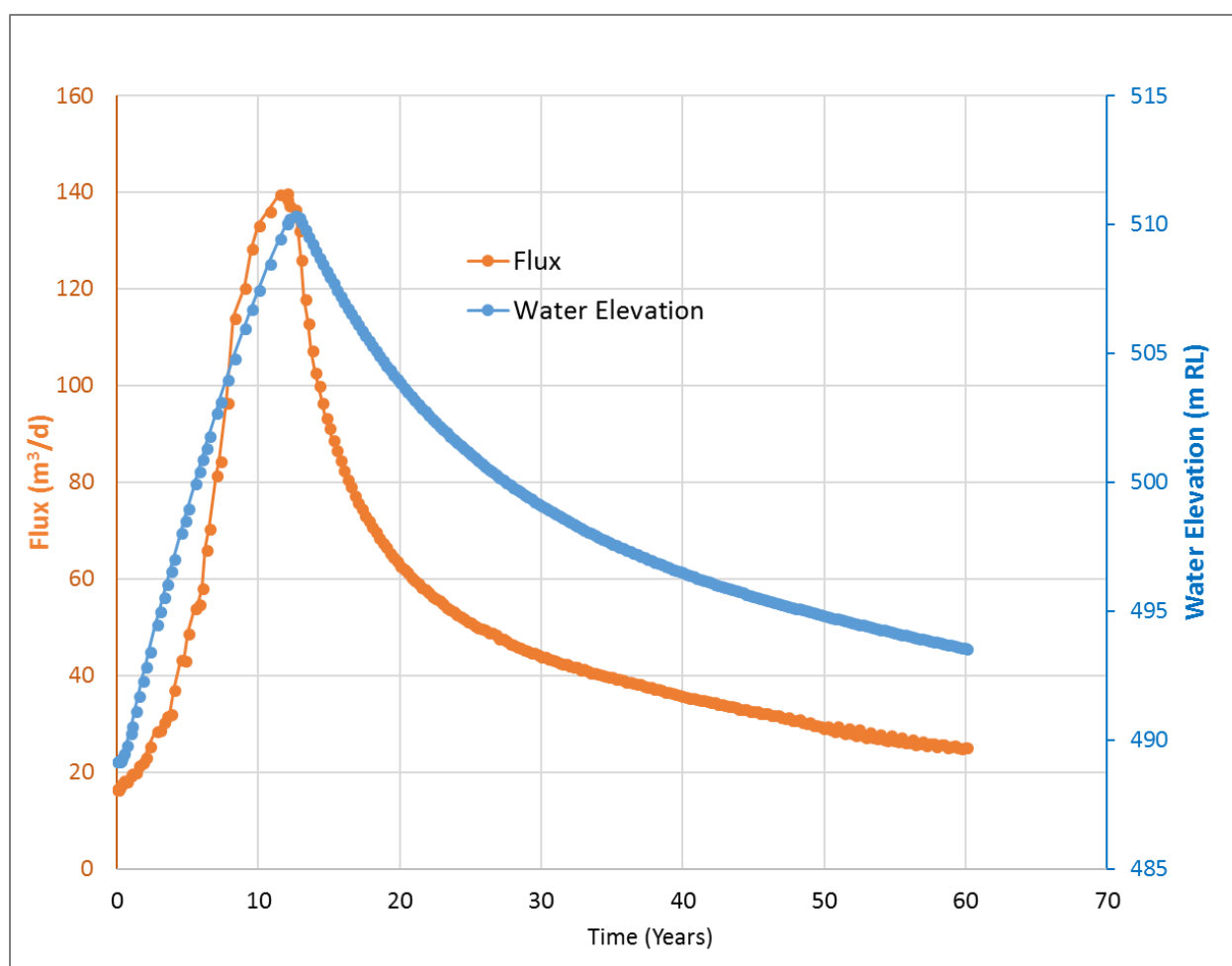


Figure 17: Water elevation – flux relationship seepage flow from K2W-N to Queen West

Outflow from QW includes:

- Seepage collected in adjacent sumps and returned to Tarong Power Station.

4.1.1.8 Environmental monitoring locations

Environmental monitoring locations reported in the model include CP3, CP1 and CP2.

CP3 weir receives water from Meandu Creek upstream of Meandu Creek Dam and upstream of Meandu Mine. CP3 weir also receives mine affected water as overflow from RD2 and RD8 and is an environmental compliance monitoring point. There is a pond of 1 ML capacity represented in the model immediately upstream of CP3 weir and water quantity and quality at CP3 is reported from the overflow of this pond. The pond elevation-storage-area curve has been estimated based on a 1 ML pond of 1 m depth.

CP1 is an environmental compliance monitoring point within Meandu Creek Dam. In the model water quantity and quality at Meandu Creek Dam is also reported as representative of CP1.

CP2 is an environmental compliance point at the outflow of RD17. Results are available in this location in the model if required.

4.1.2 Catchment areas

Catchment areas (for retention dams, pits, Meandu Creek ponds, CP3 and Meandu Creek Dam) and their sub-catchment land use surfaces (natural, rehabilitated, hardstand, active pit, and waste (spoil and rejects)) have

been assessed for stages of the 2017 Life of Mine Plan including years 2016, 2018, 2019, 2022, 2024, 2027, 2029, 2032, 2037 and post closure.

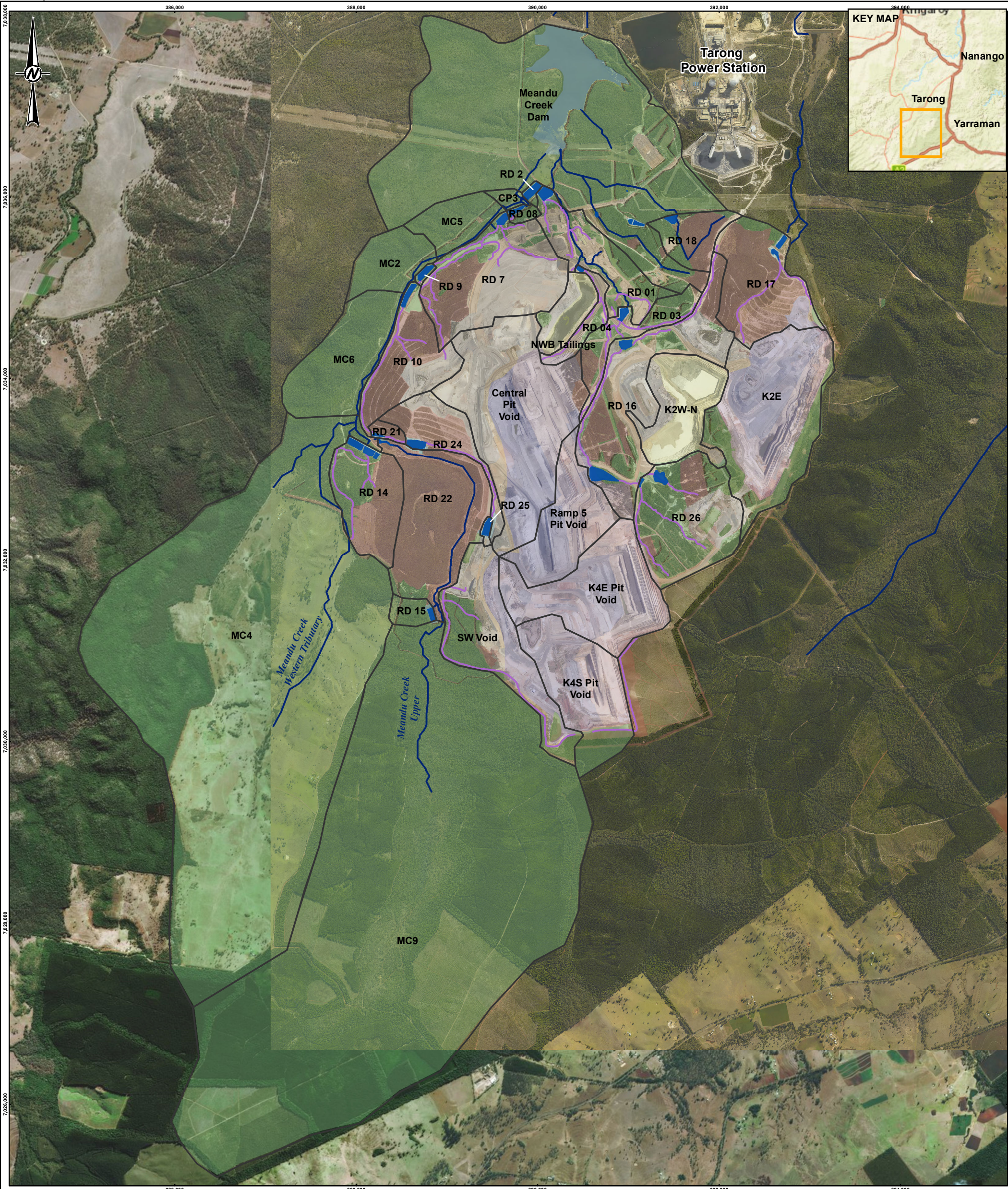
The 2016 catchments and sub-catchments were provided by Stanwell. These areas were confirmed using the supplied topographic data (in *meandu_topo_1612.dxf*) and imagery (in *amg56_meandu_patched_image_1612_050.jpg*); and with reference to the current Meandu Mine Erosion and Sediment Control Plan (Stanwell, 2016a).

The 2016 catchment areas and sub-catchment surfaces were then modified using a spatial mapping and data compilation process conducted in GIS to represent the 2017 Life of Mine Plan specifically in years 2016, 2018, 2019, 2022, 2024, 2027, 2029, 2032, 2037 and post closure. Data used for this assessment included the stage plans, rehabilitation surfaces, and spoil, waste and rejects extent for the life of mine supplied by Xenith in numerous 3D Vulcan files.

The Stanwell defined land use categories for erosion and sediment control planning have been grouped into land use categories with similar runoff characteristics for use in the model (as shown in Table 4). The modelled representation of catchment runoff is detailed in Section 4.3.2.

Table 4: Land use categories

Stanwell defined land use category for erosion and sediment control planning	Adopted land use category for runoff characteristics in the model
Natural	Natural
Cleared	Natural
Spoil	Waste
Waste	Waste
Rehabilitated	Rehabilitated
Tailings	Tailings
Ash	Ash
Hardstand	Hardstand
Active Pit	Active Pit
Dams	Dams



LEGEND

— WATERCOURSE

— INTERNAL DRAINAGE

LAND USE 2016

- ACTIVE PIT
- DAM
- HARDSTAND
- NATURAL
- REHAB
- SPOIL
- TAILINGS
- WASTE

□ CATCHMENTS 2016

■ RETENTION DAMS

DRAFT

Coordinate System: AGD 1966 AMG Zone 56
Projection: Transverse Mercator
Datum: Australian 1966

0 500 1,000 1,500 2,000
1:40,000 @ A3 METRES

NOTE(S)
SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, USGS, INTERMAP, INCREMENT P, MRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI KOREA, ESRI (THAILAND), NGCC, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS.

REFERENCE(S)
ALL DATA SUPPLIED BY STANWELL CORPORATION AND XENITH CONSULTANTS.

CLIENT
STANWELL CORPORATION

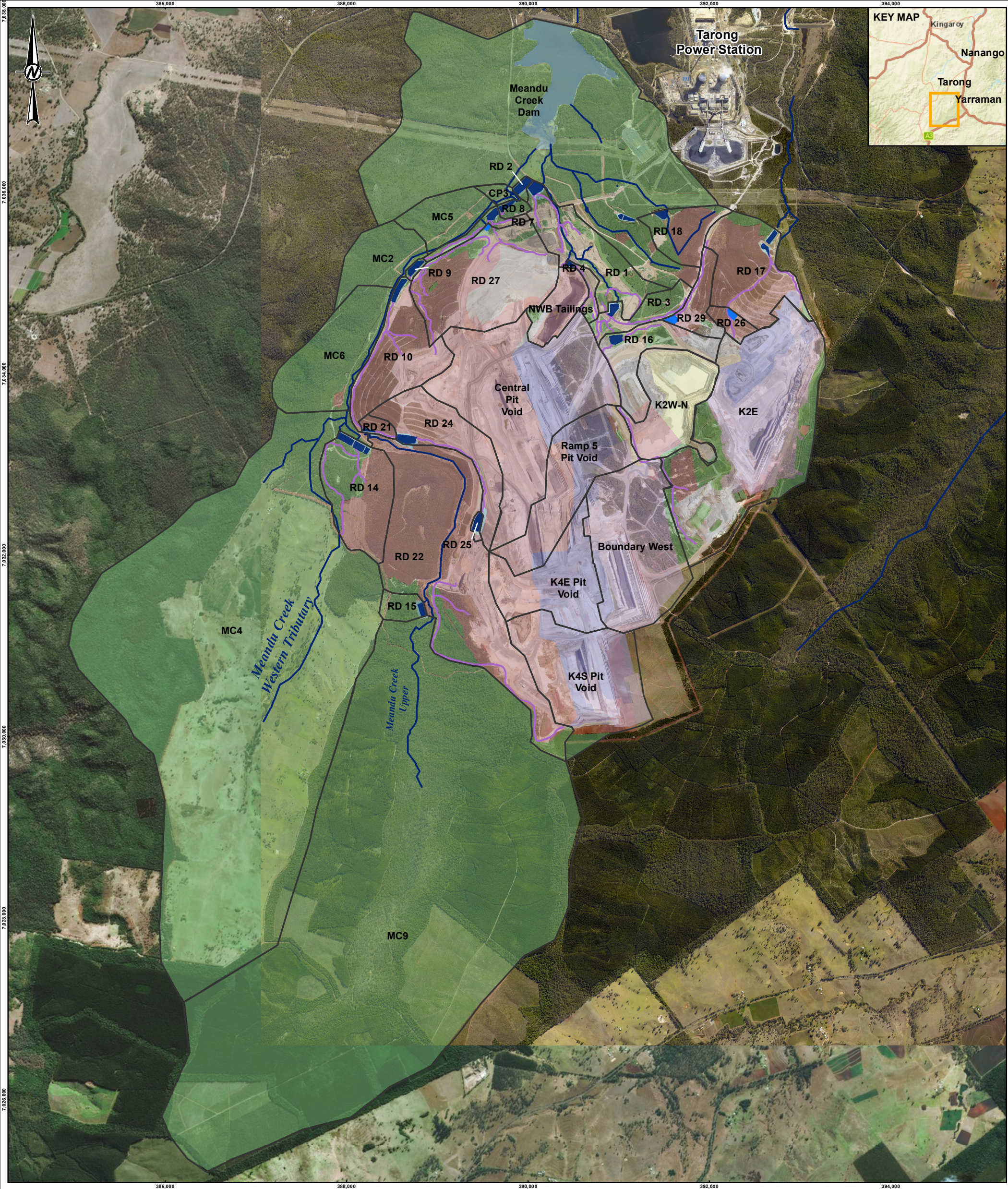
PROJECT
ENVIRONMENTAL AND ENGINEERING EVALUATION PROJECT
- INTEGRATED WATER MODEL

TITLE
CATCHMENT AREAS AND LAND USE - 2016

CONSULTANT	YYYY-MM-DD	24/07/2018
DESIGNED	DR/HG	
PREPARED	DR/HG	
REVIEWED	DP	
APPROVED	RM	

PROJECT NO.	CONTROL	REV.	FIGURE
1665629	002	0	18

GOLDER



WATERCOURSE

INTERNAL DRAINAGE

ACTIVE PIT

DAM

HARDSTAND

NATURAL

REHAB

SPOIL

TAILINGS

WASTE

CATCHMENTS 2029

RETENTION DAMS

NEW RETENTION DAMS

Coordinate System: AGD 1966 AMG Zone 56
Projection: Transverse Mercator
Datum: Australian 1966

010002000

1:40,000 @ A3

METRES

NOTE(S)

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, USGS, INTERMAP, INCREMENT P, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI KOREA, ESRI (THAILAND), NGCC, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

REFERENCE(S)

ALL DATA SUPPLIED BY STANWELL CORPORATION AND XENTITH CONSULTANTS

DRAFT

CLIENT
STANWELL CORPORATION

PROJECT
ENVIRONMENTAL AND ENGINEERING EVALUATION PROJECT - INTEGRATED WATER MODEL

TITLE
PROPOSED CATCHMENT AREAS AND LAND USE - 2029

CONSULTANT

YYYY-MM-DD

24/07/2018

DESIGNED

DR/HG

PREPARED

DR/HG

REVIEWED

DP

APPROVED

MH

PROJECT NO.
1665629

CONTROL
002

REV.
0

FIGURE
19

THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN. THE SHEET SIZE HAS BEEN ADJUSTED FROM: ISO A3

25mm

Catchment areas in the model are dynamic and are referenced in a 3-dimensional (3-D) lookup table including catchment, sub-catchment area and year. The catchment areas used for 2016 are shown in Figure 18 and for 2029 in Figure 19. Detailed catchment areas for the life of mine are provided in ATTACHMENT B.

New retention dams were added as specified in correspondence with Stanwell including:

- The addition of RD27 in 2018.
- Decommissioning of the SW void and subsequent direction of surface drainage to RD22.
- Replacement of RD26 with a nearby RD28 prior to 2027 due to RD26 being overrun by the progression of Boundary West Pit.
- The addition of RD29 to the north of K2E in 2027.

The total of sub-catchment areas assigned to each surface land use type is provided in ATTACHMENT B.

4.2 Material balance

Scheduled annual quantities, Acid and Metalliferous Drainage (AMD) classification and dump location of waste, rejects and ash were supplied by Xenith for the 2017 life of Mine Plan (to 2037) in *Meandu Dumping Summary V2.xlsx*.

The latest geological model (November 2016) used by Xenith for the Life of Mine Plan incorporated an overburden model in Vulcan software. The overburden model was a structural model only and contained no chemical or physical properties of the overburden units. Only the overburden units situated above the Ace Seam had been modelled in the overburden model (JB Mining, 2016).

The key units that had been modelled and displayed in the geological model were:

- Tertiary (TE)
- Basalt (BA)
- Upper Triassic (UT)
- Conglomerate (CG)
- Shale (SH)
- Base of Tertiary (BUTE) and
- Base of Weathering (BoW).

For the purpose of the 2017 Life of Mine Plan, the overburden units then had some classification of the strata applied with respect to some of the geochemical properties, specifically whether it was potentially acid forming (PAF) or non-acid forming (NAF). This classification was then applied to allocating 6 metres of NAF cover in all rehabilitation areas as modelled in the 2017 Life of Mine Plan.

The classification was largely based upon four fully cored holes assessed by RGS for the purpose of the development of the 2017 Life of Mine Plan and applied to the overburden structural model. The classification work was only undertaken on overburden waste above Ace seam located in the pits of K4S, K4E / Boundary West, Boundary East and Powerline Pit. The spoil that was in the path of the mining schedule also had some classification applied to it. All other material that had not specifically been classified has been treated as if it were PAF material.

The application of the overburden classification to the overburden structural model was recommended via a combined assessment by JB Mining and RGS. The summation of the recommendation for the 2017 Life of Mine Plan was as follows:

- K4S and K4E:
 - TE plus UT as NAF rehabilitation resource
 - Top 20 of CG as NAF secondary rehabilitation reserve
 - Remainder CG as PAF
 - SH as NAF primary rehabilitation reserve
- K2E:
 - TE plus top 10m of UT as PAF
 - Lower UT as NAF rehabilitation resource
 - CG as NAF rehabilitation reserve
 - SH as PAF
- Central and Ramp 5
 - Spoil can be considered as general fill if screened as NAF.

The respective quantity of materials placed in each catchment area was assigned in the model on a monthly basis. Material type and quantity were then used in the assessment of water quality from waste, rejects and ash. The method for assigning water quality parameters to each material type is described further in Section 4.6.

4.3 Water inflows

4.3.1 Rainfall

4.3.1.1 SILO data drill

SILO Data Drill (SILO) accesses grids of data interpolated from point observations by the BoM. It relies on measured data from BoM rain gauges to use for interpolation to a specified grid location, such as the Meandu Mine. SILO data is generally preferred for modelling purposes as it provides a site specific continuous and long data record.

SILO data was obtained for the Meandu Mine location. The model user has the option to run the historical data series using a dry climate time series, a wet climate time series for the period 1900 to 2017 (Queensland Government, 2018), a median climate time series or using the 2016, 2017 calibration data record (BoM Station 040199 Tarong).

The dry climate time series is the 5th percentile continuous 34 year rainfall total; the median climate time series, is the 50th percentile continuous 34 year rainfall total; and the wet climate time series is the 95th percentile continuous 34 year rainfall total (as shown in Table 5). Each data series is 34 years in length (that is the period of simulation).

Table 5: SILO Rainfall data series

Climate series	Represents over period of 34 years	Start year of record	Average annual rainfall of data series (mm)
Dry	5 th percentile rainfall total	2014	740
Median	50 th percentile rainfall total	1914	777
Wet	95 th percentile rainfall total	1940	832

The SILO data has been incorporated into the model as a time series. Time shifting of the data has been enabled which means that the record is entered as the historical data series; but the model is run according to the calendar year set in the simulation settings. Once the simulation reaches the end of the historical record (2017) it will loop back to the start (1900).

For example, 1914 is the start year of the median rainfall data series used on the model. That is, of the 117 years of data records, the median consecutive 34year total rainfall started in the year 1914. If running a simulation using the median rainfall climate series but looking at a forecast from 1 January 2016, the rainfall record used in the model for 2016 will be the record from 1914. The record used for 2017 will be the record from 1915, and so on.

4.3.1.2 Stochastic rainfall data

Stochastic rainfall generators are necessary for probabilistic modelling of hydrologic systems beyond limits of the historical record. Stochastic generators attempt to reproduce the statistical characteristics of the historical records in synthetic sequences of arbitrary length (Srikanthan & Zhou, 2003).

Golder has programmed a stochastic climate generator module for use in GoldSim which is based on the Transition Probability Matrix (TPM) method developed by Srikanthan and McMahon (2000). The TPM method uses a state-Markov approach to generate today's rainfall based on yesterday's rainfall state and a random variate. Today's rainfall is generated by linear interpolation between the rainfall state probabilities tabulated in the TPM for yesterday's rainfall state.

A Gamma distributed excess is added in the top state to generate the wettest days. The TPM is developed by simple transition counting in the rainfall record (in this case the Data Drill record) done separately for each calendar month to impose seasonality.

Observing that Australian rainfall in many areas is highly correlated with the Southern Oscillation Index (SOI), Golder developed an in-house SOI-driven TPM method. The approach entails generating separate TPM's for each of three SOI states (for each calendar month). Performance testing indicates that driving the TPM method with a stochastic SOI increases annual variance closer to the observed variance at most sites. The generated rainfalls are expected to better represent observed long-term variation in rainfall sites with a significant SOI correlation.

A comparison of the monthly average rainfall from the SILO Data Drill record and a 500-year stochastic generated record is provided in Figure 20. The SILO Data Drill and stochastic monthly rainfall are similar.

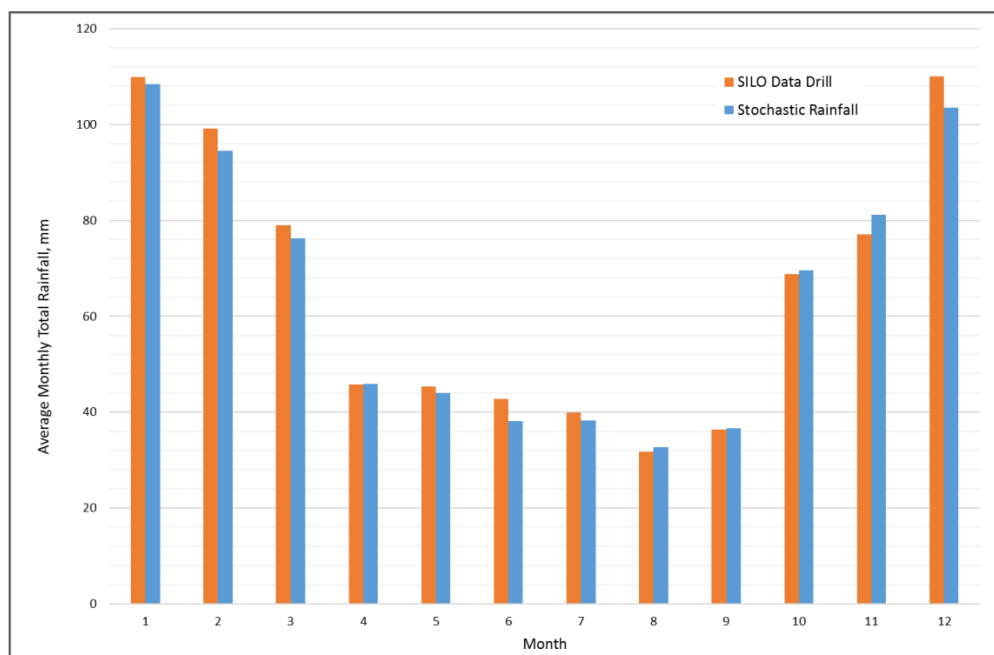


Figure 20: Comparison of stochastic rainfall and SILO Data Drill rainfall

The model input rainfall data (Data Drill and stochastic) are also compared in terms of extreme rainfall. A Log Pearson Type 3 distribution analysis shows the annual peak daily rainfall series of all records were similar as shown in Figure 21.

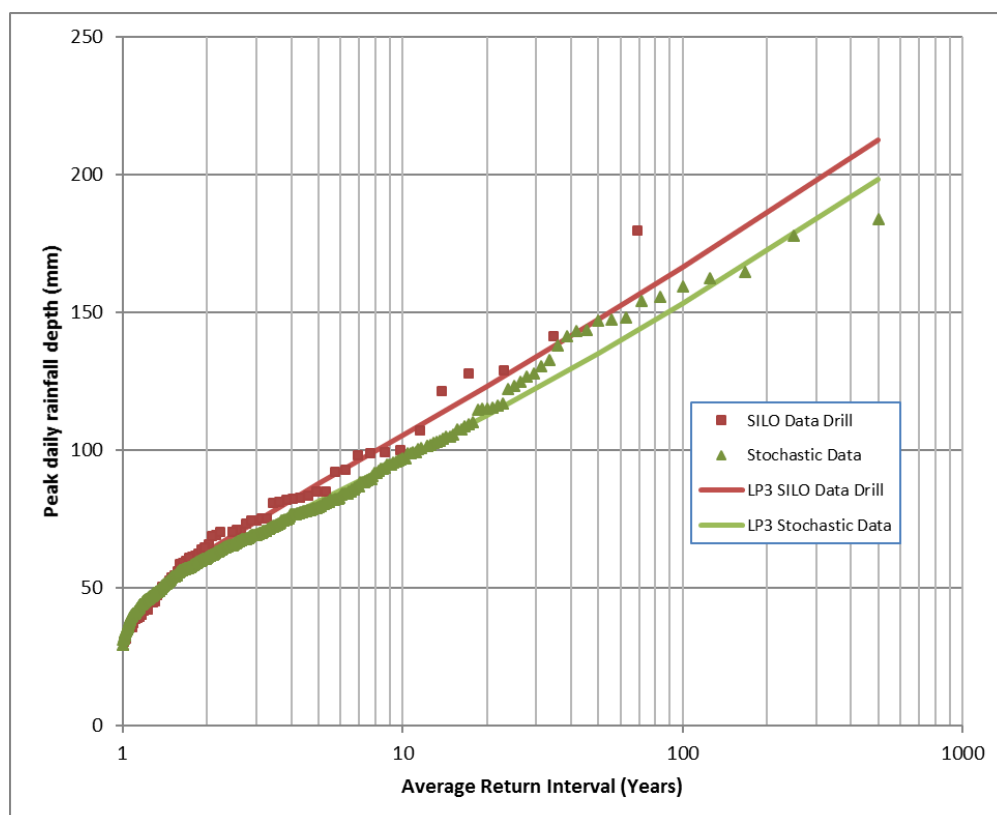


Figure 21: Log Pearson 3 distribution of historical and model data sets

From analysis of the different rainfall records available, SILO Data Drill records used to generate 500 years of stochastic daily rainfall records provided a good representation of rainfall at the Meandu Mine site for use in the water balance model.

4.3.2 Catchment runoff

The model uses the Australian Water Balance Model (AWBM) to simulate catchment runoff and streamflow response to rainfall. The AWBM takes into account catchment characteristics and antecedent (preceding) climatic conditions. A concurrent data series of rainfall and runoff for a period is used to calibrate the model for a specific catchment. Once calibrated, AWBM is used to predict runoff from much longer rainfall records used in predictive modelling.

A schematic of the components and parameters of the AWBM is shown in Figure 22.

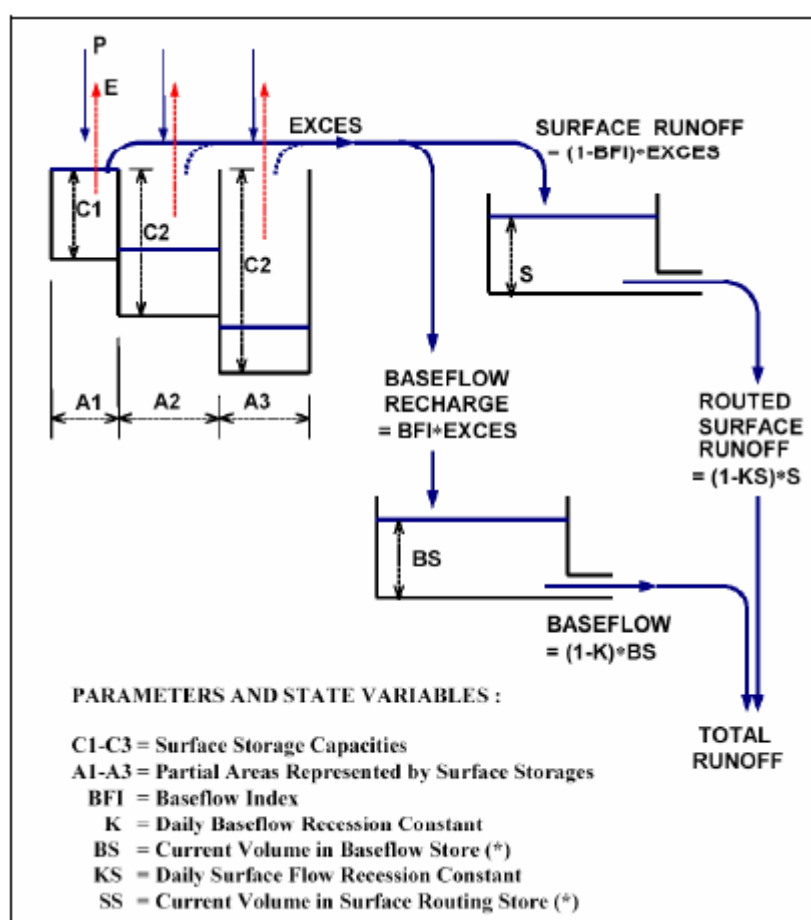


Figure 22: Structure of the AWBM rainfall-runoff model (reproduced from the Cooperative Research Centre for Catchment Hydrology (2004))

Calibration parameters include:

- C1 – C3: The surface storage unit capacities (mm) to represent partial areas of runoff. At each time-step rainfall is added to each of the surface water storage and evapotranspiration is subtracted. If the quantity of water in the store exceeds the capacity of the store the water in excess of the capacity becomes runoff.
- A1 – A3: Partial areas represented by surface storages (fraction of 1.0). A default pattern is generally used of 0.134, 0.433, 0.433.

- BFI: Baseflow Index is the fraction of the runoff from the surface stores that is used to recharge the baseflow store.
- K_b : The daily baseflow recession constant. $(1 - K_b) \times \text{Baseflow Store}$ is the daily rate of release of water to streamflow from the baseflow store.
- BS: The baseflow store unit volume (mm).
- K_s : The daily surface recession constant. $(1 - K_s) \times \text{Surface Store}$ is the daily rate of release of water to streamflow from the surface store.
- SS: The surface store unit volume (mm).
- Total runoff is the quantity of water released from surface and baseflow stores each day.

The AWBM has been calibrated for a catchment to the west of the Meandu Creek catchment by JBT Consulting (2014). The Barker Creek Catchment Brooklands Gauge (136203A) was used for the assessment based on the availability of long continuous stream flow records, proximity to the mine site and size relative to the Meandu Creek catchment area (JBT Consulting, 2014). Additionally, the catchment comprises a majority of natural and grazing land use, consistent with the catchment of upper Meandu Creek (JBT Consulting, 2014).

The calibrated calculated (blue) and observed (red) runoff is shown in Figure 23. There is generally a good alignment between the calculated runoff and observed runoff at Barker Creek at Brooklands using the calibrated parameters for the period of record (1968 – 2014).

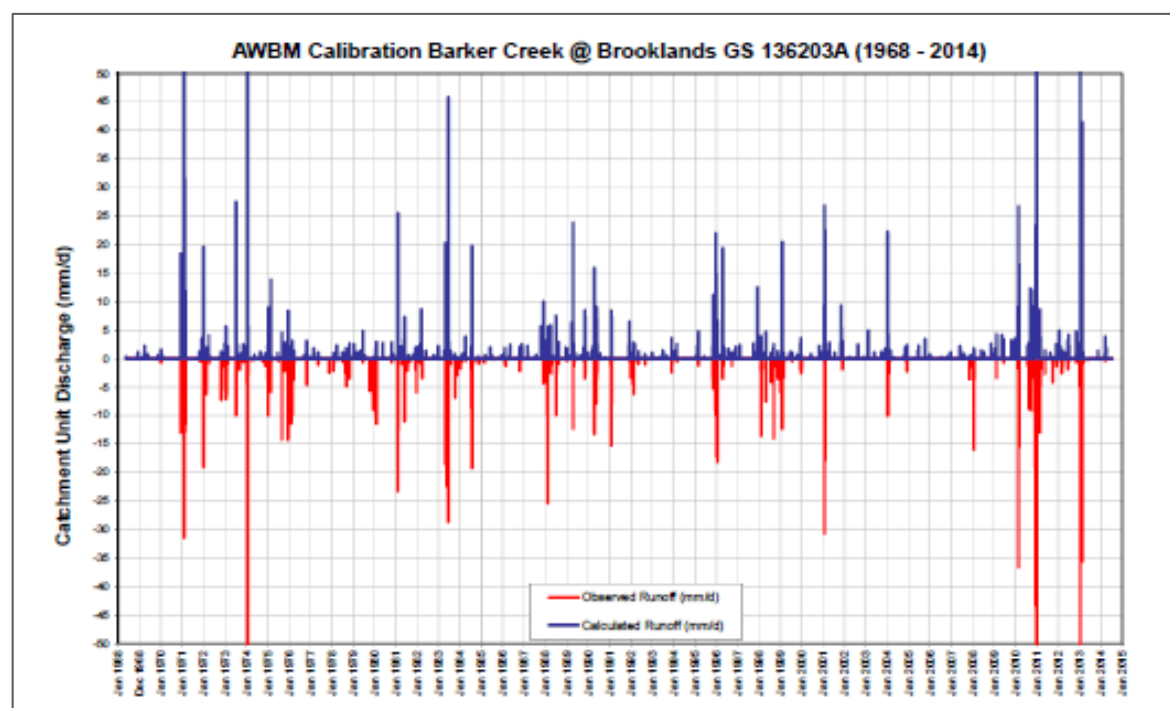


Figure 23: Observed and calculated runoff Barker Creek at Brooklands (reproduced from JBT, 2014)

The cumulative calculated runoff over the period of record also provides a good alignment of total runoff during the calibration period (as shown in Figure 24) at Barker Creek at Brooklands.

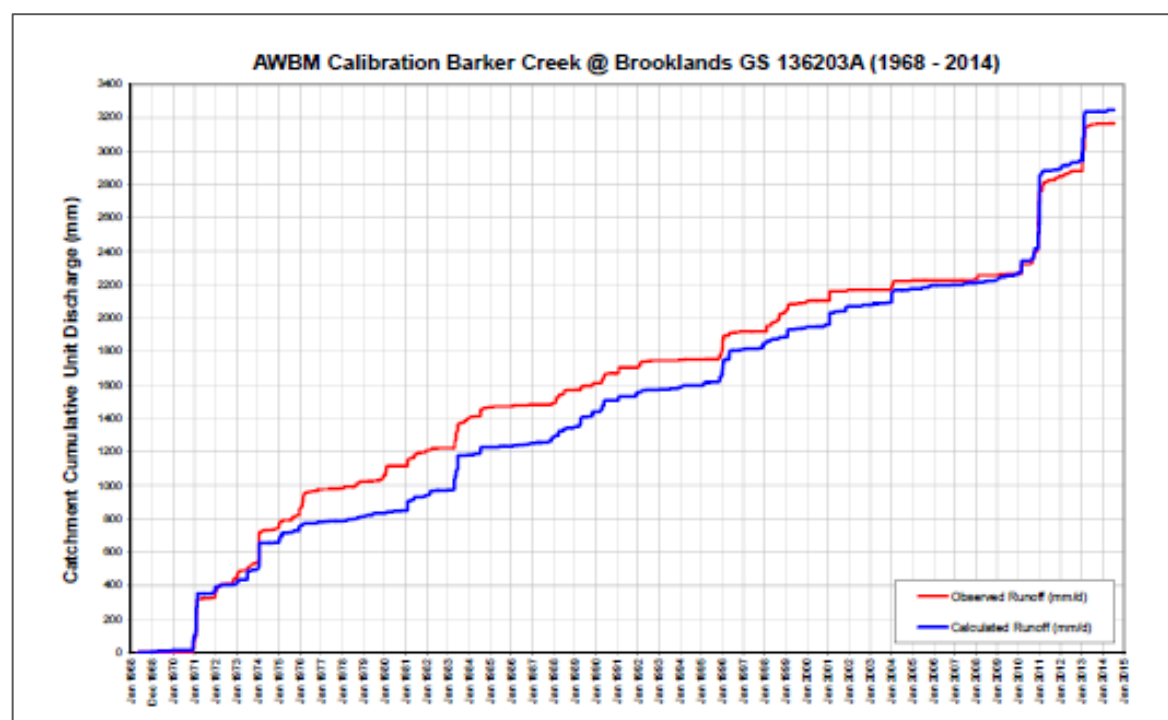


Figure 24: Cumulative observed and calculated runoff Barker Creek at Brooklands (reproduced from JBT, 2014)

The AWBM model has been reproduced in a standardised AWBM module by GoldSim (GoldSim Technology Group, 2017). The standard AWBM module has been used in the model to represent rainfall runoff process for each of the land use categories identified in Table 4. The calibration parameters from the calibration process undertaken by JBT in 2014 was used as initial inputs to the GoldSim model for natural and rehabilitated land use areas.

The AWBM parameters are provided in Table 6.

Table 6: AWBM calibrated parameters for natural land use at Barker Creek catchment

AWBM Parameter	Calibrated value natural land use (Barker Creek)
C1	30 mm
C2	240 mm
C3	480 mm
BFI	0.2
Ks	0.7
Kb	0.1

4.3.3 Groundwater inflow to pits

Groundwater inflows are based on estimates made for the annual reporting on associated water take for the water year 2016/2017 (Golder, 2017b) and from anecdotal information from Stanwell site personnel regarding groundwater encountered in pits at Meandu Mine.

The range of potential groundwater inflow to pits, based on the method described in Marinelli and Niccoli (2000), is shown in Table 7. Ramp 5 was included with Central Pit in this assessment.

Table 7: Estimate of steady state pit inflows for the water year 2016/2017

Pit	Central		K2E		K4E		K4S	
Hydraulic Conductivity (m/day)	0.0015	1×10^{-5}	0.0015	1×10^{-5}	0.0015	1×10^{-5}	0.0015	1×10^{-5}
Recharge (mm/year)	7.3		7.3		7.3		7.3	
Head at nearest bore (m AHD)	460		463		463		463	
Pit base head (m AHD)	390		390		400		450	
Radius of Influence (estimated) (m)	800		1200		850		530	
Anisotropy parameter	0.1		0.1		0.1		0.1	
Effective Radius (m)	333		605		437		418	
Pit Bottom Inflow (L/s)	13	1.2	37.5	3.0	16	1.3	3.5	0.3
Pit wall inflow (L/s)	0.4	0.4	1.0	1.0	0.4	0.4	0.1	0.1
Total inflow (m ³ /day)	1140	136	3320	350	1410	148	317	34
Total inflow (ML/year)	450	54	1311	138	557	59	125	13

Anecdotally (Stanwell), Queen coal seam is the wettest coal seam and as a result K4E and K2E have a higher inflow of groundwater than other pits. K4S Pit has in the past received higher rates of groundwater inflow due to localised faults acting as flow conduits to the pit. Central Pit receives more significant quantities of water from spoil on the western side of the pit than other pits.

Groundwater inflow is entered in the model in terms of L/s/ha of pit area. Calibration of groundwater inflow to pits is discussed in Section 5.1.3.

4.4 Water outflows

4.4.1 Evaporation

4.4.1.1 SILO data drill

Evaporation data has been obtained from the SILO data drill for the period 1900 to 2017, location latitude - 26.8, longitude 151.9 (Queensland Government, 2018). Two data series are used in the model. Moreton's shallow lake evaporation is used for evaporation from retention dams and pit sumps. Moreton's actual evapotranspiration is used in AWBM.

The evaporation record corresponding to the relevant rainfall record is applied when selecting low, median and high rainfall data scenarios. For stochastic simulations, an average evaporation record (January to December in all years) from the SILO Moreton's shallow lake evaporation and Moreton's actual evapotranspiration is applied to daily data series.

4.4.2 Coal Handling Preparation Plant water use

A water balance for the Coal Handling Preparation Plant (CHPP) was provided by Stanwell for reference water use. The balance was completed on 1800 tonne per hour feed, then converted to I/ROM tonne.

Water in = water in feed coal + raw water addition + retention dam water addition (RD2, RD8).

Water out = water in product + water in coarse rejects + water in tailings.

The assumptions used in this assessment by Stanwell are as follows:

- feed total moisture = 4.2% (value obtained from 2014 large diameter bore core laboratory data)
- total product moisture = 10.6% (average of analytical laboratory samples from 2013 – 2015)
- total rejects moisture = 13.3% (QCC LIMN model, and design specification)
- tailings solids weight percent = 32% (recent solid bowl centrifuge trial)
- the balance assumes washing 100% of the time, that is no dry bypass.

By calculating the water in the feed coal and the water out on product and reject streams the remainder is the required water input from raw water addition and retention dam water addition. The calculated water demand of the CHPP from raw and retention dam sources supplied by Stanwell is provided in Table 8. An estimate of the demand once solid bowl centrifuges are installed in the CHPP (from 2018) has also been provided by Stanwell.

Table 8: CHPP water balance (Stanwell)

Product quality	Current operations at 1800 tph (m ³ /hr)	Current operations I/ROM (t/hr)	Solid bowl centrifuge at 1800 tph (m ³ /hr)	Solid bowl centrifuge I/ROM (t/hr)
Low yield coal	362	201.1	217	120.6
High yield coal	224	124.4	165	91.7
Medium yield	269	149.4	181	100.6

The range of water demand has been entered in the model as a stochastic element with a triangular distribution resampled on a daily basis. This form of data input allows the model user to represent uncertainty in an input parameter (when future coal yield data on a day to day basis is not available). GoldSim uses the Monte Carlo method to sample stochastic elements to introduce variability within an anticipated range of values with the greatest proportion of sampling occurring in the centre of the range. An example triangular distribution entry is shown in Figure 25.

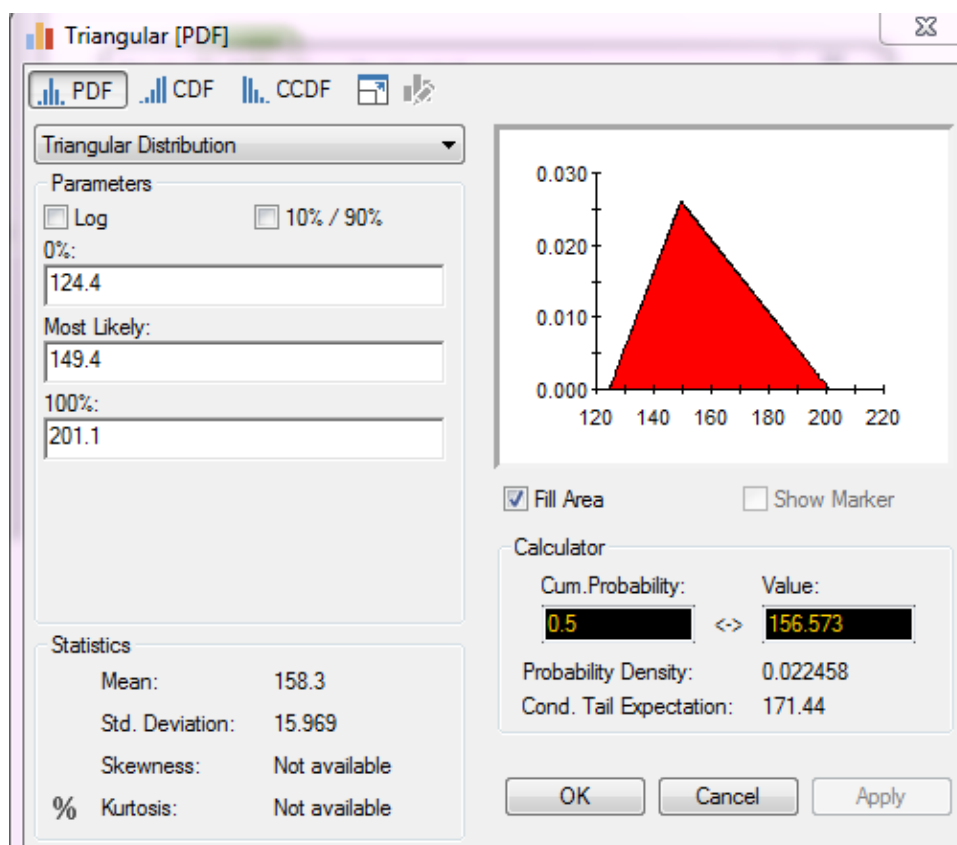


Figure 25: CHPP triangular distribution data entry pre-calibration simulations (years 2016, 2017)

Calibration of the input data to the cumulative total water use is discussed in Section 5.1.5.

4.4.3 Truck-fill water use

The water outflow from assigned retention dams for haul road dust suppression is applied in the model as a fixed daily rate of use and is based on site water data records as shown in Table 9 (model assumptions were confirmed via email from Stanwell dated 8 February 2018).

Table 9: Truck fill water use

Location	Years	Source RD	Hours (per day)	Pump rate (L/s)	Supply (ML/d)	Comment
Central	2016, 2017	RD10	2.2	60	0.47	
Central	2018 - 2037	RD27; RD10	6.6	60	0.47	Assume 30% of requirement is sourced from RD27, remainder from RD10.
K4	2016 - 2023	RD25	1.4	90	0.44	Moved to the east when mining starts in K2E in 2024.
K4	2024 - 2037	RD26	1.4	90	0.44	RD26 is re-located (that is, replaced by a new RD26) when current RD26 is lost to K4E Pit progression.
Sparrows	2016 - 2037	RD26	0.5	50	0.50	see above comment
ROM	2016, 2017	RD2	fixed day rate		0.67	
ROM	2018 - 2037	RD27, RD2	fixed day rate		0.67	Assume 30% of requirement is sourced from RD27, remainder from RD2.

4.4.4 Seepage from retention dams

All retention dams have an allowance for seepage losses that depends on an assumed hydraulic conductivity of the base materials 1.00E-06 m/s for Meandu Creek ponds, 1.00E-07 m/s for constructed retention dams and 1.00E-08 m/s for Meandu Creek Dam. Seepage is calculated at each time-step using the following method:

$$\text{Seepage loss} = (\text{water depth} / \text{maximum depth}) * \text{hydraulic conductivity} * \text{storage area}.$$

4.4.5 Overflow from retention dams

All retention dams have a spill elevation defined within the geometry data at which elevation the reservoir will overflow. Overflows are linked as indicated in the block flow diagrams (provided in Figure 6 and Figure 7) and contribute to the inflows of the linked dam allocated on a daily time-step.

4.5 Water transfers

4.5.1 Pumps and pipes

The transfer of water between pits and retention dams or between retention dams using pumps occurs in the model as shown in the block flow diagrams (Figure 6 and Figure 7). Pumping information was supplied by Stanwell in *pump register (2017).xls*.

Each pump transfer has an assigned pump efficiency and date range assigned. All pumped flows are potential flow demands. The reservoir element in GoldSim will only supply water if the quantity of water demand is available in the reservoir on a particular time-step.

Dewatering of pits has been calibrated to site dewatering records by adjusting the pump efficiency inputs (as described in Section 5.1.3).

4.6 Water quality

4.6.1 Analytes

Water quality analytes are included in the model as a vector of species elements that follow water flow paths in water transfers and mixed in mixing cells. The volume of the mixing cell is either the quantity of water in a flow pathway or reservoir. This mass balance approach provides a time history of the concentration of the group of species at each location described in the model; including pits, retention dams and compliance points.

Each input water quantity component has a water quality value assigned. There are two forms of water quality input data used in the model.

- 1) A fixed concentration for a particular flow based on the average of historical laboratory analysis at representative locations (for example, natural catchment runoff).
- 2) A decay equation based on kinetic leach testing is applied as a species load per mass of material per month for deposited materials including waste, rejects and ash.

The analytes tracked throughout the model are provided in Table 10.

Table 10: Analytes

Cations, Anions	Metals	Acidity
Calcium	Aluminium	Hydrogen ions
Potassium	Iron	
Magnesium	Manganese	
Sodium	Zinc	
Chloride	Copper	
Fluoride	Nickel	
Sulfate		

4.6.2 Water quality parameters

4.6.2.1 Fixed water quality inputs

The model contains the following water quality parameters attached to inflows from the identified sources (Table 11). Analyte concentrations were provided by RGS (in *RGSRev3 GoldSim Source Terms*); with the exception of the groundwater input parameter provided by JBT Consulting (in *Chemistry Data – Background vs Mine Affected.xls*) and blowdown water quality provided by Stanwell (in *Tarong_WQData_ESP_Collated.xlsx*).

Values are based on the average of measured water quality at the assigned location and are considered to be representative of the inflow path used in the model.

Water quality parameters assigned to each inflow path are provided in Table 12. pH data is entered in the model as H^+ ions but is shown here as pH for ease of reference.

Table 11: Water quality assigned to flow paths representative data source code and location

Inflow path	Representative source data - Location code	Representative source data – Location description
Natural runoff	CKME (cations, anions, pH); Rehab Ck Div; Rehab K1 Central; Rehab NW, Rehab SW, RHBK01, KHBNW Seep; RD21; RD22 (metals)	Meandu Creek draining forestry catchment just below southern lease boundary; Multiple rehabilitation site
Hardstand runoff	RD1	CHPP/Workshop/Industrial Area Water Dam
Active pit runoff	Pit CENTRAL; K4E, K4S	Pit CENTRAL; K4E, K4S
Rehabilitation runoff	Rehab Ck Div; Rehab K1 Central; Rehab NW, Rehab SW, RHBK01, KHBNW Seep; RD21; RD22	Multiple sites
Tailings supernatant	RGS process water in tailings	Collected at Meandu Mine CHPP
Tailings voids	NWB1 SURF; Tailings Void	NWBFP; NWB
Ash supernatant	RGS ash water samples	K2W-N
Ash voids	K2W ash, K2N, K2N SEEP	K2W; K2N
Resurgent seepage NWBFP	Bullgang drain; Ramp 7-1; Ramp 7-2	Bullgang Corner and Ramp 7 drain
Lime treated resurgent seepage NWBFP	Total of 6 samples from Ramp 7-2 and Bullgang Corner treated with lime in the laboratory to pH 7 – 8	
Groundwater	Multiple GW sample sites	Median value of King Seam samples
Blowdown water TPS	W1	Licence Point – TPS blowdown
Blowdown water TNPS	W4	Tarong North blowdown line

Table 12: Fixed concentration parameters data entered in the model

Analyte	Natural Runoff	Hard- stand Runoff	Active Pit Runoff	Rehab Runoff	Tailings supernatant	Tailings voids	Ash supernatant	Ash voids	Resurgent Seepage NWBFP	Lime treated resurgent seepage	Groundwater	Blowdown water TPS	Blowdown water TNPS
Calcium	5.60	32.4	45.0	9.7	82.8	60.5	187.0	139.5	62.5	170.3	8.0	141.3	119.2
Potassium	5.00	14.0	16.0	8.1	20.3	22.1	26.5	26.5	35.3	28.8	8.0	21.6	19.0
Magnesium	4.70	37.5	48.0	15.9	65.8	65.3	112.5	110.2	152.3	90.3	42.0	194.3	150.3
Sodium	15.2	135.1	188.0	65.0	195.8	226.4	451.0	360.9	303.8	237.2	229.0	164.11	160.0
Chloride	26.5	238.8	304.0	97.8	303.5	370.7	553.0	656.7	461.0	456.8	401.0	392.5	382.0
Fluoride	0.10	0.20	0.15	0.10	0.47	0.30	10.6	6.3	0.15	0.10	0.10	0.67	0.68
Sulfate	5.20	144.9	186.0	72.8	333.8	422.7	465.0	758.8	1156.2	993.7	47.0	138.3	148.0
pH	7.1	8.1	7.8	6.3	7.3	7.2	6.7	6.8	5.2	8.4	6.8	8.1	8.0
Aluminium	0.167	0.010	0.138	0.167	0.206	0.012	1.022	0.100	0.560	0.005	0.010	0.029	0.032
Iron	0.069	0.435	0.165	0.069	0.659	0.028	0.040	0.030	98.80	0.025	2.40	0.246	0.151
Manganese	0.517	1.077	0.720	0.517	0.472	0.271	0.186	0.611	32.2	4.628	0.10	0.277	0.257
Zinc	0.045	0.169	0.027	0.045	0.072	0.041	0.223	0.240	4.27	0.003	0.008	0.005	0.013
Copper	0.001	0.001	0.003	0.001	17.05	0.001	7.60	0.006	0.002	0.003	0.001	0.011	0.015
Nickel	0.012	0.033	0.010	0.012	5.12	0.010	16.9	0.081	0.512	0.039	0.002	0.002	0.002
Vanadium	0.005	0.005	0.005	0.005	27.7	0.005	34.3	1.433	0.005	0.005	0.040	0.013	0.008
Molybdenum	0.001	0.002	0.001	0.001	1.38	0.011	2.12	0.723	0.001	0.001	0.002	0.004	0.005

4.6.3 Material decay equations

Materials (rejects, PAF waste, NAF waste and ash) are assigned to a pit, tailings or ash catchment as discussed in Section 4.2. A quantity of materials is assigned on a monthly basis conceptually as a new block of materials stacked on top of the previous month's quantity of materials. The available analytes per unit mass of material have been assigned as a decay function (provided by RGS) with an independent variable of month, that is in the form of:

$$\text{Load (mg/kg/month)} = \text{coefficient} * (\text{month} ^ \text{exponent})$$

To simulate progressive and stacking decay functions requires complex coding in GoldSim. Explanatory notes are provided to aid the model user in understanding the model method. The structure of the module is shown in Figure 26.

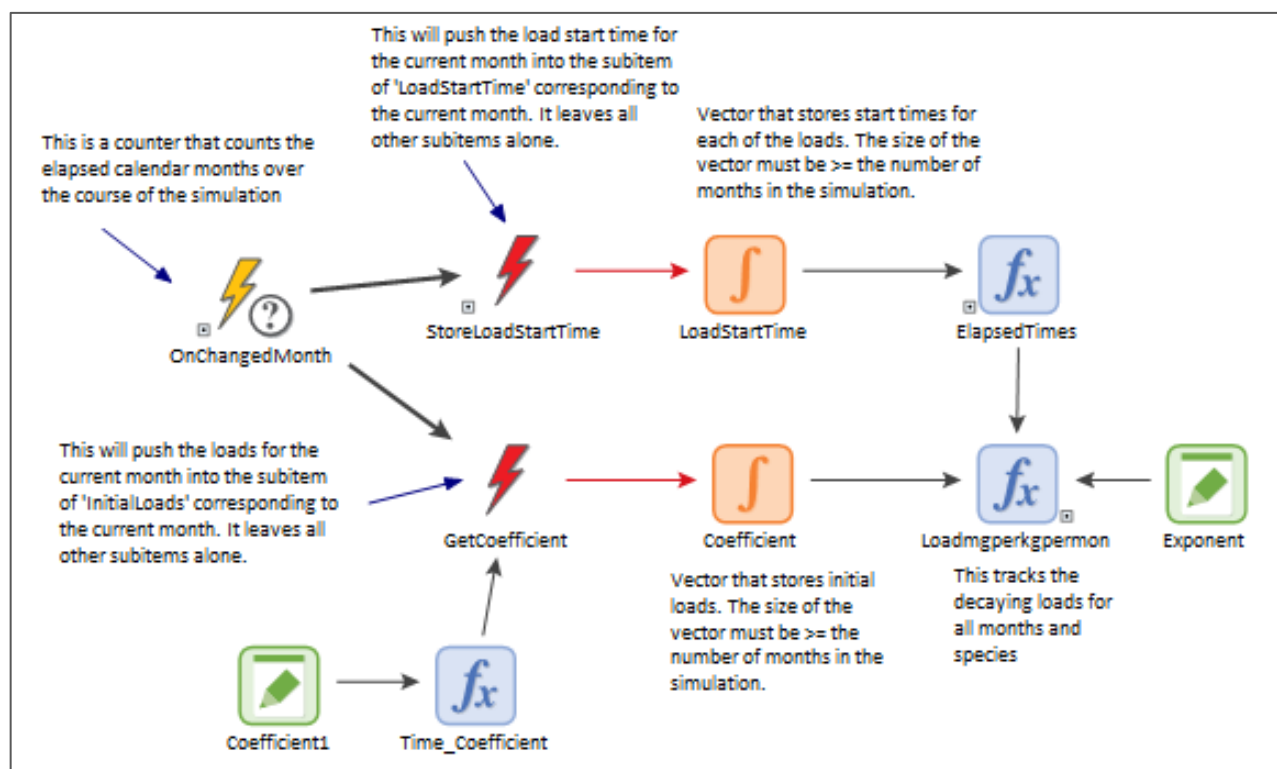


Figure 26: Coding in GoldSim for the material load decay functions for each analyte

Decay curves are assigned to each new load of material as shown in Figure 27. The colour denotes a new load of material being deposited each month and shows each analyte with a different decay curve (figure legend details are too detailed to view).

The load/kg waste/ month is then multiplied out by the applicable material mass to give a load of each analyte. The load is then totalled for each time-step to total the crest of a curve along with tails from previous month load deposition. A 1% contact factor is applied to represent the contact made between available load and infiltrated water. Further details about the derivation of a suitable contact factor is discussed in RGS report *Mine material characterisation and management*.

The decay curves assigned to each analyte (as provided in Table 10) and each material type (rejects, PAF waste, NAF waste and ash) are calculated from kinetic leach tests and were provided by RGS. Further information about the relevant leach tests assigned to each material type is provided in the RGS report *Mine material characterisation and management*.

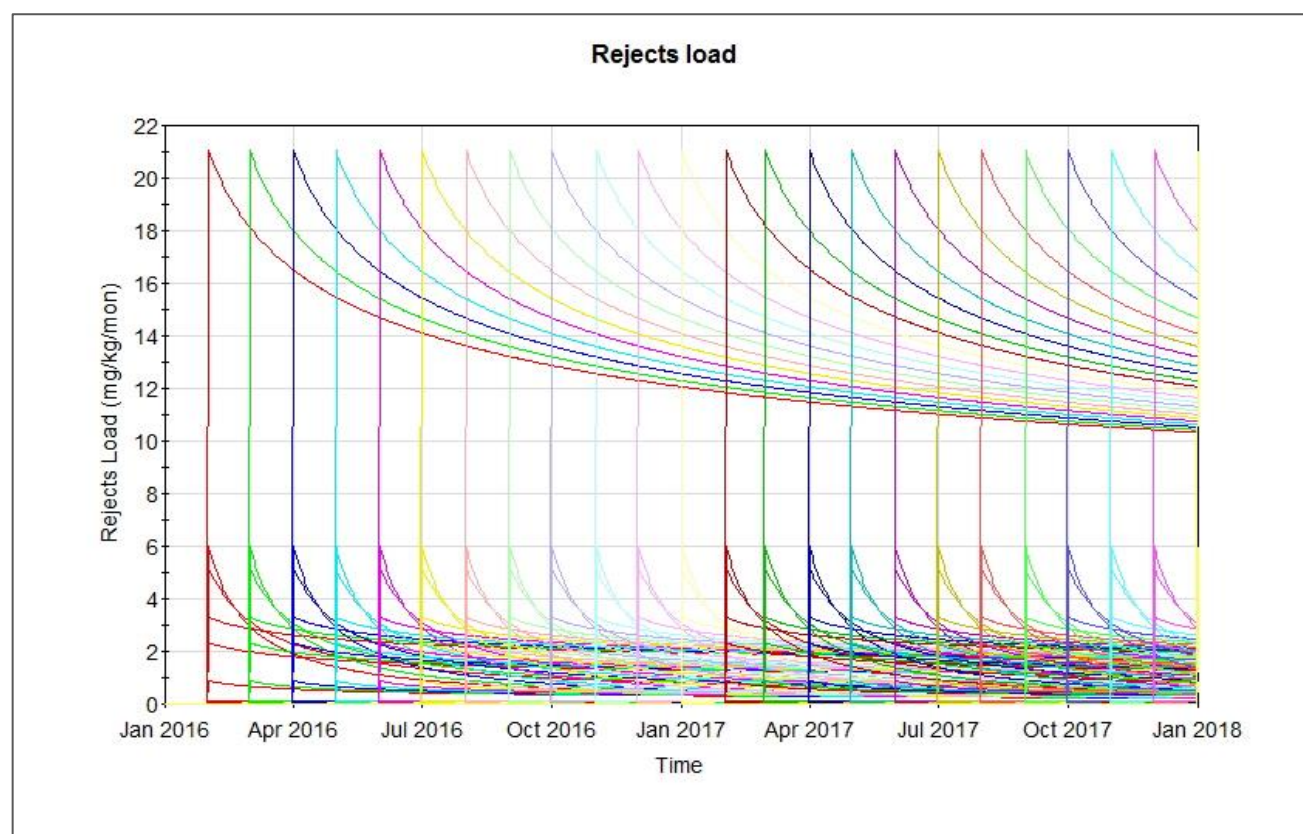


Figure 27: Decay curves are assigned to each new load of deposited material

4.6.4 Initial values

Initial values for each pit, retention dam, Meandu Creek Dam, NW tailings, K2W-N ash storage and Meandu Creek pond use measured values from the Meandu Mine water quality data base with sample dates as close as possible to the simulation start date of 1 January 2016. Where measured values are not available for a particular location an alternative representative location has been used.

4.6.5 Lime dosing system

Lime treatment of AMD occurs during 2016 and 2017 in RD7 and subsequently from 2018 in RD27. The lime dosing system at RD7 requires manual periodic replenishment of lime. The new system in RD27 will be a continuous application of lime dose at the low flow inlets from Bullgang Corner and Ramp 7.

The rate of flow of the low flow inlets to RD27 is limited to 19 L/s from Bullgang Corner and 11 L/s from Ramp 7. Flow in excess of the capacity of the low flow inlets is directed to RD7.

Lime treated resurgent seepage water quality (as detailed in Table 12) is applied to flow from Bullgang Corner and a low flow component of Ramp 7 discharge (equivalent to 4.7 L/s representing the diffuse seepage from NWBFP). Subsequent to 2018, any flow in excess of the low flow capacity of the Bullgang Corner inlet to RD27 carries the water quality of NWBFP resurgent seepage (without treatment) to RD7. Flow from Ramp 7 mixes in the Ramp 7 channel (with applied relevant water qualities) and the excess is directed to RD27.

4.6.6 Electrical Conductivity conversion factor

A Total Dissolved Solids (TDS) to Electrical Conductivity (EC) conversion factor has been defined for Meandu Mine based on laboratory analysis of over 1350 samples collected at sampling point W1 over the period 1985 to 2013.

The correlation between EC and TDS is expressed as:

$$\text{TDS} = F * \text{EC}$$

Where: TDS is the sum of the concentration of the ions sodium, potassium, calcium magnesium, fluoride, chloride, phosphate, bromide, nitrate, sulfate and carbonate expressed in mg/L.

F is the site specific (Meandu Mine) correlation factor of 0.5346

EC is electrical conductivity expressed as $\mu\text{S}/\text{cm}$.

5.0 CALIBRATION

All calibration simulations use measured climate data including the Tarong (BoM Station 040199) rainfall record for the period 1 January 2016 to 31 December 2017 and SILO Moreton's evaporation and actual evapotranspiration records for the same period. The model structure and inputs and assumptions for the various inflows and outflows are used as reference start parameters for inputs to the calibration process.

5.1 Quantity

5.1.1 Water flow rate at CP3

CP3 receives flow from across the Meandu Mine site and from Meandu Creek upstream of Meandu Creek Dam (including catchment flow from upstream of the mine). It is the ultimate drainage point for discharge to Meandu Creek from Meandu Mine. Details of inflows and outflows to CP3 are described in Section 4.1.1.8.

The main contribution to the flow at CP3 is catchment runoff from the various surfaces at the mine and the natural catchment of Meandu Creek as well as water from dewatering of runoff and groundwater that enters the pits and is not utilised at the CHPP. Flow at CP3 was calibrated by adjusting the parameters of the AWBM (described in Section 4.3.2) and in conjunction with calibration to the measured dewatering from pits. The calibrated model results at CP3 are shown in Figure 28. There is a fair alignment in the rainfall runoff response for modelled results of flow through the CP3 weir when compared to measured flow rates during peak and low flow periods.

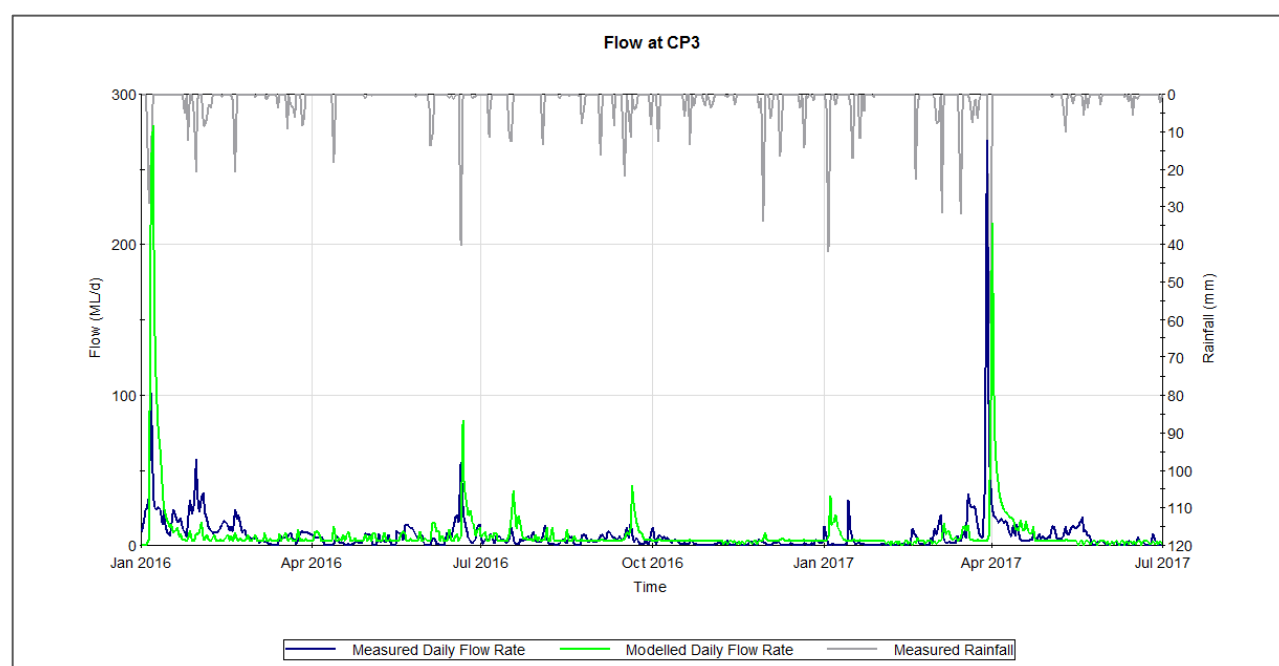


Figure 28: Flow calibration at CP3

5.1.2 Water level in Meandu Creek Dam

Meandu Creek Dam is the ultimate reservoir of total flow from Meandu Creek and Meandu Mine downstream of Meandu Mine. There is a fair alignment between modelled and measured water level in the dam as shown in Figure 29. The peak flow event early in January 2016 is slightly overestimated with flow through the spillway (at elevation 418.1 m RL) and non-retention of flow subsequent to this event. For the remainder of 2016 and early 2017 there is good alignment in fluctuations in water level response. In response to a short-term increase in blowdown water discharge to the dam in May – June of 2017, there is a gradual rise in water level consistent with the measured record. There was no rainfall during this period.

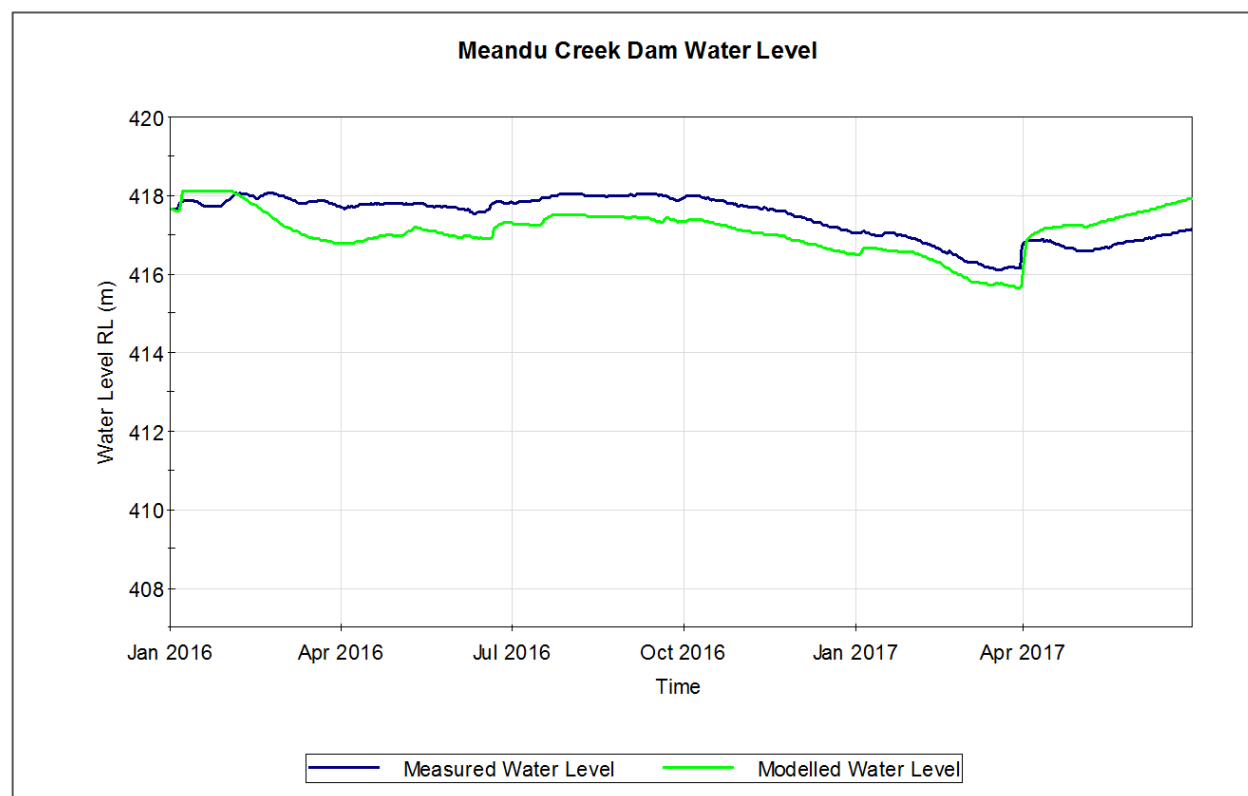


Figure 29: Water level calibration at Meandu Creek Dam

5.1.3 Pit water levels

The inputs and outputs to the water balance in pits was discussed in Section 4.1.1.1.

Measured data is available in the form of:

- quarterly total dewatering volumes for each pit
- quarterly water level in pits that currently store water, that is K4S and K2E.

Adjustable parameters for inflows and outflows include:

- groundwater inflow (defined as a potential range of values discussed in Section 4.3.3)
- pump efficiency (fraction of pump capacity)
- AWBM parameters that determine the runoff (surface flow and infiltration from waste (spoil and rejects)).

A good alignment was achieved between modelled and measured dewatering at K4S by adjusting the relevant input parameters within the available range (as shown in Figure 30). The pump efficiency is a fixed fraction of pump capacity the inflection point being reached when the available water to pump becomes limited.

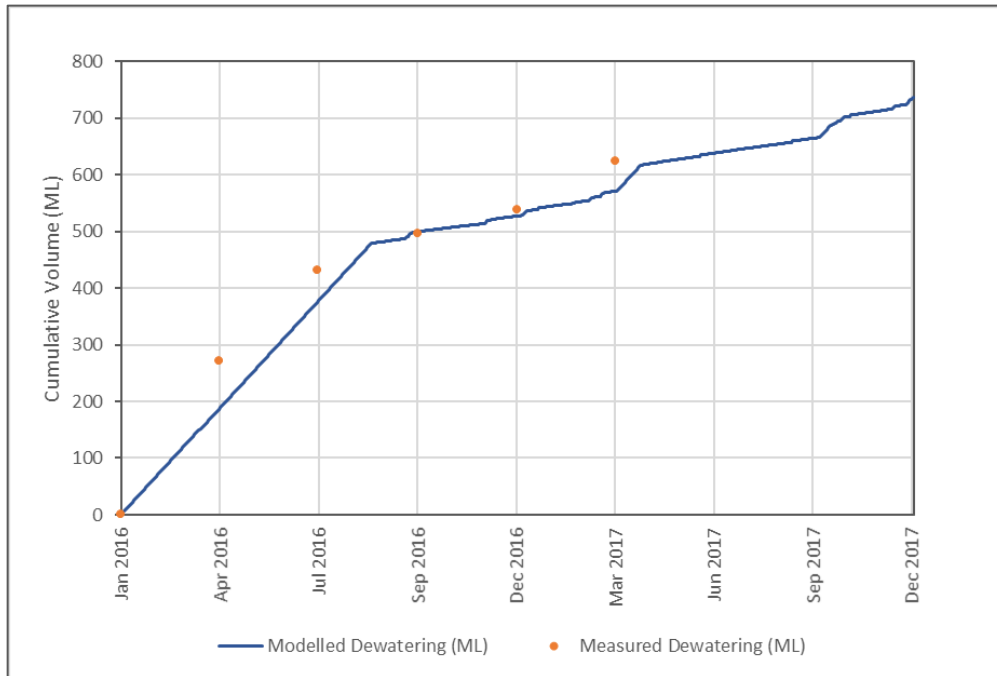


Figure 30: Cumulative Dewatering at K4S

The measured and modelled in pit water level is provided in Figure 31. The differences between measured and modelled levels may be due to inaccuracies in pit geometry in the location of the stored water. The model will assume a level water layer stored across the base of the pit at low water levels which is likely not the case in an empty pit. Increasing inflows to correct the water level representation will over compensate in inaccurate representation of dewatering flow volumes.

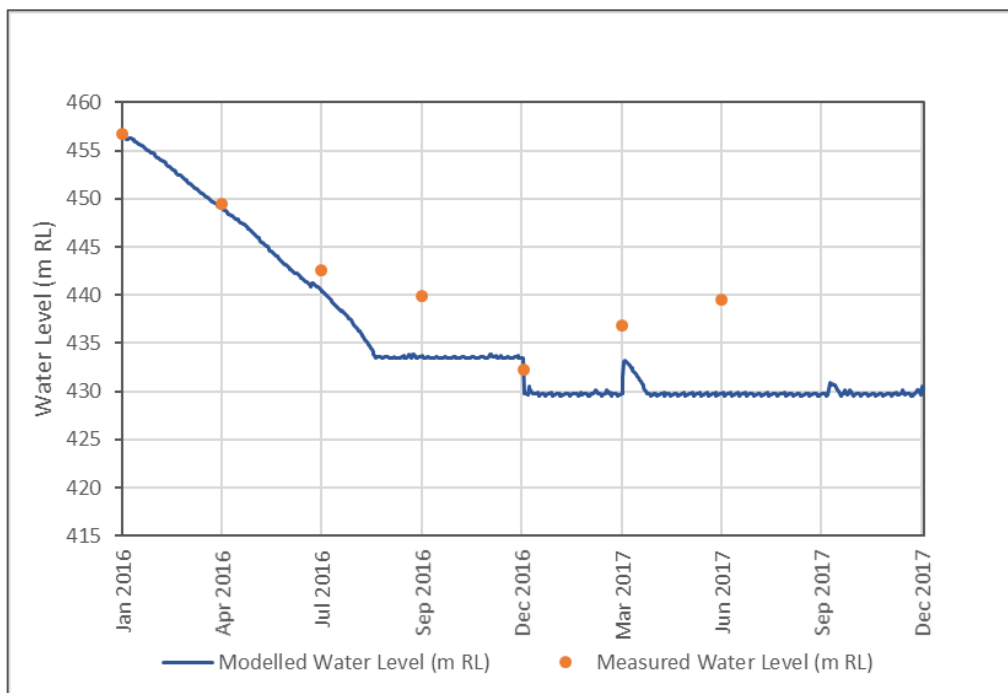


Figure 31: Water level at K4S

Similarly, at K2E Pit there is a fair alignment between modelled and measured cumulative dewatering as shown in Figure 32 achieved by adjusting the input parameters within the available range. The dewatering regime in the model is fixed and does not reflect day to day operational water management decisions, however, in general, the dewatering quantities that enter the water management system are similar in total over time. The measured and modelled water level is shown in Figure 33. There is again fair alignment over a period of time though poor representation of the day to day operational water use.

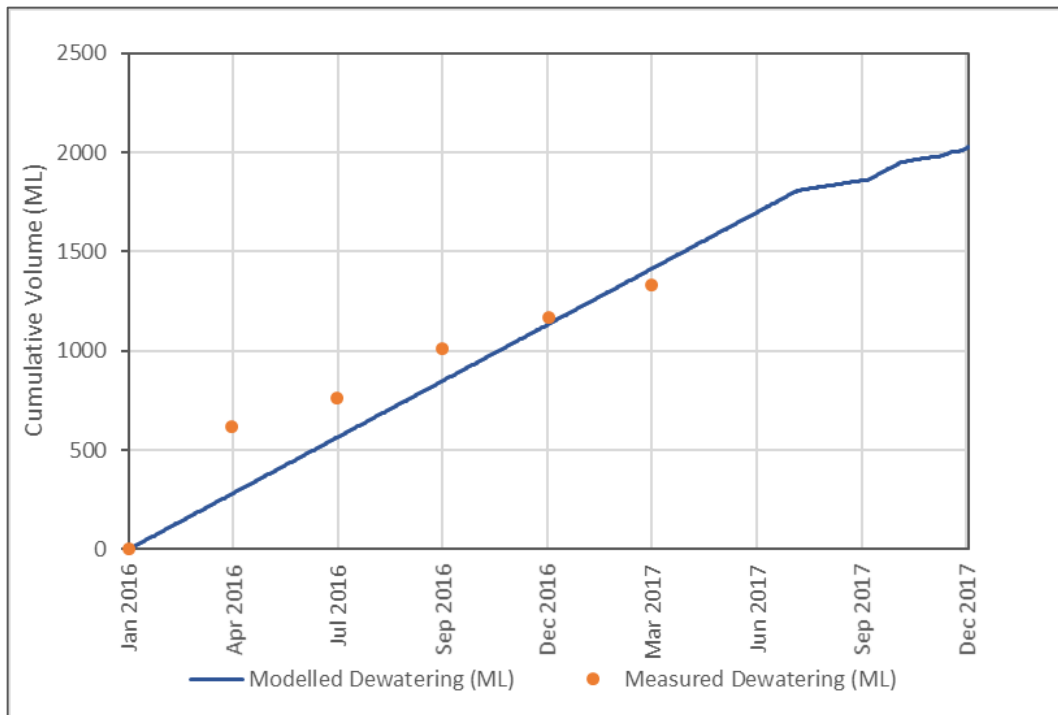


Figure 32: Cumulative dewatering at K2E

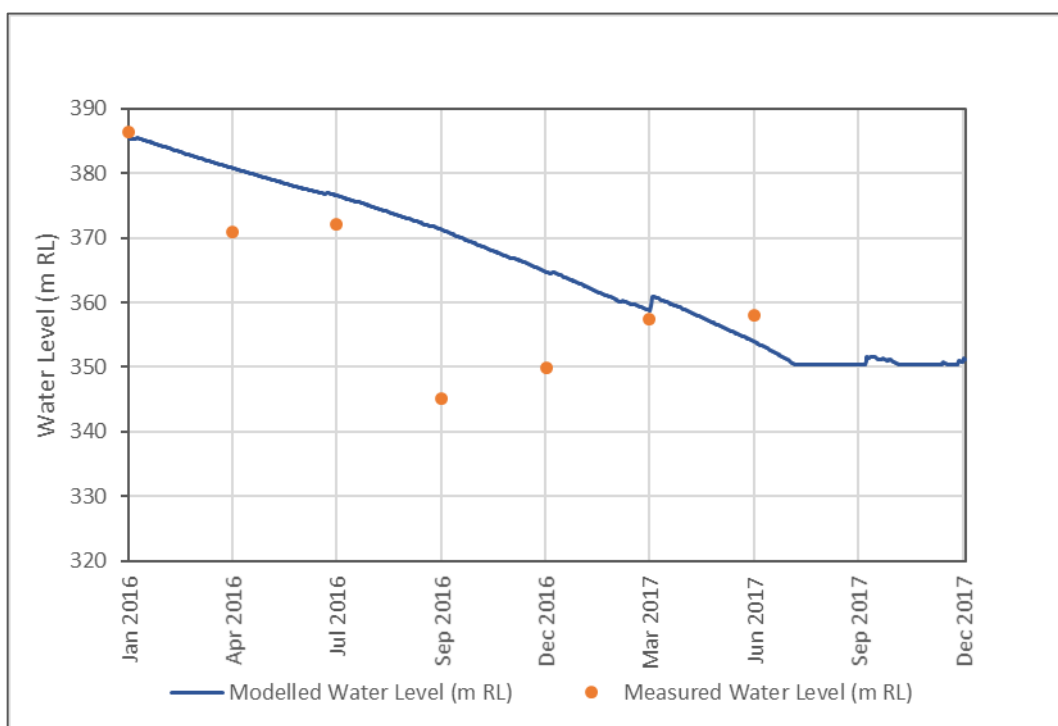


Figure 33: Water level at K2E

The groundwater inflow parameters used in the calibration process are provided in Table 13.

Table 13: Groundwater calibration parameters

Pit	Central		K2E		K4E		K4S	
Hydraulic conductivity (m/day)	0.0015	1×10^{-5}	0.0015	1×10^{-5}	0.0015	1×10^{-5}	0.0015	1×10^{-5}
Total inflow range (L/s)	13.4	1.6	38.5	4.0	16.4	1.7	3.6	0.4
Inflow used in calibration (L/s)	9.5		14.7		17.7		5.1	

5.1.4 Calibrated AWBM parameters

AWBM parameters have been optimised during the calibration process at pits and the ultimate flow and retention locations of CP3 and Meandu Creek Dam and are provided in Table 14. The parameters identified in calibration of the AWBM to the natural catchment of Barker Creek at Brooklands (described in Section 4.3.2) have been used to represent natural land use runoff response. Other land use surfaces have been parameterised manually by calibration of the model and understanding of the components of the AWBM model (described in Section 4.3.2).

Table 14: Calibrated AWBM parameters for the identified land uses in the model

AWBM Parameter	Represents	Natural land use	Rehabilitated land use	Hardstand land use	Waste land use
C1	Surface store capacity	30 mm	30 mm	5 mm	15 mm
C2	Surface store capacity	240 mm	240 mm	15 mm	80 mm
C3	Surface store capacity	480 mm	480 mm	30 mm	190 mm
BFI	Baseflow index	0.2	0.2	0	0.2
Ks	Surface recession constant	0.7	0.7	0.1	0.2
Kb	Baseflow recession constant	0.1	0.1	0.7	0.95

5.1.5 CHPP water use

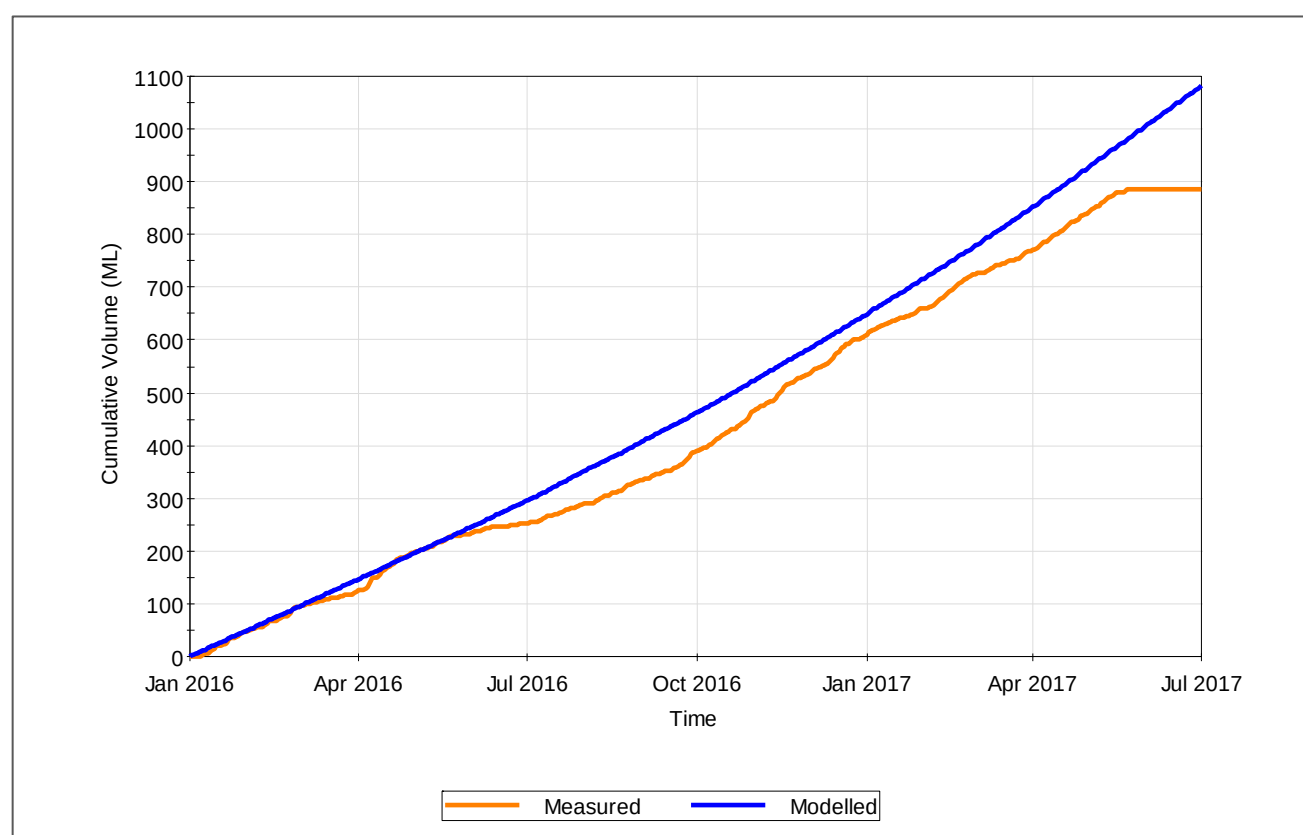
The CHPP water use is based on the water demand identified in the CHPP water balance assessment undertaken by Stanwell as reported in Section 4.4.2. The range of variability is set using the potential variability identified in the water balance for low, medium and high yielding coal, that is 201.1, 149.4 and 124.4 L/tonne respectively. The water use identified at the CHPP is the total of water from RD8 and RD2 along with raw water used in processing.

Measured CHPP water use for the period 2016, 2017 was supplied from PIMS measured values at pumps 18 and 19 and is provided in Table 15. The water use for both 2016 and 2017 are at the lower end of the potential range as determined by the CHPP water balance undertaken by Stanwell.

Table 15: CHPP water use 2016, 2017

	Unit	2016	2017
Average daily CHPP water use	ML/d	1.39	1.94
Value per ROM tonne	L/t	106.8	128.0

The values used in the model were initially set to the rate per ROM tonne (based on the CHPP water balance) and then adjusted to achieve better agreement with measured cumulative water use from RD8 and RD2 in 2016 and 2017 (Figure 34). There is a good agreement between measured and modelled cumulative total water use (Figure 35). Modelled values exhibit less variability as they are based on a daily demand resampled from a potential and more narrow range of yields.

**Figure 34: Measured and modelled cumulative retention dam water use at the CHPP**

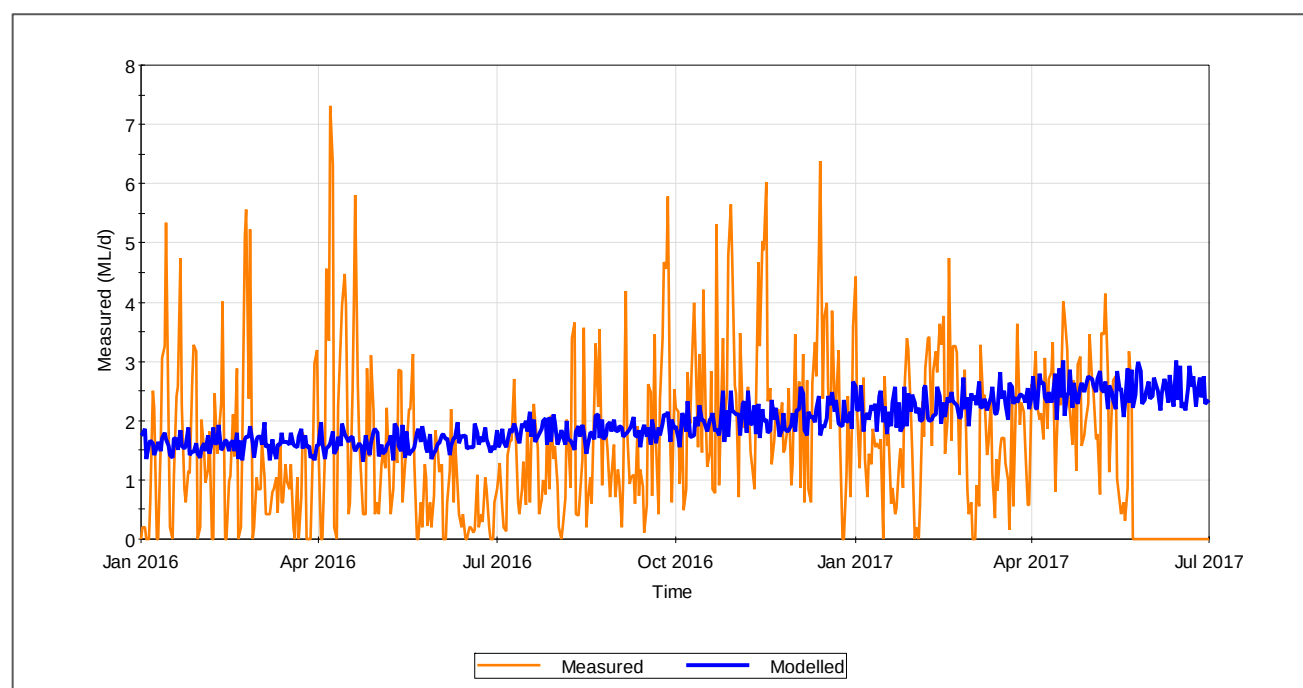


Figure 35: Measured and modelled daily water use at the CHPP

5.1.6 Calibrated CHPP water demand

Calibrated CHPP water demand are provided in Table 16. The solid bowl centrifuge has recently been installed and as a result there are no measured values for water demand given the change in water use anticipated at the CHPP. The CHPP water model estimated solid bowl centrifuge water demand has been revised down by the same ratio as the calibrated CHPP water demand. The calibration assumes that all forms of coal yield were processed during 2016 / 2017.

Table 16: Calibrated CHPP water demand from retention dams per tonne of ROM

Coal yield	Operations (2016 / 2017) (L/t)	Solid bowl installed (from 2018) (L/t)
Low yield coal	141	84
Median yield coal	105	70
High yield coal	87	64

5.1.7 Ramp 7 and Bullgang Corner

Flow rate (or seepage rate) data was recorded at the Ramp 7 culvert and at Bullgang Corner between June and December 2016. Comparison of modelled and measured flow rates are shown in Figure 36 (Ramp7) and Figure 37 (Bullgang Corner). Note that anecdotal information from Stanwell site personnel is that the flow in the Bullgang Corner drain has not been observed to cease and that the zero values are considered spurious.

Modelled values match measured values well, with similar ranges of values and behaviour. Modelled values appear to be more responsive to rainfall events.

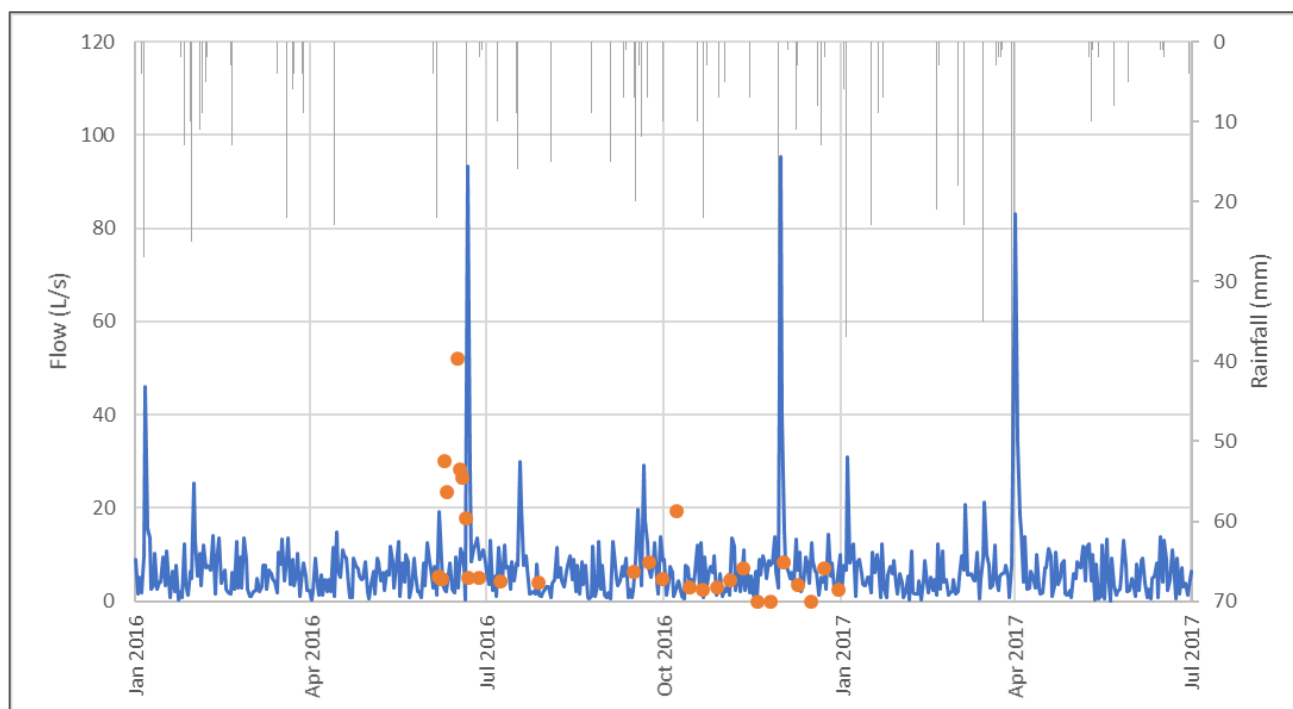


Figure 36: Comparison of modelled and measured flow rates at Ramp 7 culvert

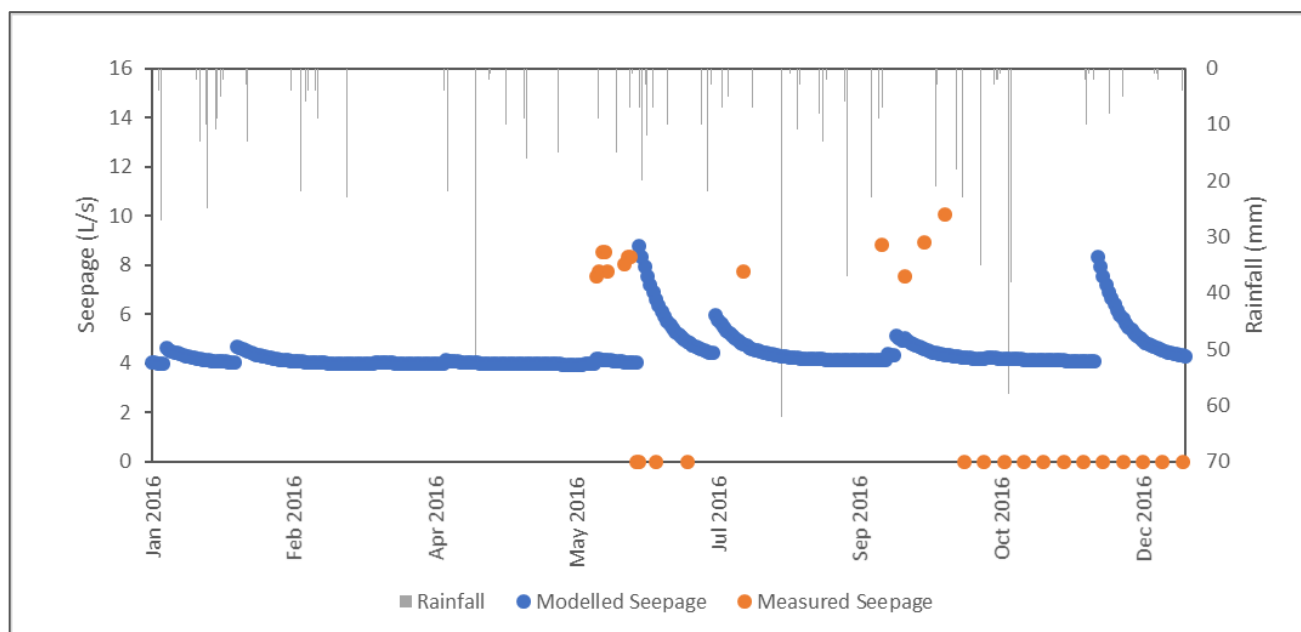


Figure 37: Comparison of modelled and measured flow rates at Bullgang Corner

5.1.8 NWB tailings

The pump efficiency of the return water from the decant pond on the NWB tailings was calibrated to quarterly measured values. Calibration results are provided in Figure 38. Using the calibrated modelled pump efficiency resulted in a good alignment to measured values.

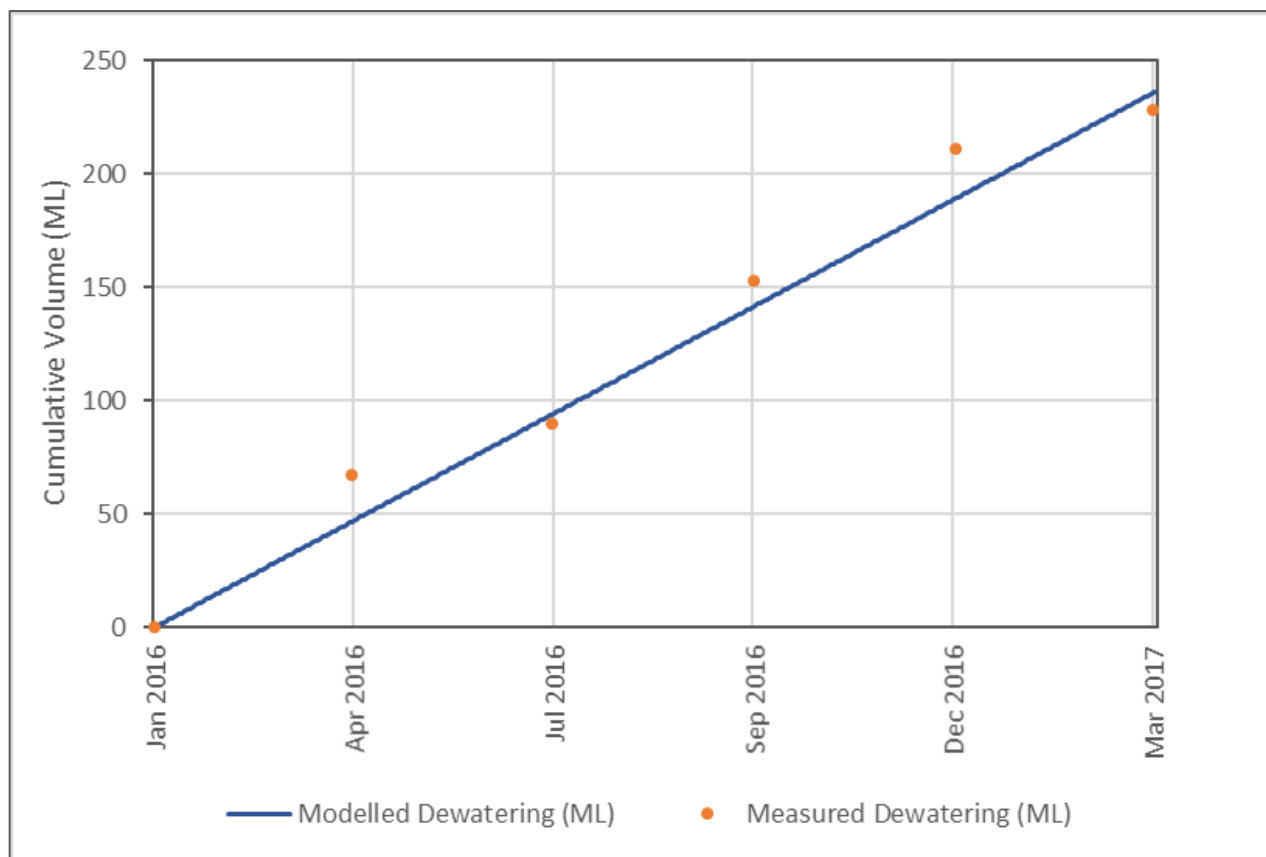


Figure 38: Measured and modelled dewatering at NWB tailings

5.1.9 K2W-N Ash

The pump efficiency of the return water from the decant pond on the K2W-N Ash was calibrated to a short period of available daily measured values. Calibration results are provided in Figure 39. Using the calibrated modelled pump efficiency resulted in a good alignment to measured values.

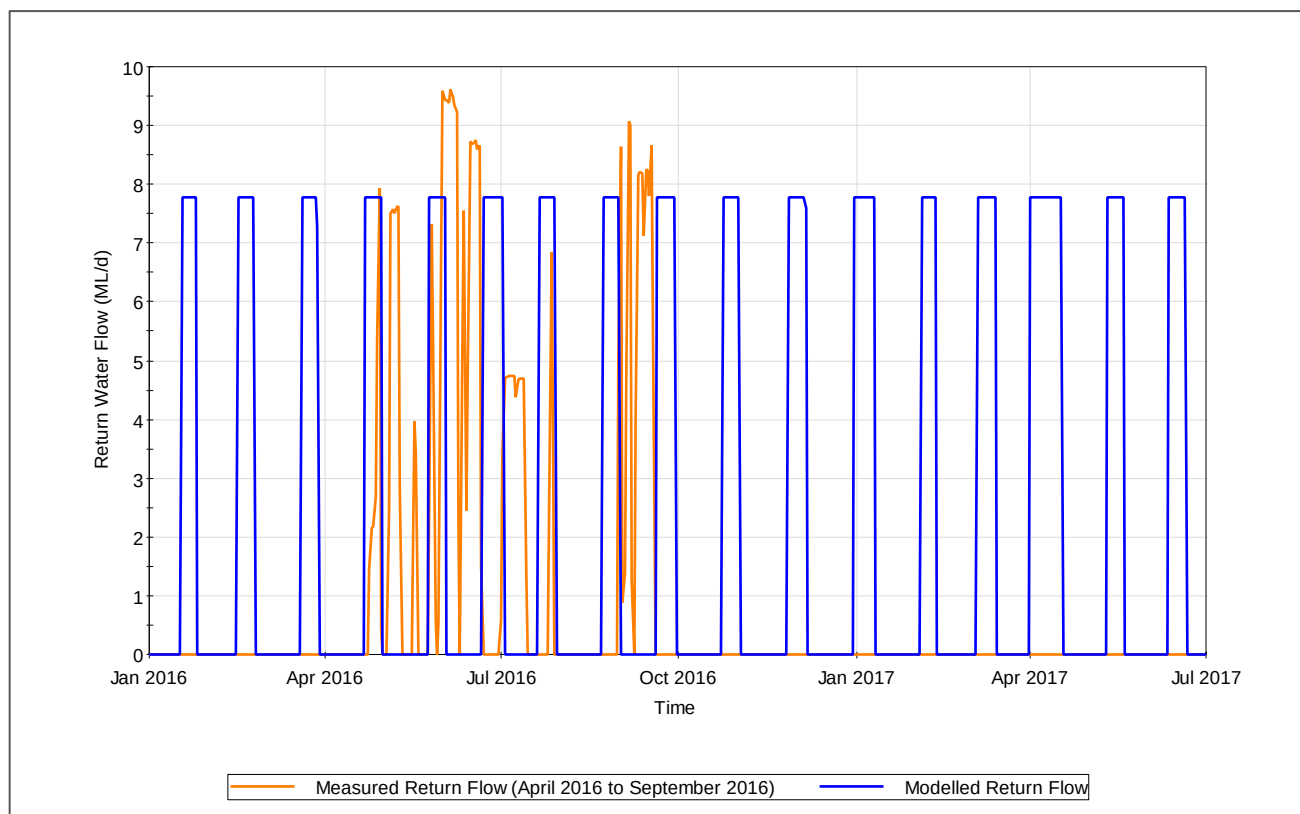


Figure 39: Measured and modelled dewatering at K2W-N Ash

5.2 Water quality

Water quality inputs and assumptions are described in Section 4.6.2 and were supplied for modelling by RGS and have not been calibrated in the model. Verification of water quality results during the period 2016/2017 is discussed in Section 6.2.

6.0 VERIFICATION

6.1 Quantity

The 2016/2017 measured data has been used where available for the calibration process. Minimal flow data is available at mine impacted AMD source locations, Bullgang Corner and Ramp 7. It is understood that flow monitoring equipment will be installed at the low flow inlets to the new RD27 and continuous flow monitoring data will be available for both Bullgang Corner and Ramp 7 once the equipment is operational. The installation of measuring weirs has been considered but are deemed unsuitable due to potential interference with measuring high-flow/low-flow combinations. A different type of flow measurement will be sourced.

It is recommended that the model results for seepage at Bullgang Corner and Ramp 7 be verified against measured data, once this data is available, to provide confidence in the assumptions and conceptual model developed for this location (as shown in Figure 14) or adjust input parameters if required.

6.2 Quality

6.2.1 CP3

A verification between modelled and measured EC results was undertaken at CP3. Generally, modelled values are in the range of those measured at CP3. A dilution response is more evident in the modelled data following rainfall events. The peak EC in the modelled record is 2644 $\mu\text{S}/\text{cm}$ and occurs during an extended dry period.

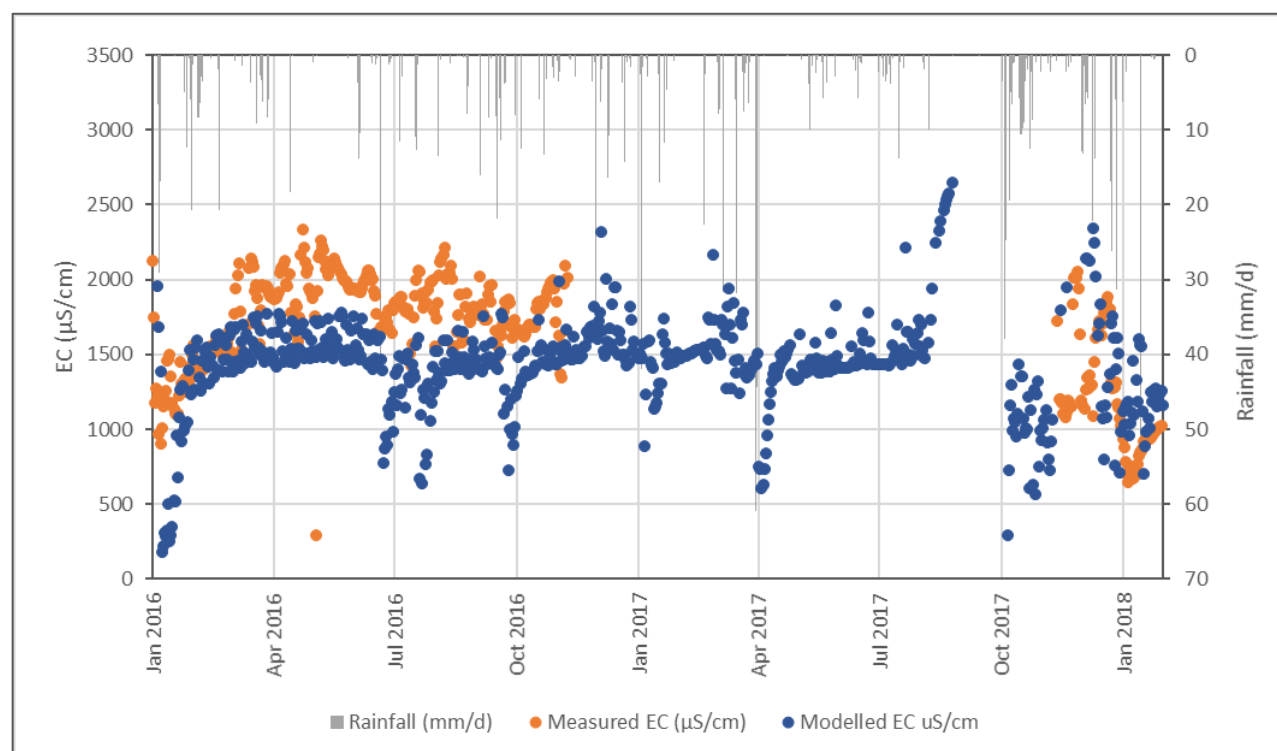


Figure 40: EC verification at CP3

For verification of pH at CP3, the modelled values occur across the range of measured data, but there is poor variability in the modelled data when compared to measured data in early 2018 (as shown in Figure 41). The greater variability in measured data may be due to current lime dosing processes occurring for approximately 12 hours per day. The model will assume dosing is occurring 24 hours a day. Further verification may be obtained when continuous data becomes available after the new dosing system is installed in RD27.

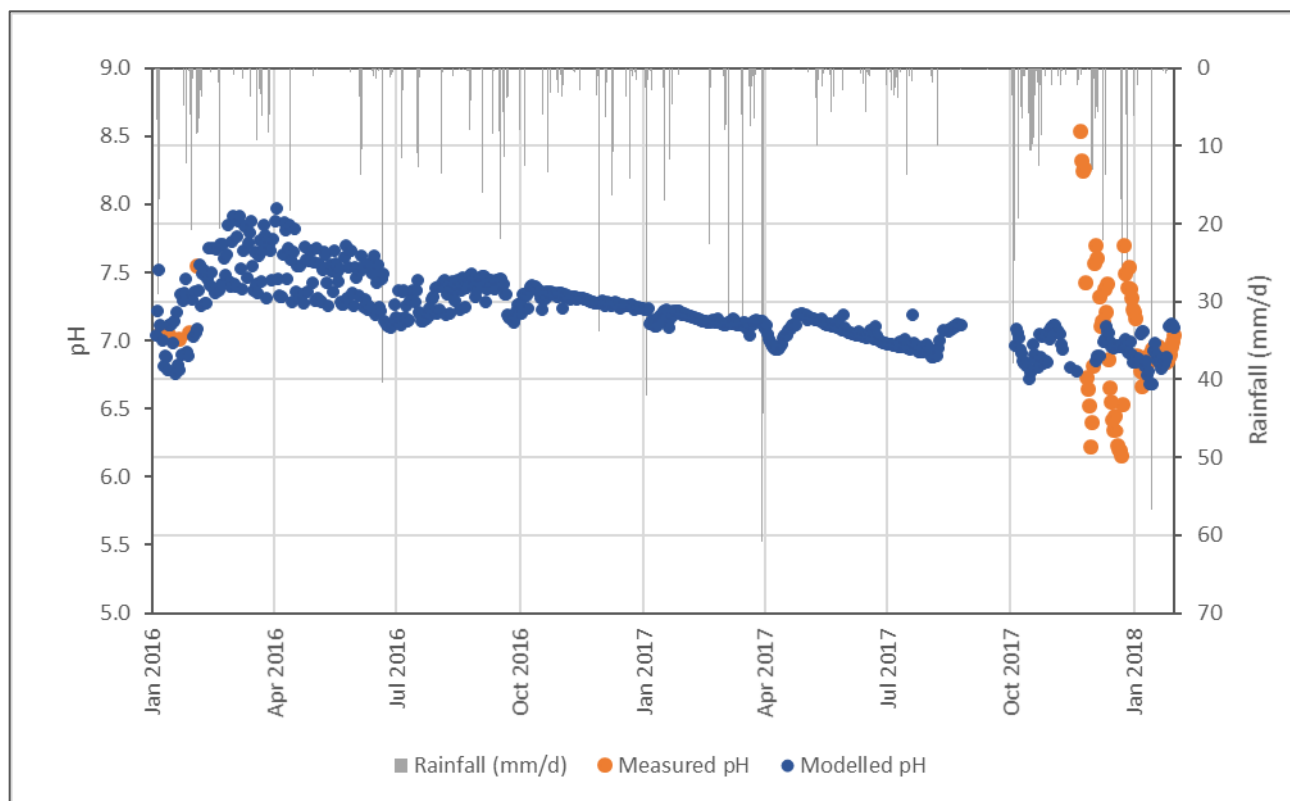


Figure 41: pH verification at CP3

Modelled sulfate concentrations are in the range of those measured (as shown in Figure 42). There are limited measured data points available. CP3 receives mine impacted flow from RD8 (Ramp 7 – Bullgang – RD7 – RD8 flow path), as well as from the eastern side of the mine from RD2. RD8 is preferentially pumped to the CHPP and is programmed to do so in the model. Sulfate verification at RD8 and RD2 are provided in Section 6.2.3.

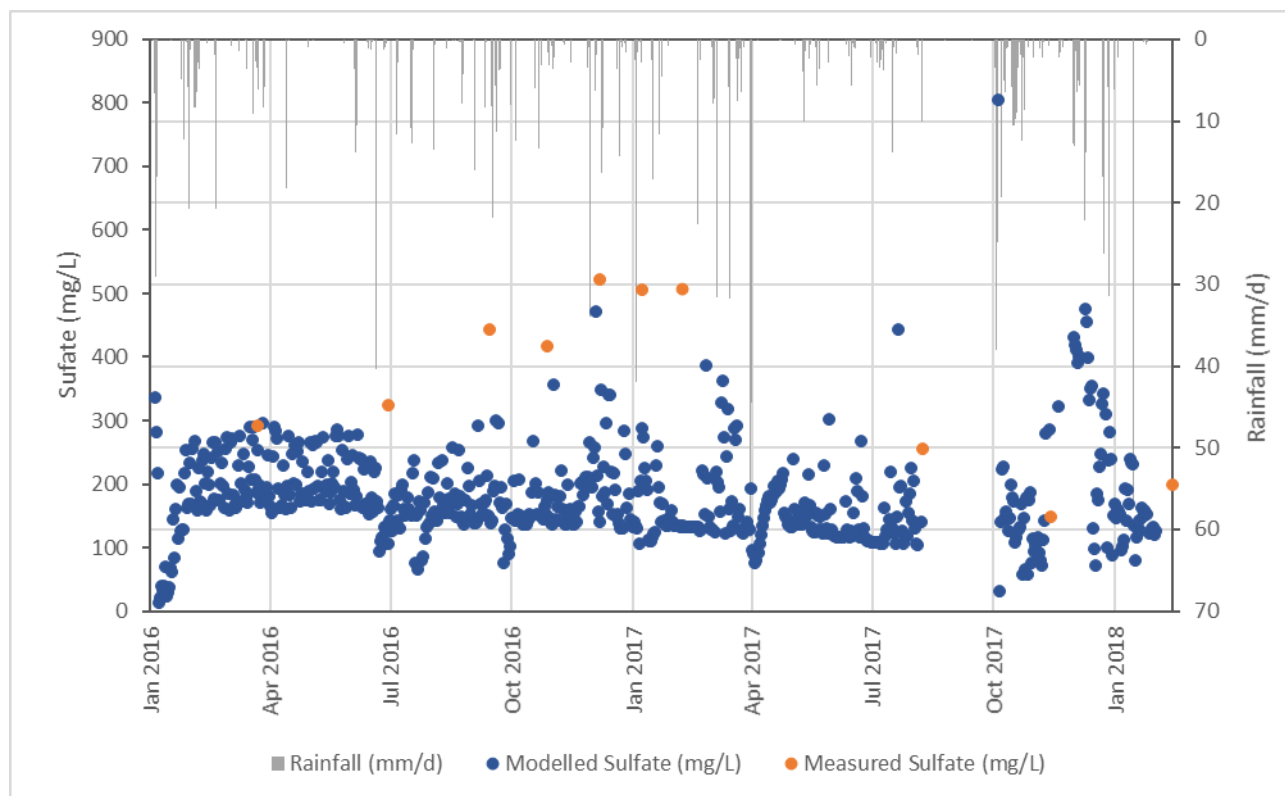


Figure 42: Sulfate verification at CP3

Measured concentrations of manganese at CP3 were higher than modelled results (as shown in Figure 43). The lower estimates of manganese concentration in the model, may occur as a result of the model simulating daily time-steps and therefore assuming continuous lime dose treatment. The manganese concentration in seepage from the NWBFP without lime dose treatment used for modelling is 32.2 mg/L, as indicated in Section 4.6.2.1, with lime dose treatment is 4.63 mg/L. Other inflows to CP3 that influence the mixed solution at this location have a manganese concentration of < 1 mg/L.

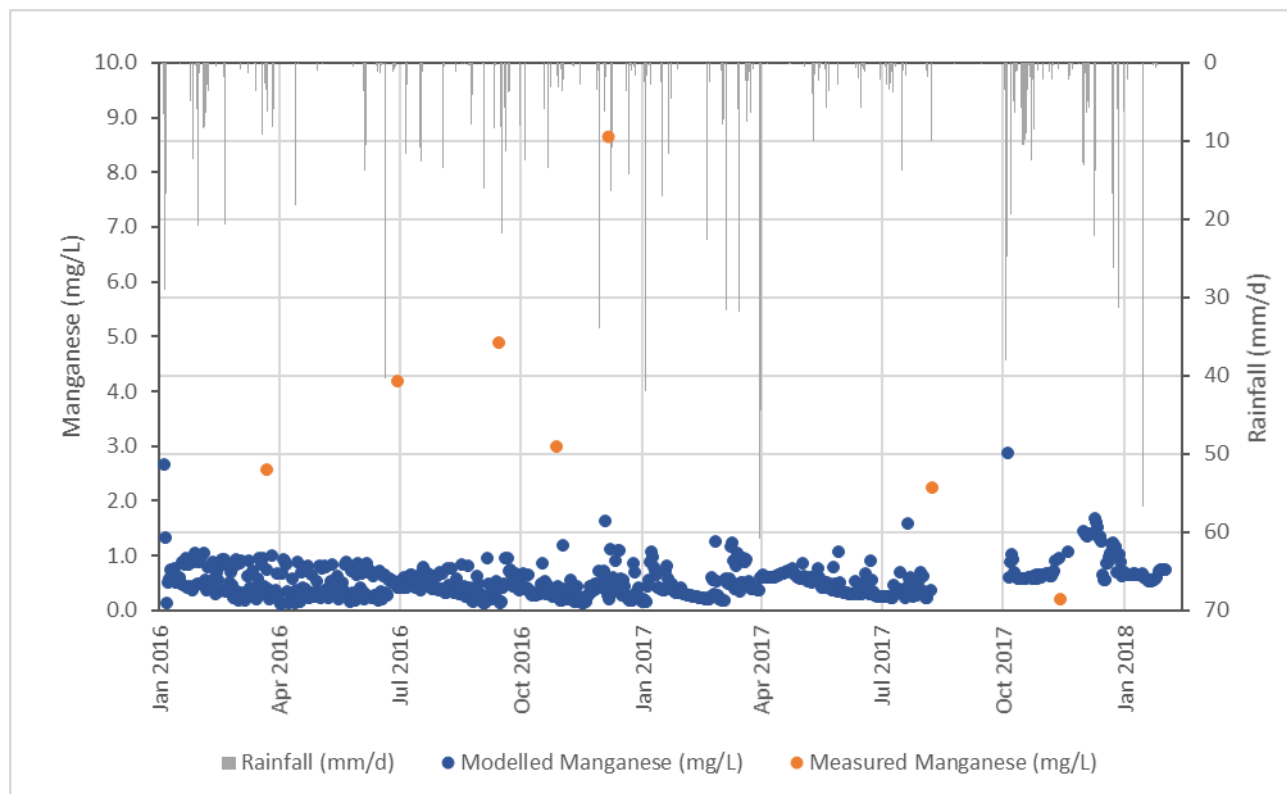


Figure 43: Manganese verification at CP3

Modelled estimates of nickel and zinc concentrations at the CP3 weir are generally lower than the measured values, as shown in Figure 44 and Figure 45 respectively. Lower modelled estimates of nickel and zinc may also be due to the assumption of continuous lime dose treatment in the daily time-step model. As indicated in Section 4.6.2, input concentrations of nickel are 0.512 and 0.039 mg/L in resurgent seepage and in lime treated water respectively. Input concentrations of zinc are 4.27 and 0.003 mg/L respectively.

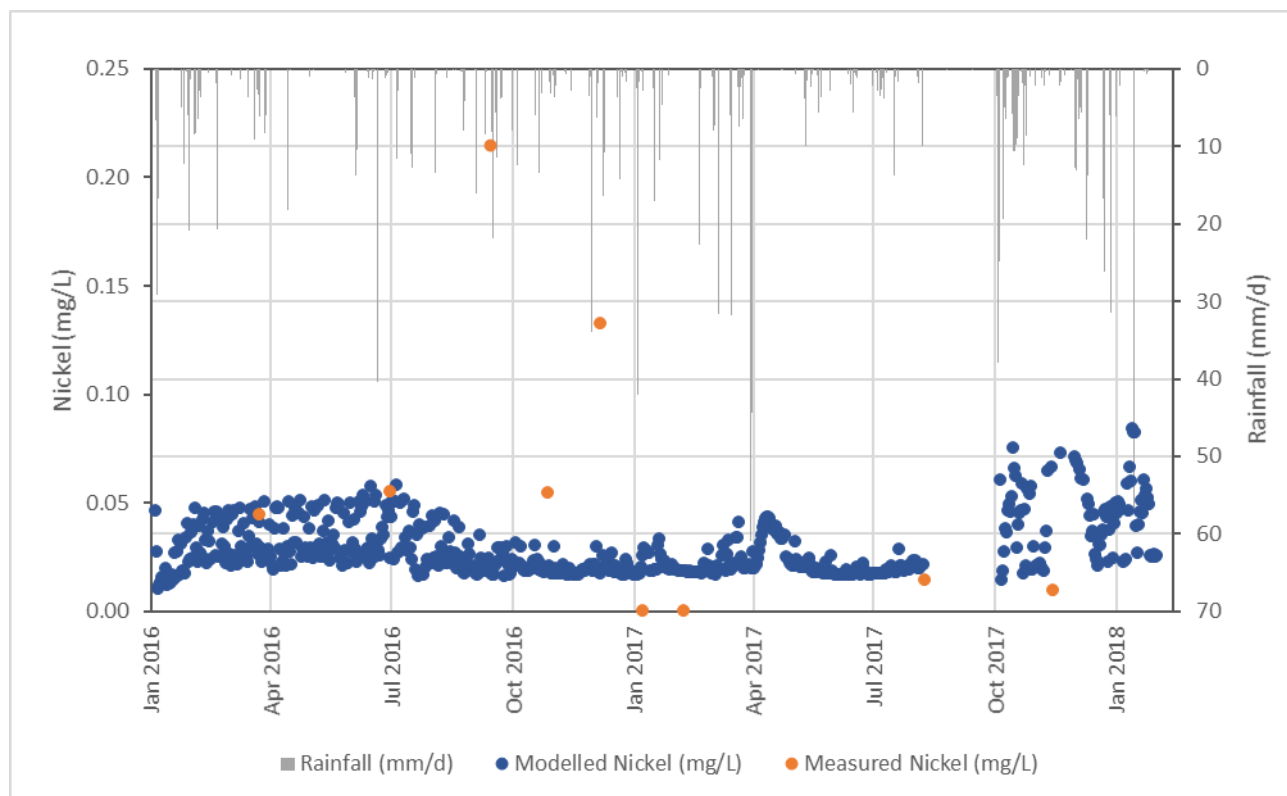


Figure 44: Nickel verification at CP3

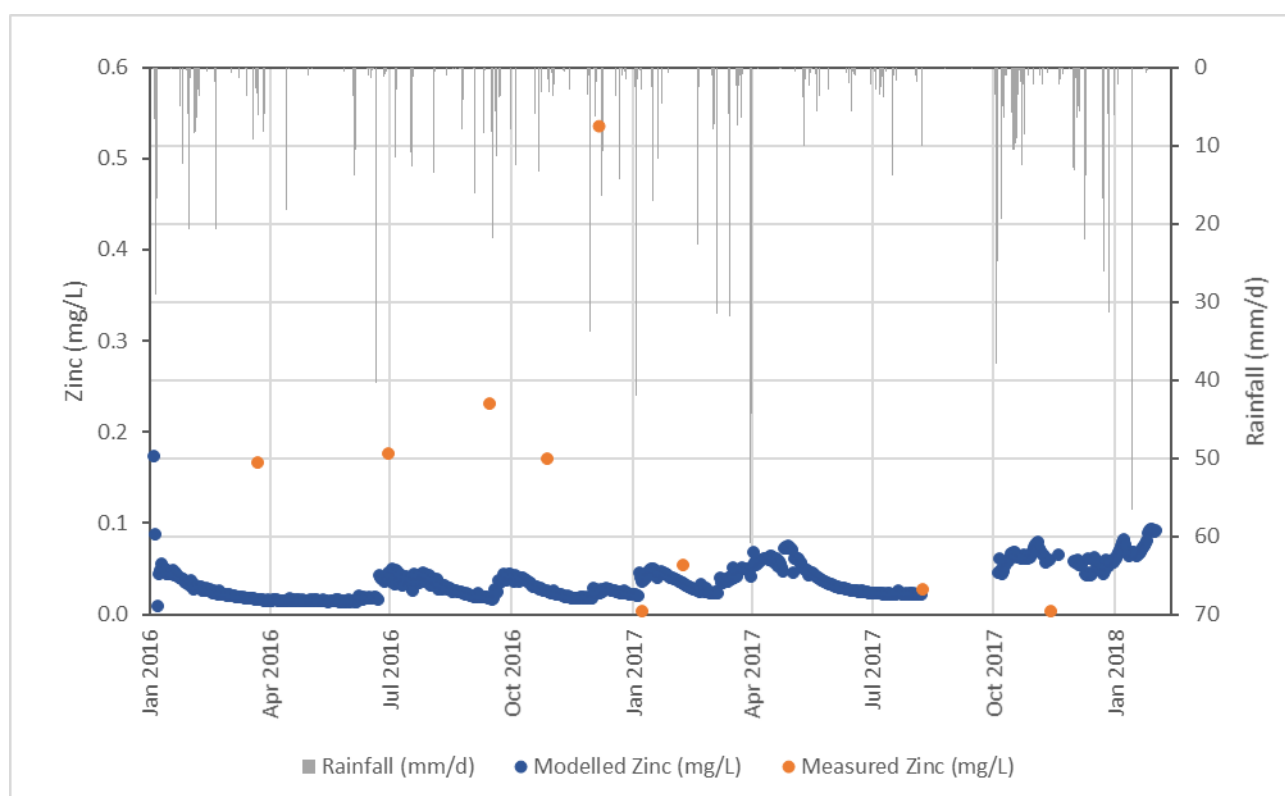


Figure 45: Zinc verification at CP3

6.2.2 Meandu Creek Dam

Measured and modelled values of EC in Meandu Creek Dam (Compliance Point 1 (CP1)) are shown in Figure 46. There is a good alignment between measured and modelled data at this location. There is less variability in EC results as expected in a large water storage. The lower values in the model in the early months of 2016 correspond to the high estimation of a rainfall event at the start of the simulation, as discussed in Section 5.1.2, with a longer period of overflow from the dam than in the measured data.

The model estimation of pH at Meandu Creek Dam (CP1) shows less variability in the modelled record when compared to measured data. The dominant constant inflow at Meandu Creek Dam is blowdown water that has an assumed fixed value, as shown in Table 12, of 8.0 and 8.1 mg/L at Tarong North Power Station and Tarong Power Station, respectively. Some improvement in variability may be achieved by using a monte carlo input parameter (randomised values within a user specified range) for this dominant flow stream.

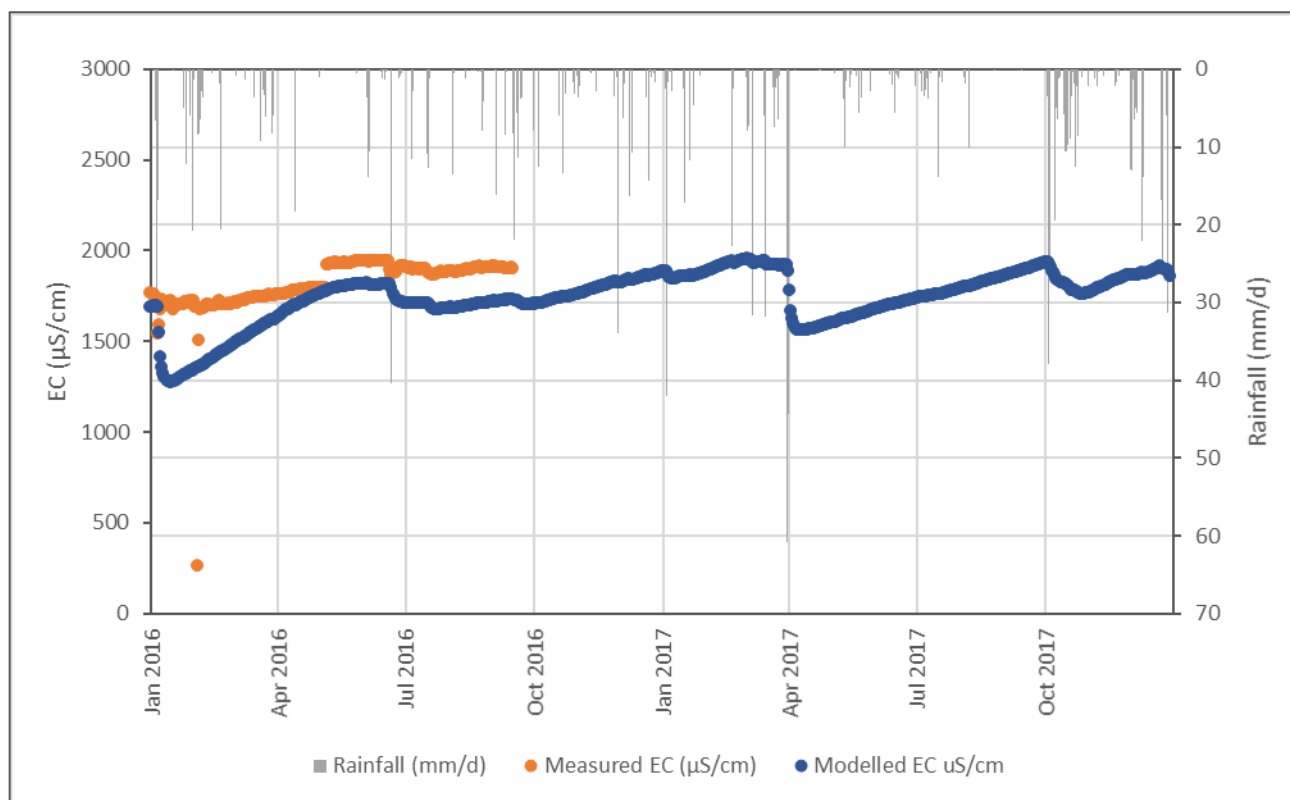


Figure 46: EC verification at Meandu Creek Dam (CP1)

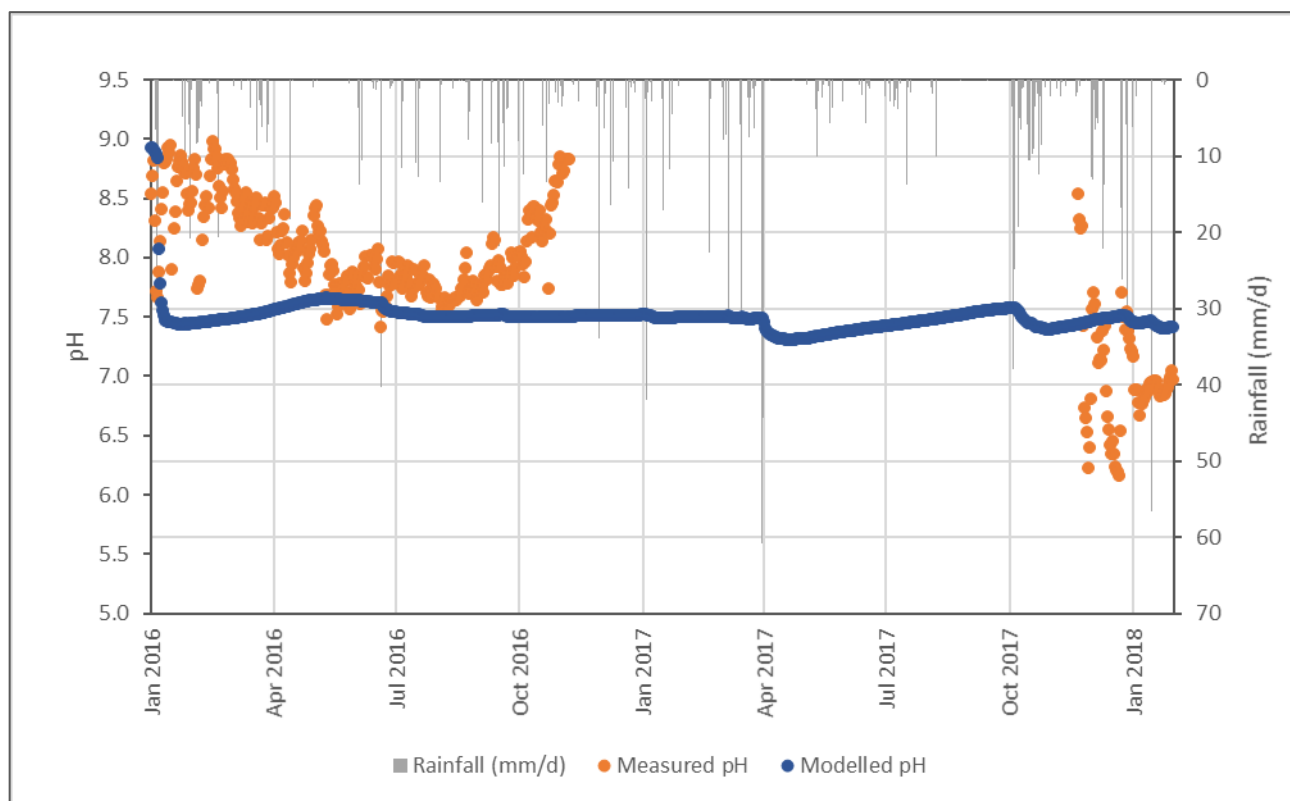


Figure 47: pH verification at Meandu Creek Dam (CP1)

6.2.3 Retention dams RD7, RD8 and RD2

The modelled estimation of EC is representative of the available measured data at RD7 and RD8 (as shown in Figure 48 and Figure 49 respectively).

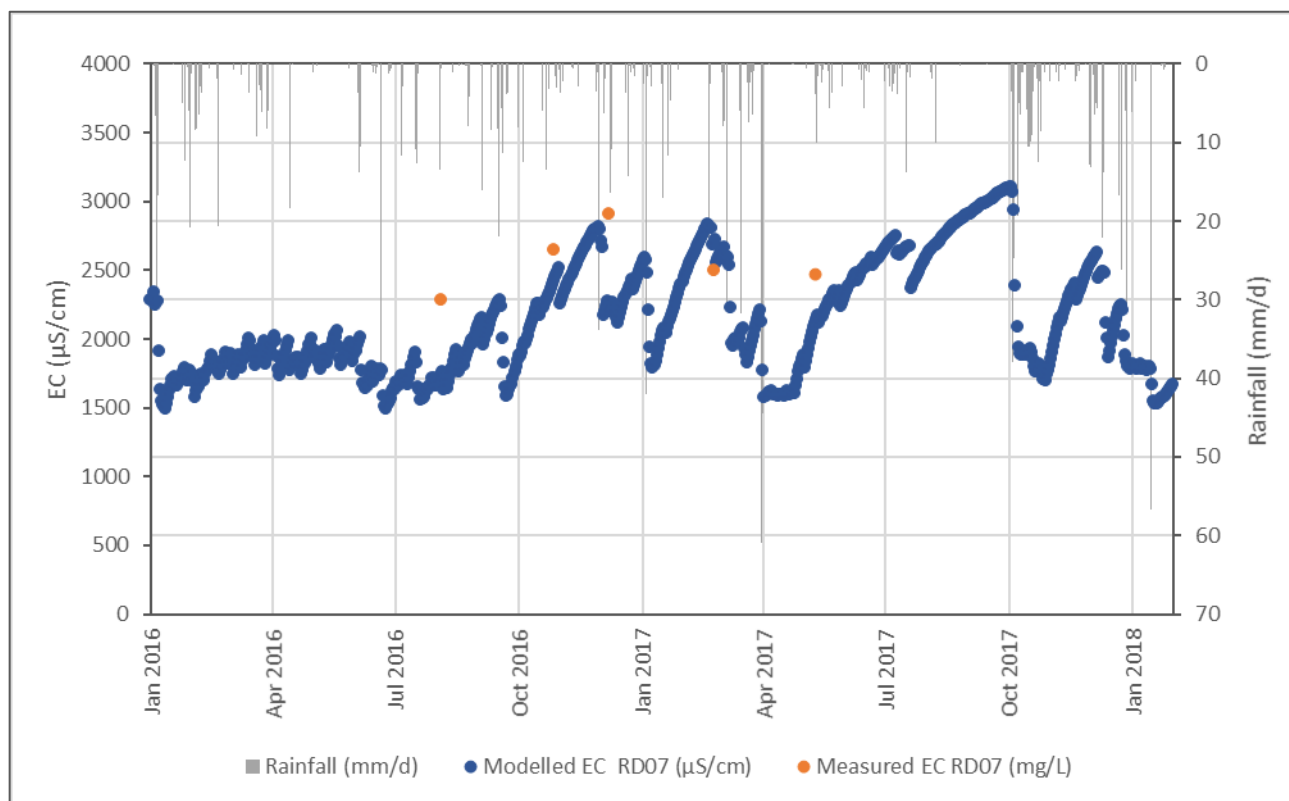


Figure 48: EC verification at RD7

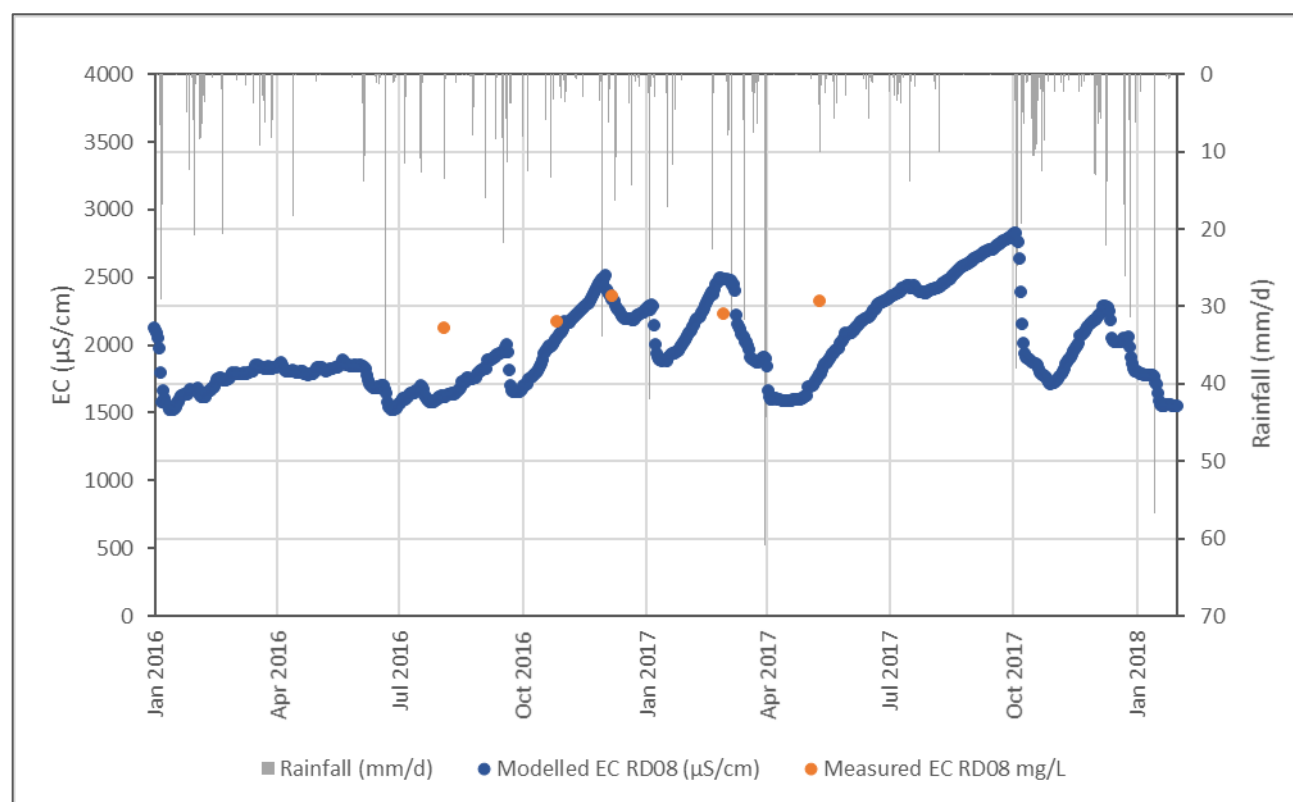


Figure 49: EC verification at RD8

EC at RD2 is less well represented but in the order of the EC of the available measured data (as shown in Figure 50).

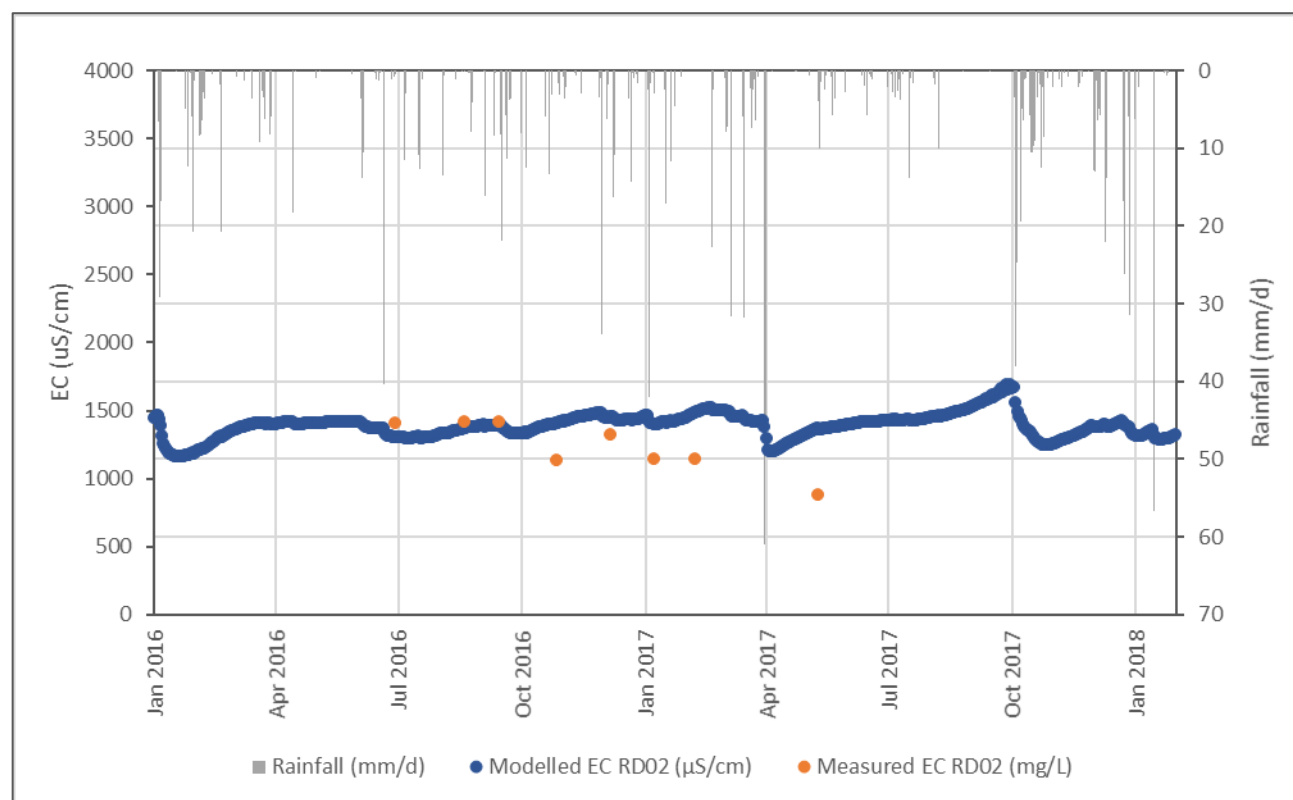


Figure 50: EC verification at RD2

Sulfate values at RD7, RD8 and RD2 (Figure 51 - Figure 53) are reasonably well aligned to the available measured record. The initial model value in these simulations is set to the closest measured data point in July 2016 and alignment may improve if additional measured sulfate data is available for Q1 and Q2 2016.

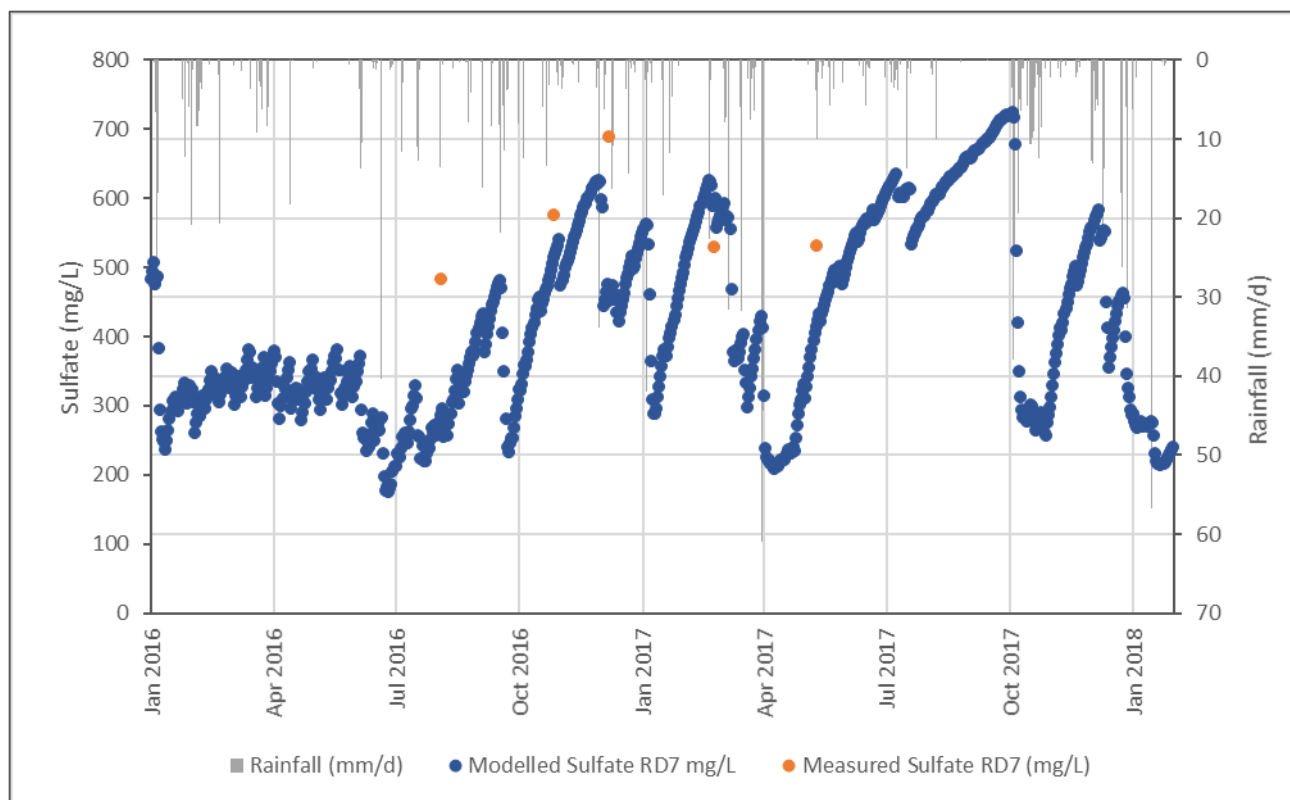


Figure 51: Sulfate verification at RD7

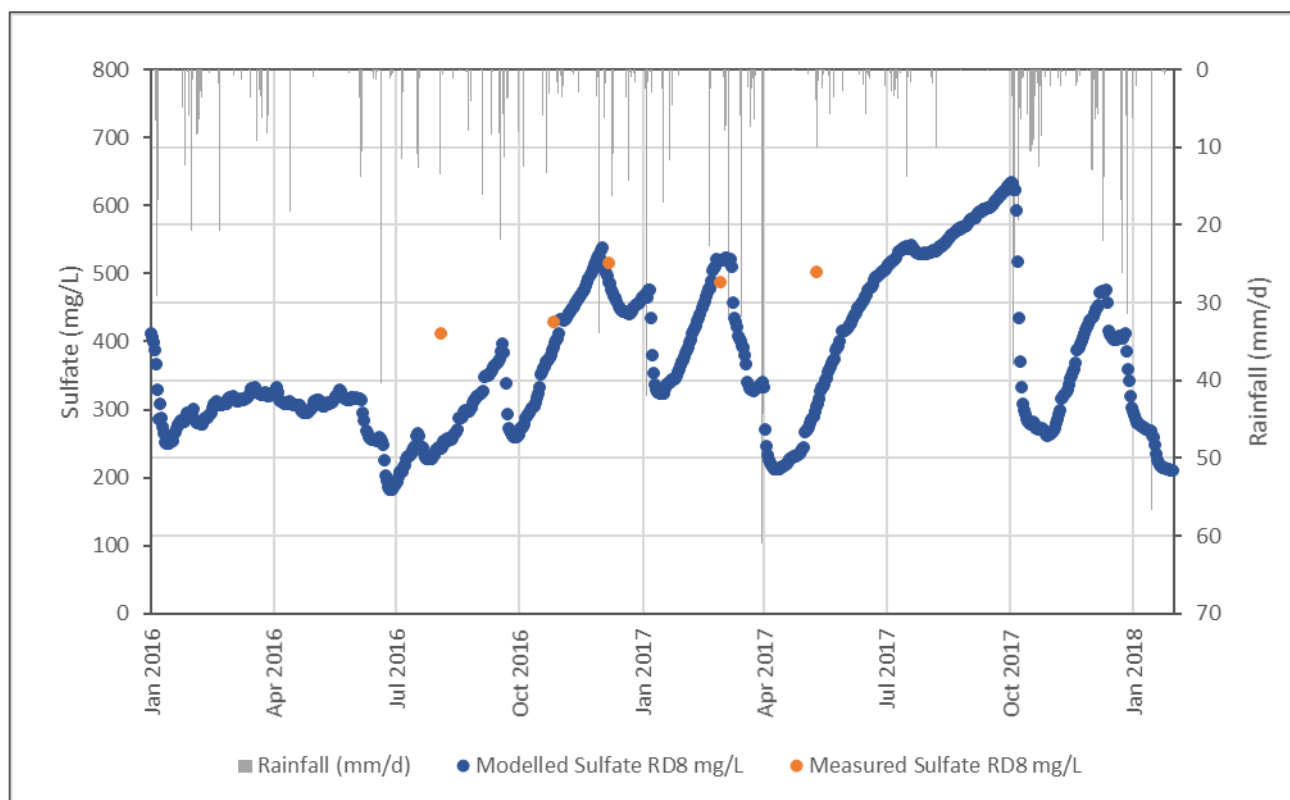


Figure 52: Sulfate verification at RD8

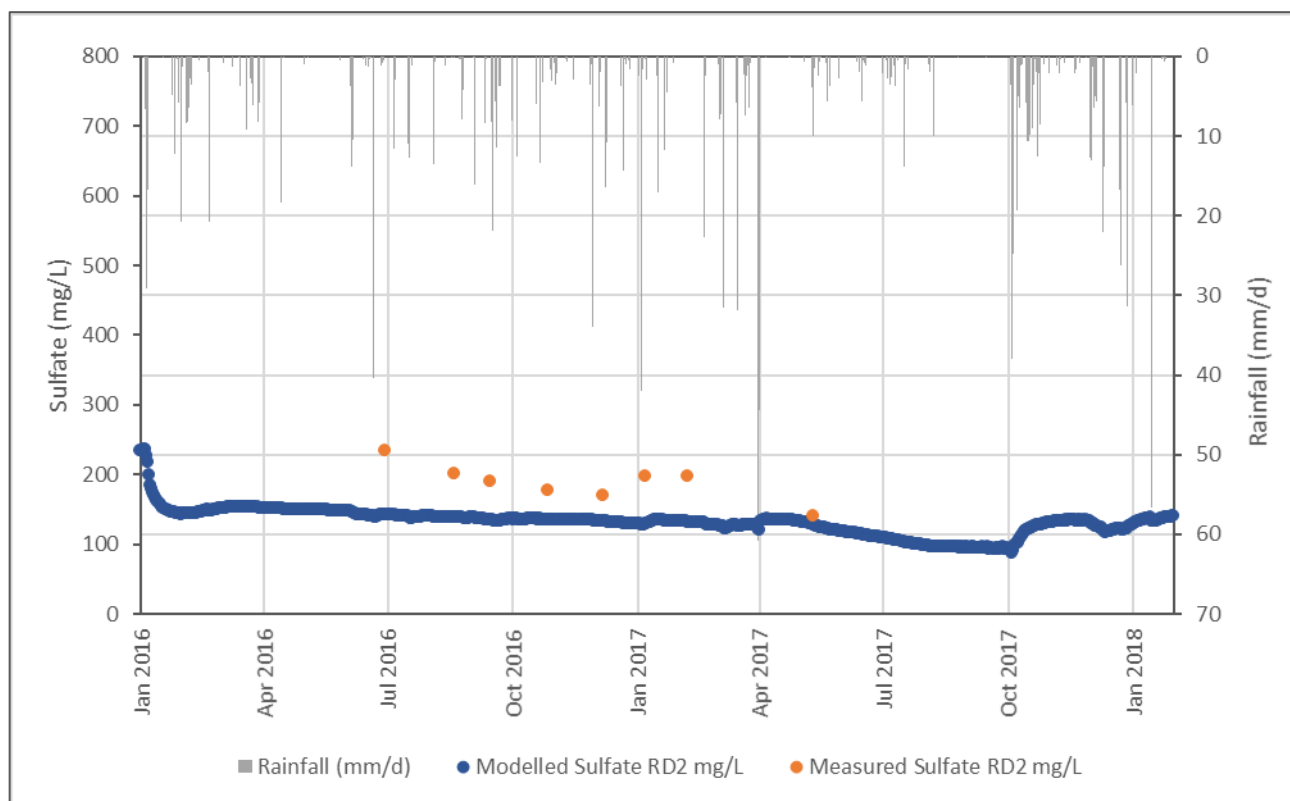


Figure 53: Sulfate verification at RD2

7.0 RESULTS

Simulations were run on daily time-steps for the period 2016 to 2050 for the base case simulation and two scenario trials of engineering controls. In most cases, three climate scenarios were used for this assessment; that is the low, median and high rainfall data records detailed in Section 4.3.1.

The base case scenario as described in Section 3.4.2 includes any control measures that have been implemented by Stanwell prior to 2018 including the construction of RD27 with continuous lime dosing of low flow inflows to RD27; and the change to high density tailings, removing the tailings slurry flow input to NWB tailings and reducing water demand at the CHPP. Additionally, the base case includes anticipated changes to water infrastructure required during the life of mine that will be required to support the 2017 Life of Mine Plan.

Following a review of the base case results and source and extent information gathered from other EEE Project technical studies; two engineering controls were identified for further assessment using the model.

- Scenario 1: Dewatering of the NWBFP using 1 bore (at 6 L/s) or 2 bores (at 12 L/s).
- Scenario 2: Improving (thickening) the rehabilitation cover to an area of 1 m – 3 m cover on the north-east surface and embankment of the NWBFP referred to as rejects storage area 1 (RSA1).

7.1 Base case simulations

7.1.1 Quantity

7.1.1.1 NWBFP – Bullgang Corner and Ramp 7 Seepage

Baseline simulations of seepage at Bullgang Corner under three climate conditions (low, median and high rainfall periods) have been conducted. The sensitivity of modelled seepage at Bullgang Corner to NWBFP hydraulic parameters has been examined by varying the hydraulic conductivity values of the materials in the groundwater (Seep/W) model (as discussed in Section 4.1.1.4). In addition to the base case, two sensitivity cases were defined (using the parameter values specified in Table 17) to generate two sensitivity curves for the NWBFP water level – seepage rate relationship (Figure 54). Case A has lower hydraulic conductivity values for spoil and rejects (other parameter values remain unchanged from the Base case). Case B has a higher hydraulic conductivity value for tailings (other parameter values remain unchanged from the Base case).

Table 17: NWBFP hydraulic conductivity sensitivity cases

Case	Unit	Spoil	Tailings	Rejects	Hard Rock
Base	m/s	2.00E-06	2.0E-09	2.0E-05	5.0E-10
Case A	m/s	1.00E-06	(same as Base)	1.0E-05	(same as Base)
Case B	m/s	(same as Base)	5.0E-07	(same as Base)	(same as Base)

Water level in NWBFP using the Base, Case A and Case B NWBFP water level - baseflow relationships are shown in Figure 55 to Figure 57. The corresponding discharge at Bullgang Corner is shown in Figure 58 to Figure 60. Case A has the lowest NWBFP water level - baseflow relationship resulting in lower seepage rates and a slower decline in the NWBFP water level. Case B has the highest NWBFP water level - baseflow relationship, resulting in a more rapid decline in the NWBFP water level.

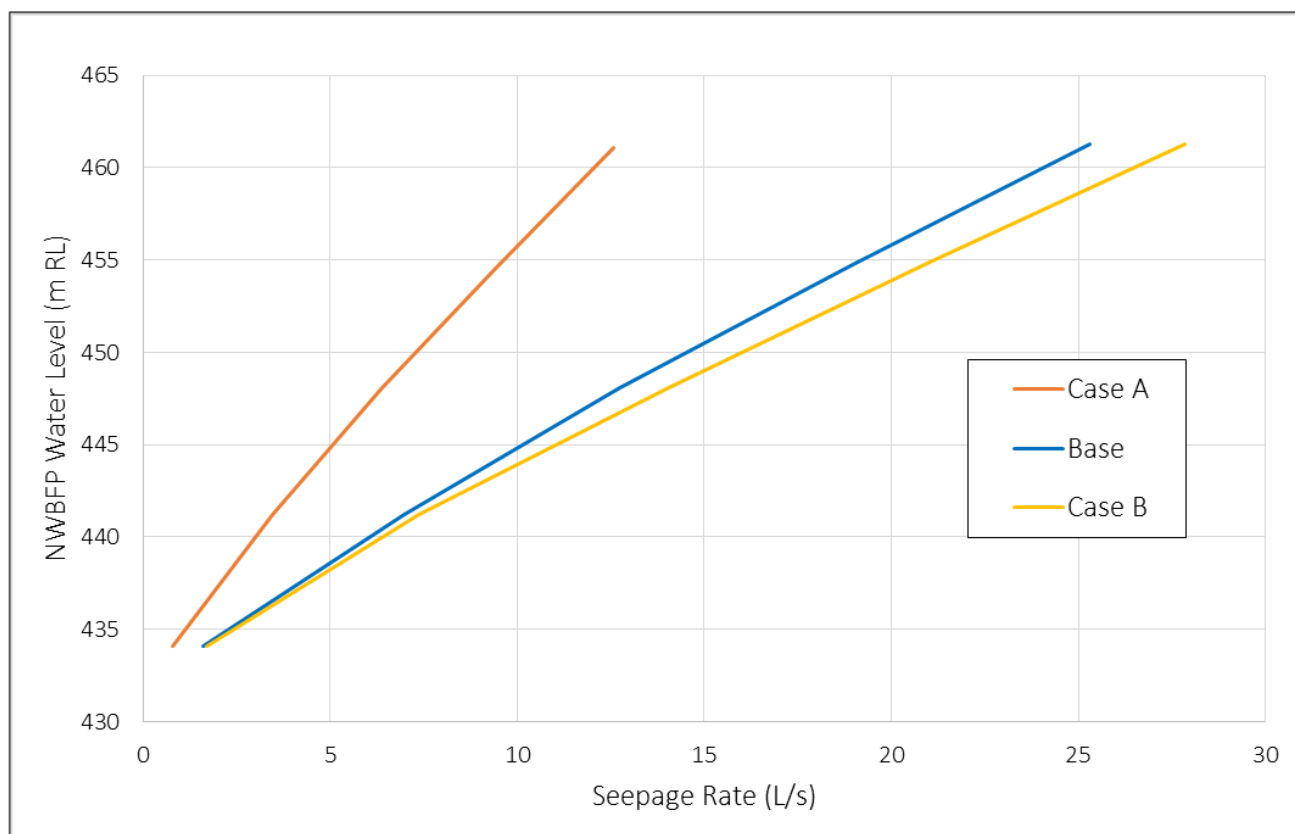


Figure 54: Sensitivity results for the NWBFP water level - baseflow relationship

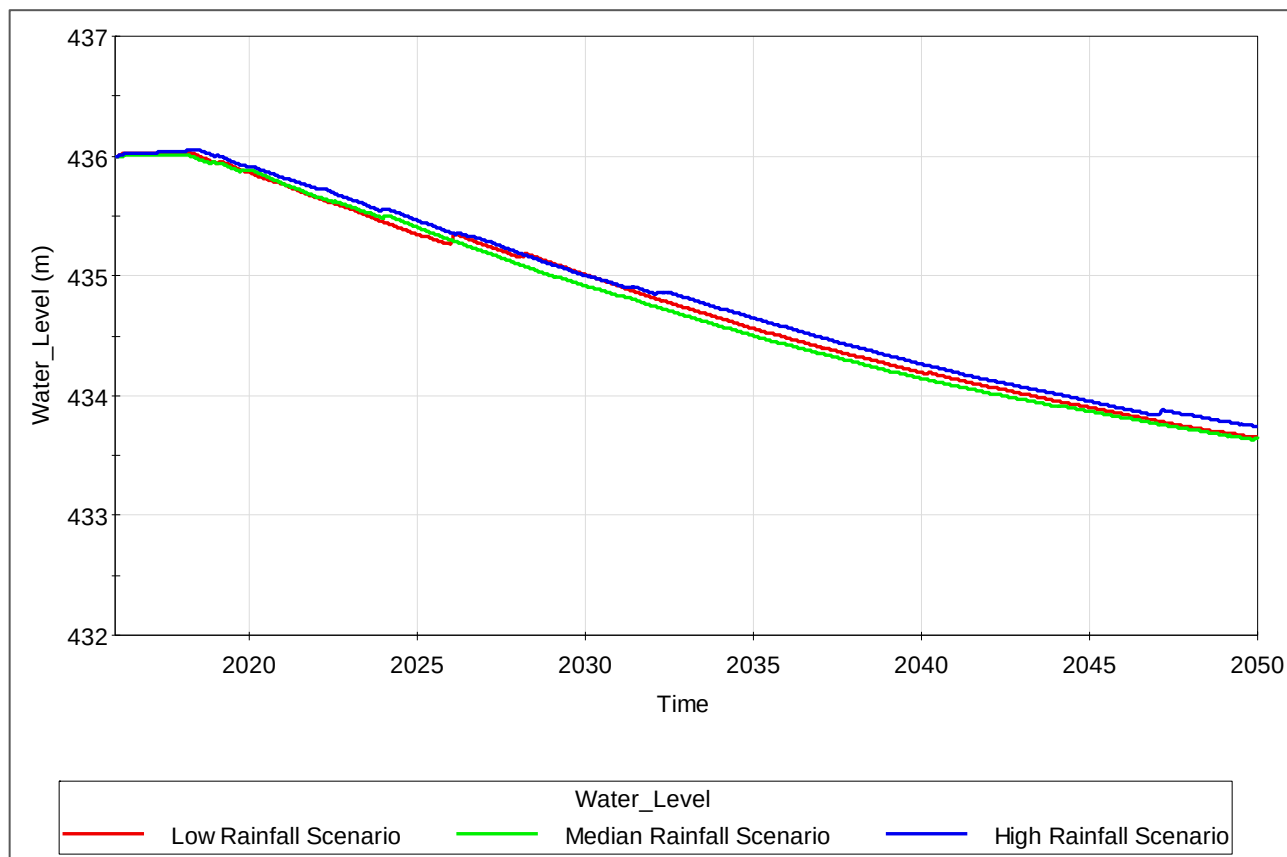
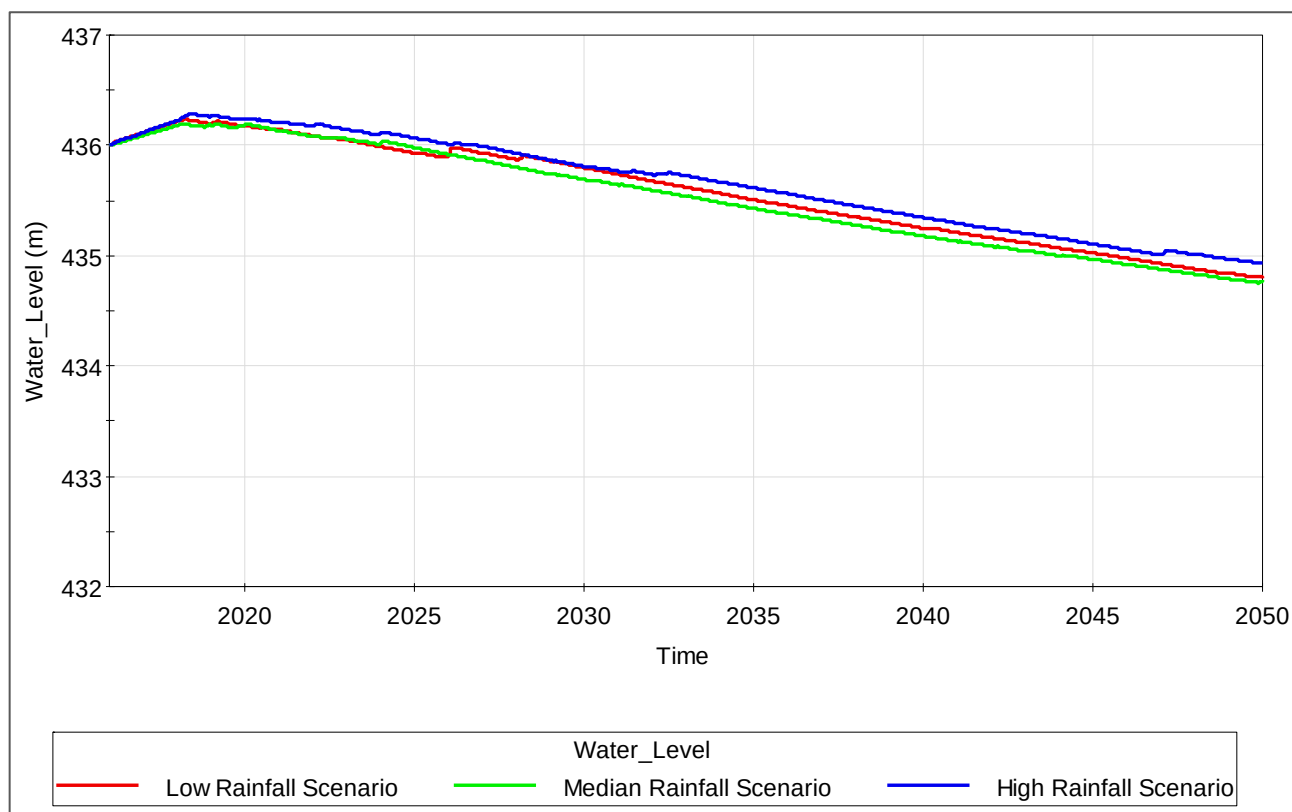
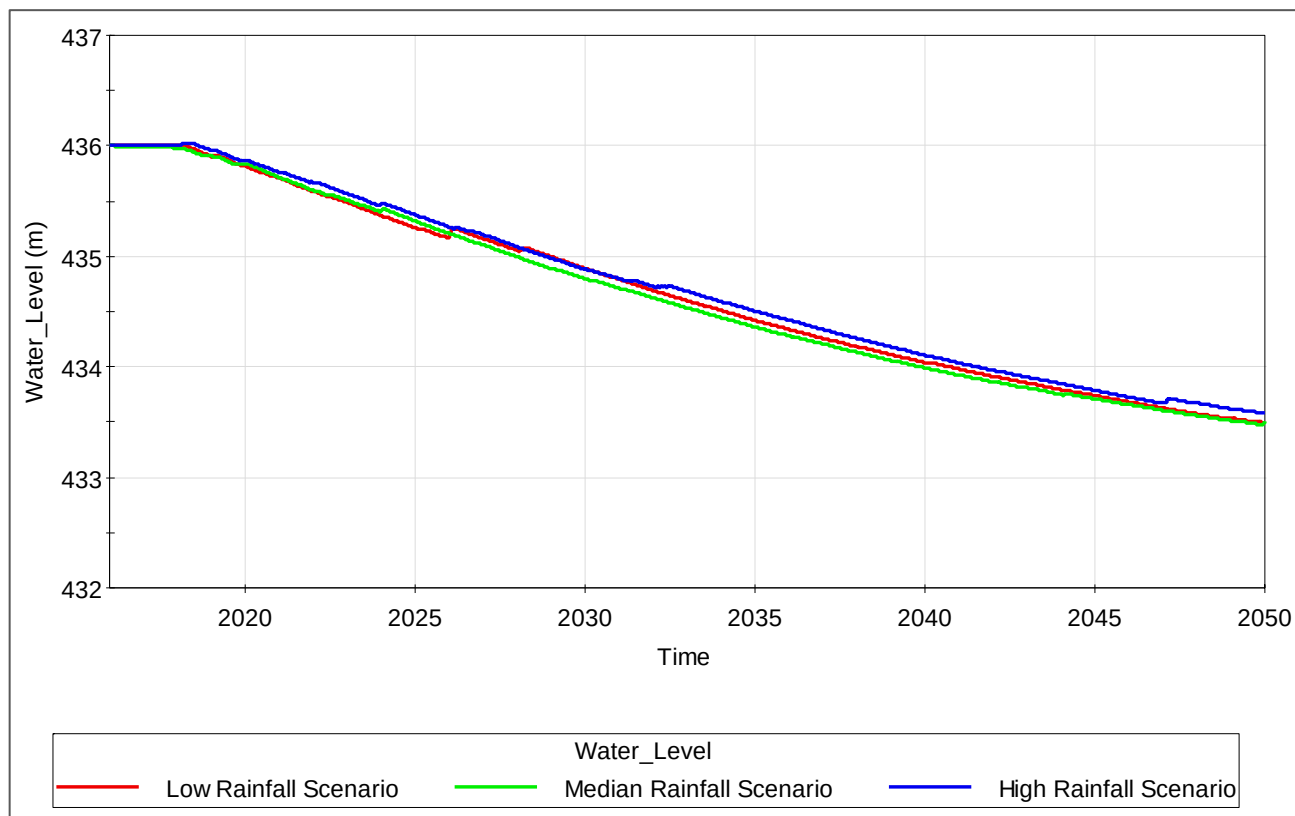


Figure 55: Water level in NWBFP base case

**Figure 56: Water level in NWBFP Case A****Figure 57: Water level in NWBFP Case B**

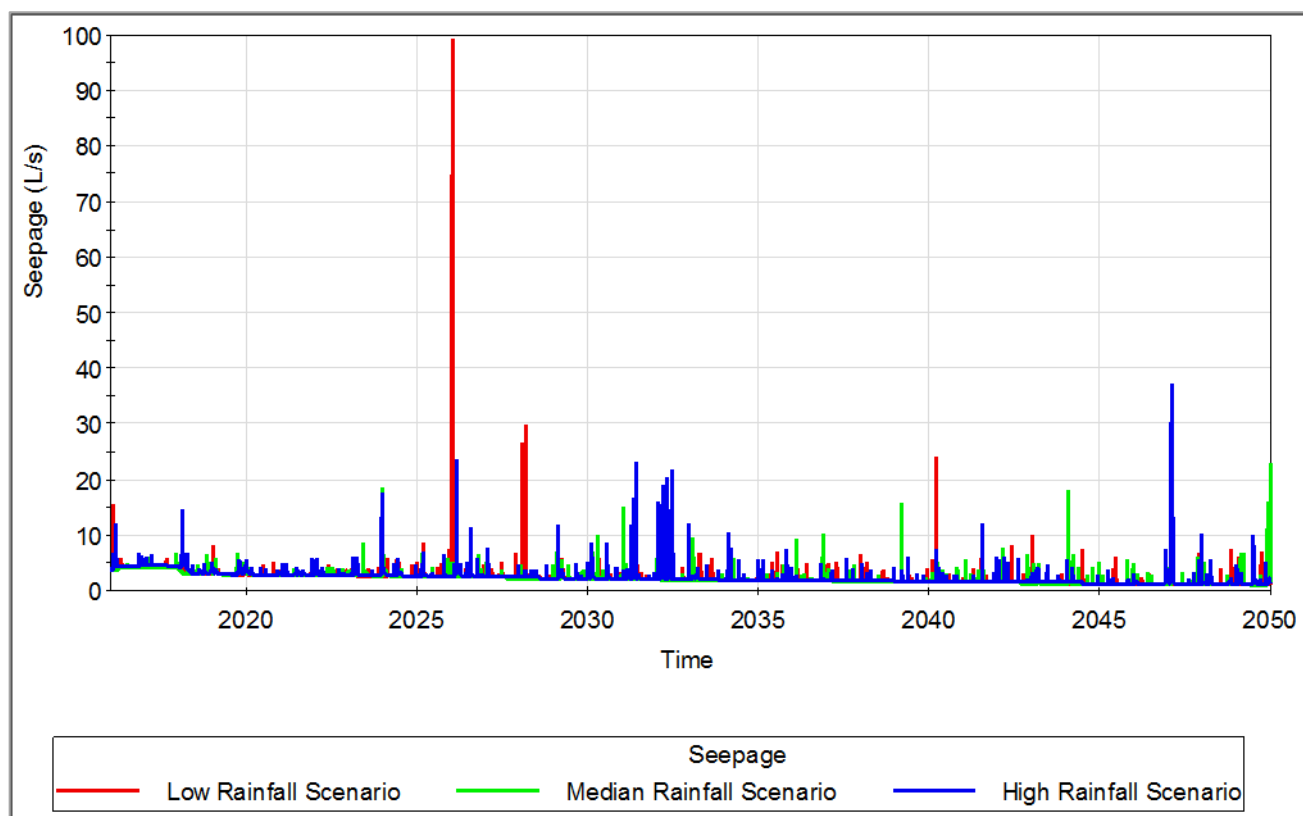


Figure 58: Total Seepage from NWBFP Base case

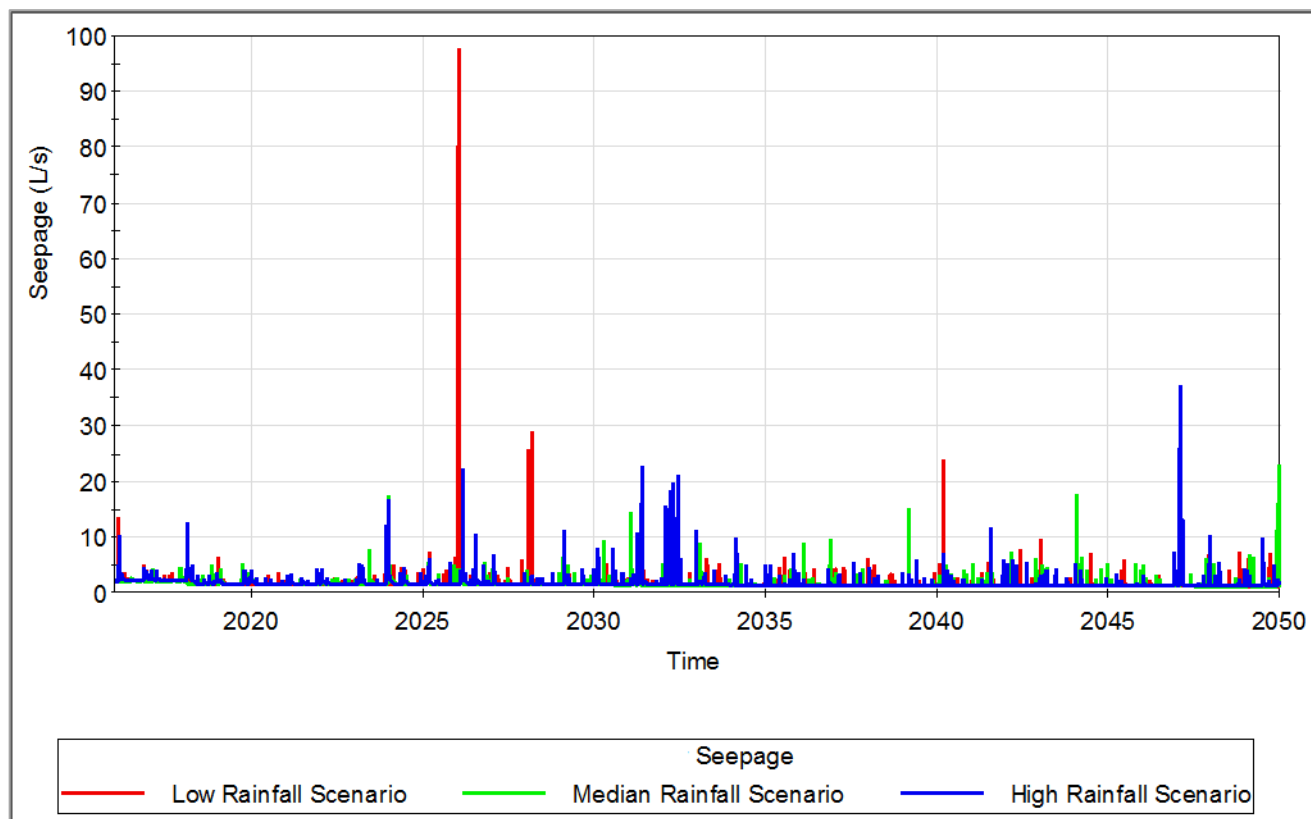


Figure 59: Total seepage from NWBFP Case A

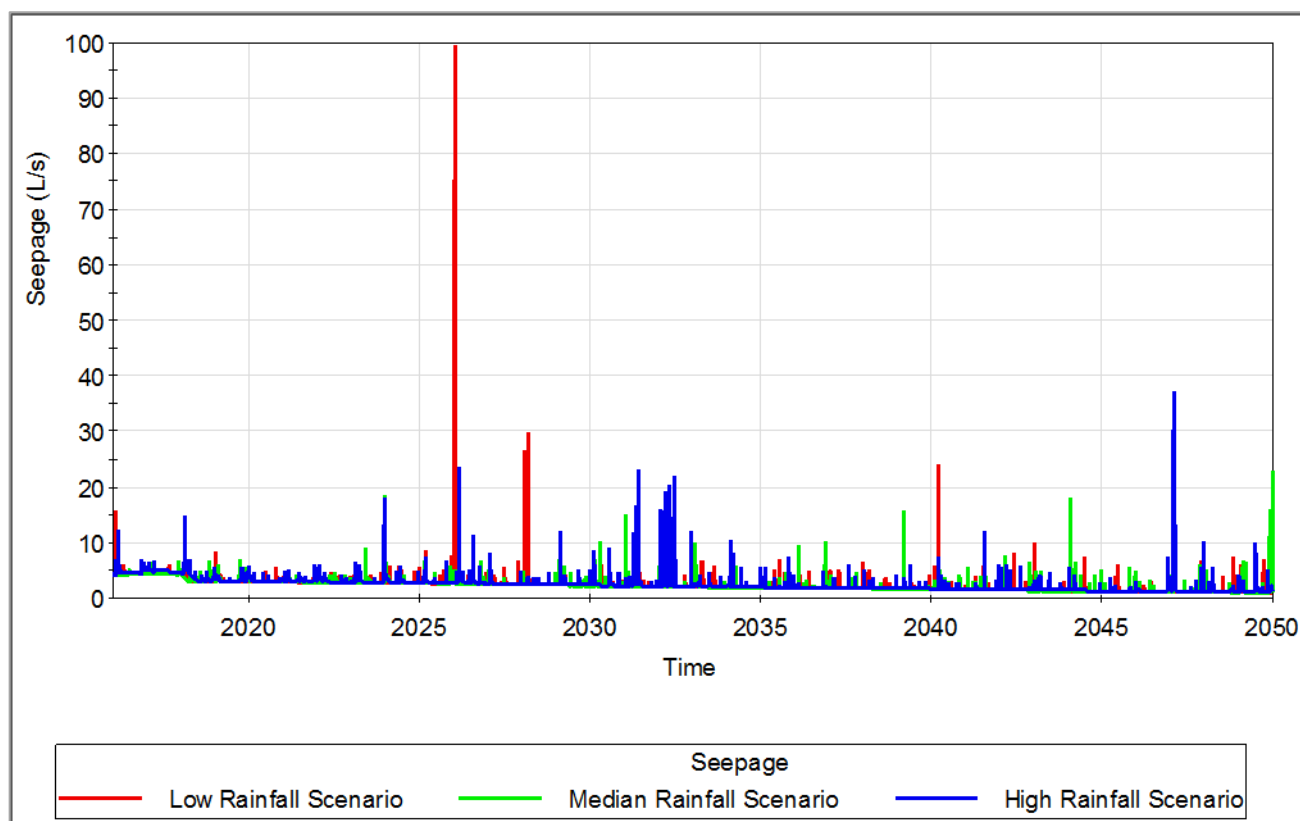


Figure 60: Total seepage from NWBFP Case B

7.1.1.2 Flow at CP3

Flow at CP3 simulated using the three climate scenarios is shown in Figure 61, Figure 62 and Figure 63. There are periodic high and low flows in both operational and closure periods in all scenarios as well as periods of no flow. Periods of low flow are more frequent during mining operations.

An assessment of exceedance probability supports these observations, as provided in Figure 64. There is a 50% probability that flow will exceed 3.87 and 0.04 ML/d during operations and post closure respectively.

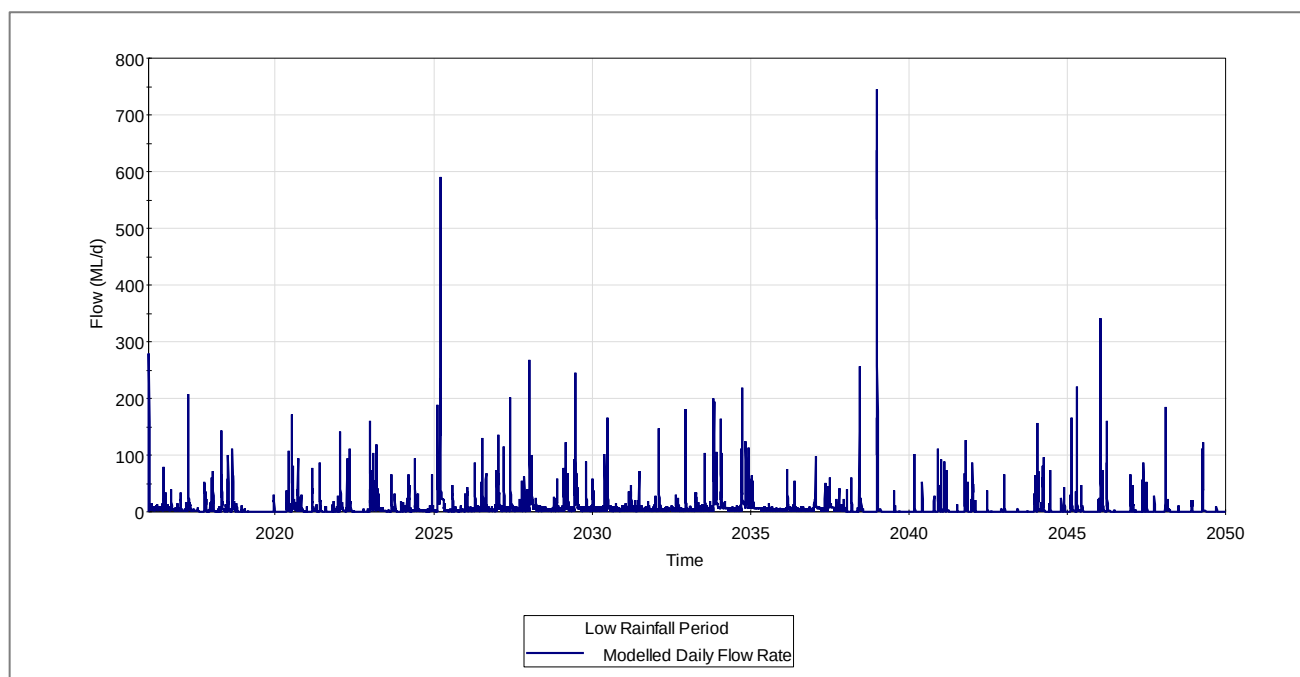


Figure 61: Daily flow at CP3 low rainfall period (Base case)

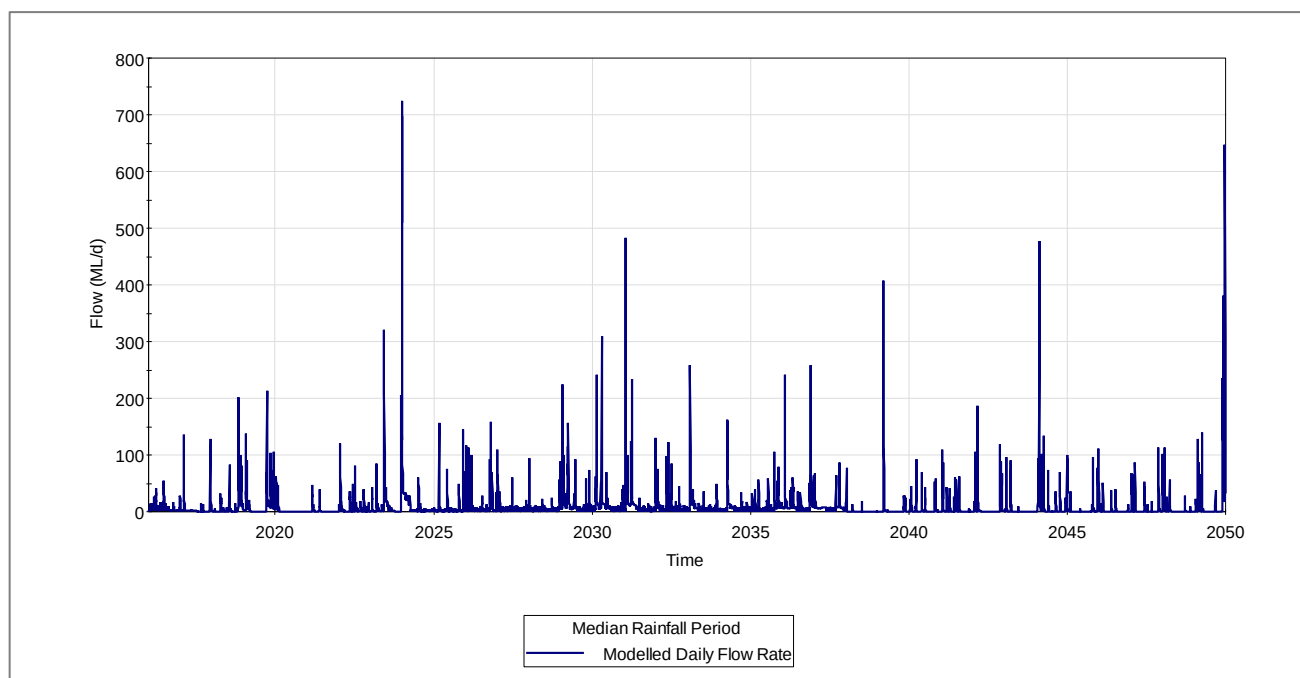


Figure 62: Daily flow at CP3 median rainfall period (Base case)

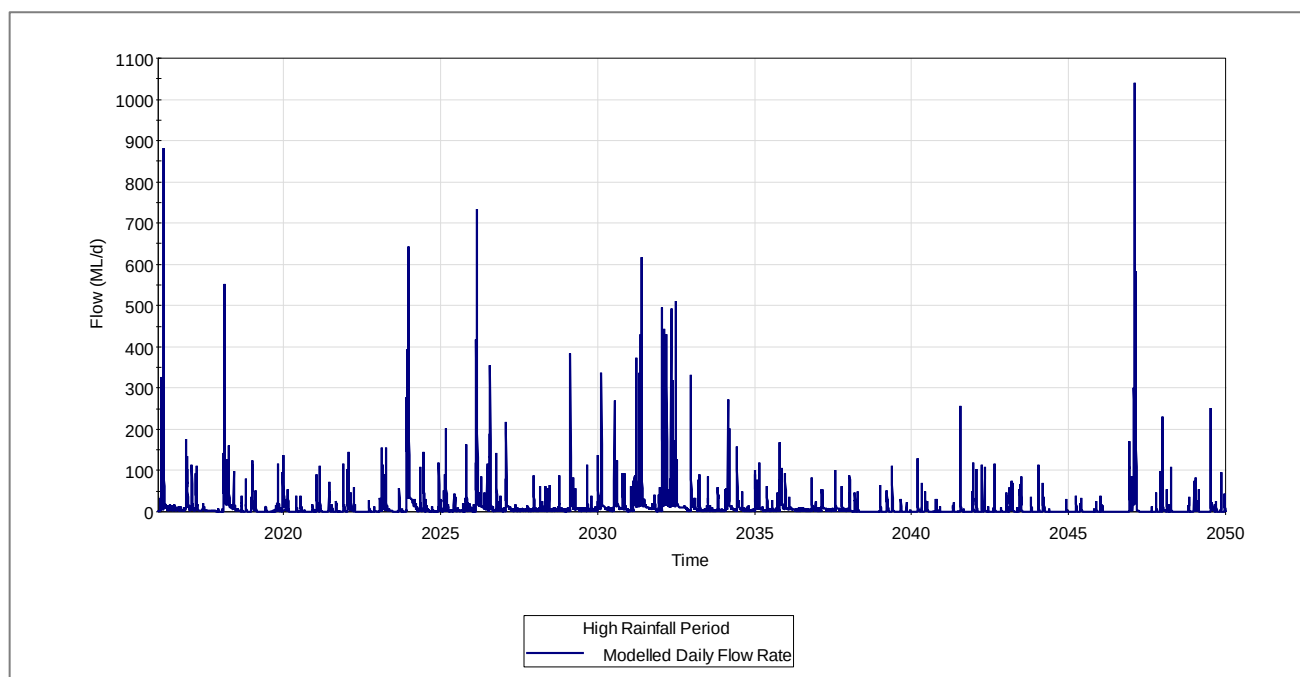


Figure 63: Daily flow at CP3 high rainfall period (Base case)

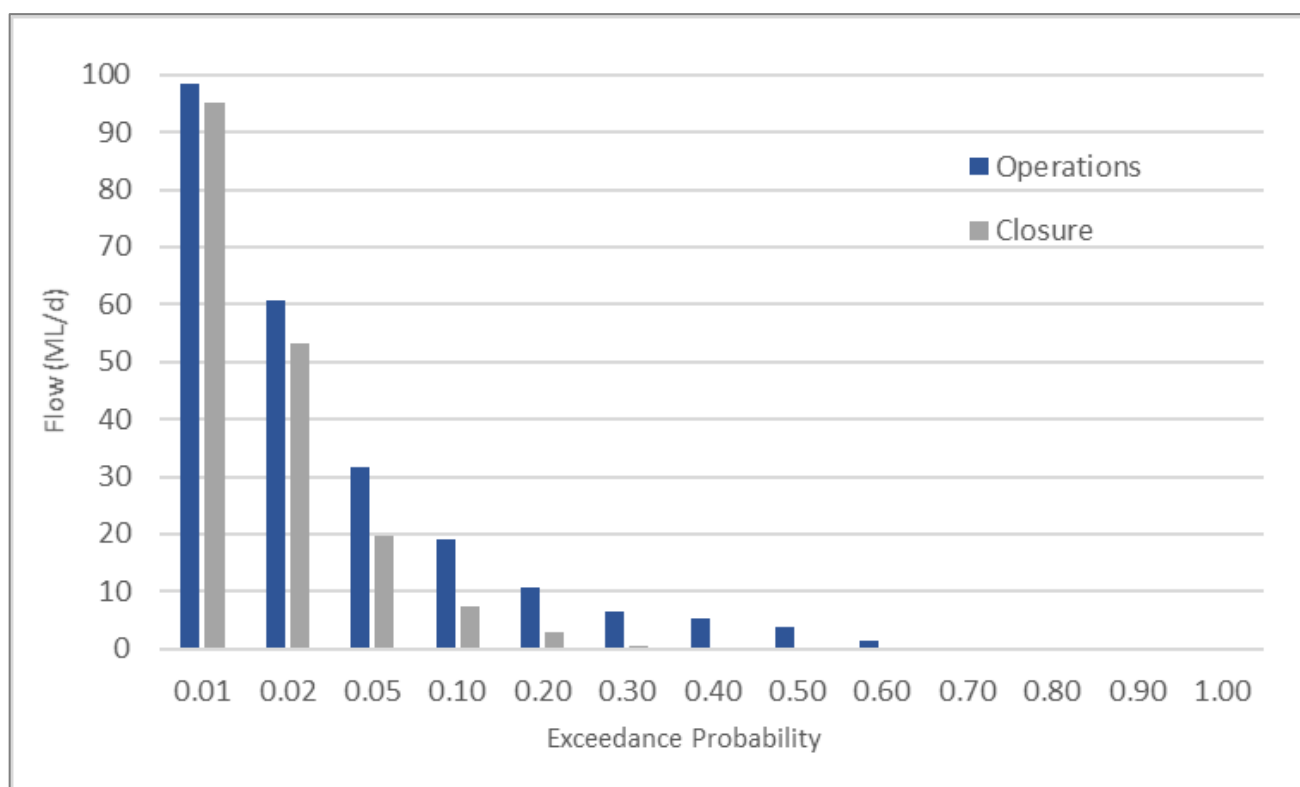


Figure 64: CP3 flow exceedance probability during operations and post closure (Base case)

7.1.1.3 Meandu Creek Dam water level

Two scenarios were simulated for the operational and post closure period at Meandu Creek Dam. The first, shown in Figure 65, is the storage volume in low, median and high rainfall scenarios with power station blowdown water inflow and low flow releases discontinued after 2037. In this scenario, Meandu Creek Dam is at or close to capacity throughout the operational and post closure period. There is a period of 2 years between 2021 and 2023 where the dam is less than capacity and no overflows occur in low and median rainfall scenarios. This is a period of high production and water demand at the CHPP; when less water is available from dewatering (Ramp 5 is closed and K2E is about to recommence mining); and at a time corresponding to a low rainfall period in both low and median records.

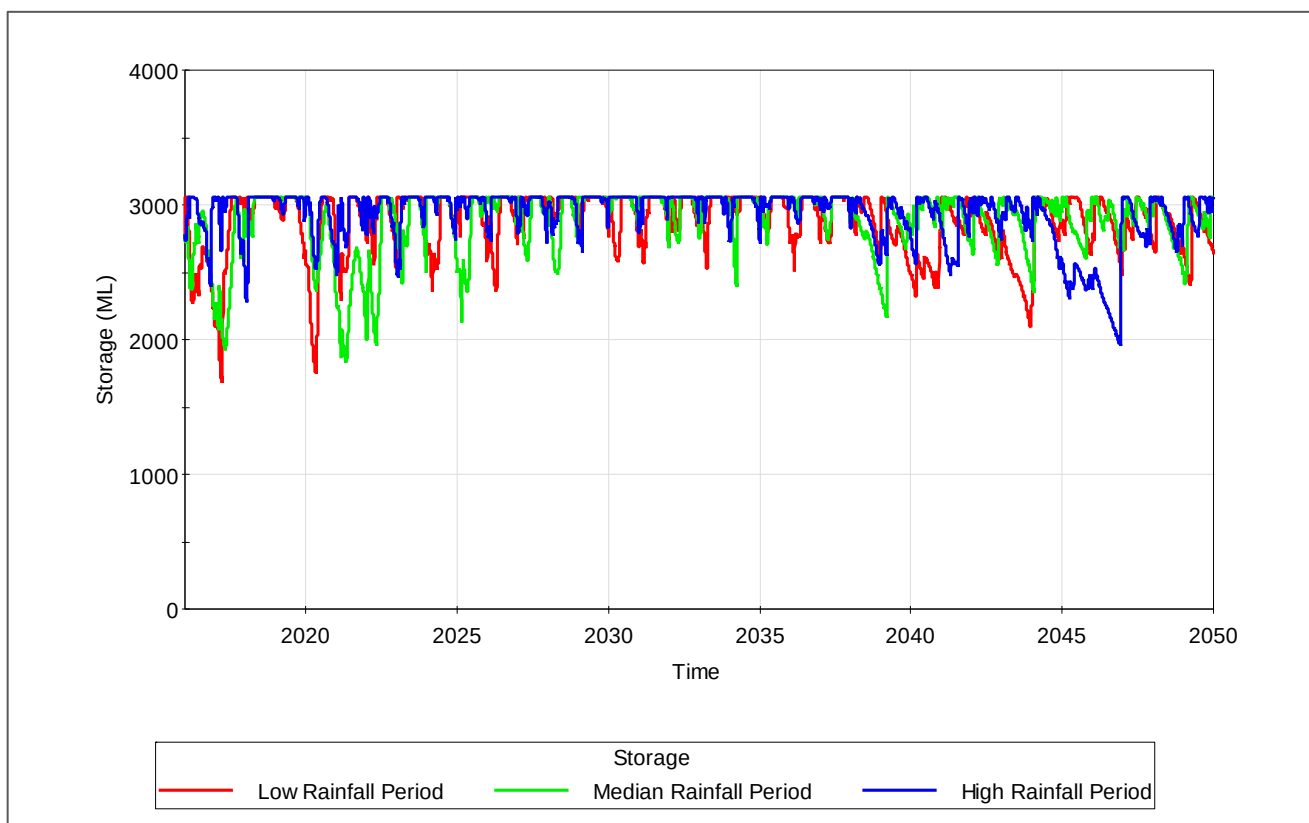


Figure 65: Meandu Creek Dam storage without low flow release post closure (Base case)

In the second scenario, as shown in Figure 66, power station blowdown water inflow ceases after 2037 and low flow discharges from Meandu Creek Dam are continued after closure; the low flow demand is the current average monthly discharge (as provided in Figure 9). In this scenario, there is a rapid decline in water stored at closure.

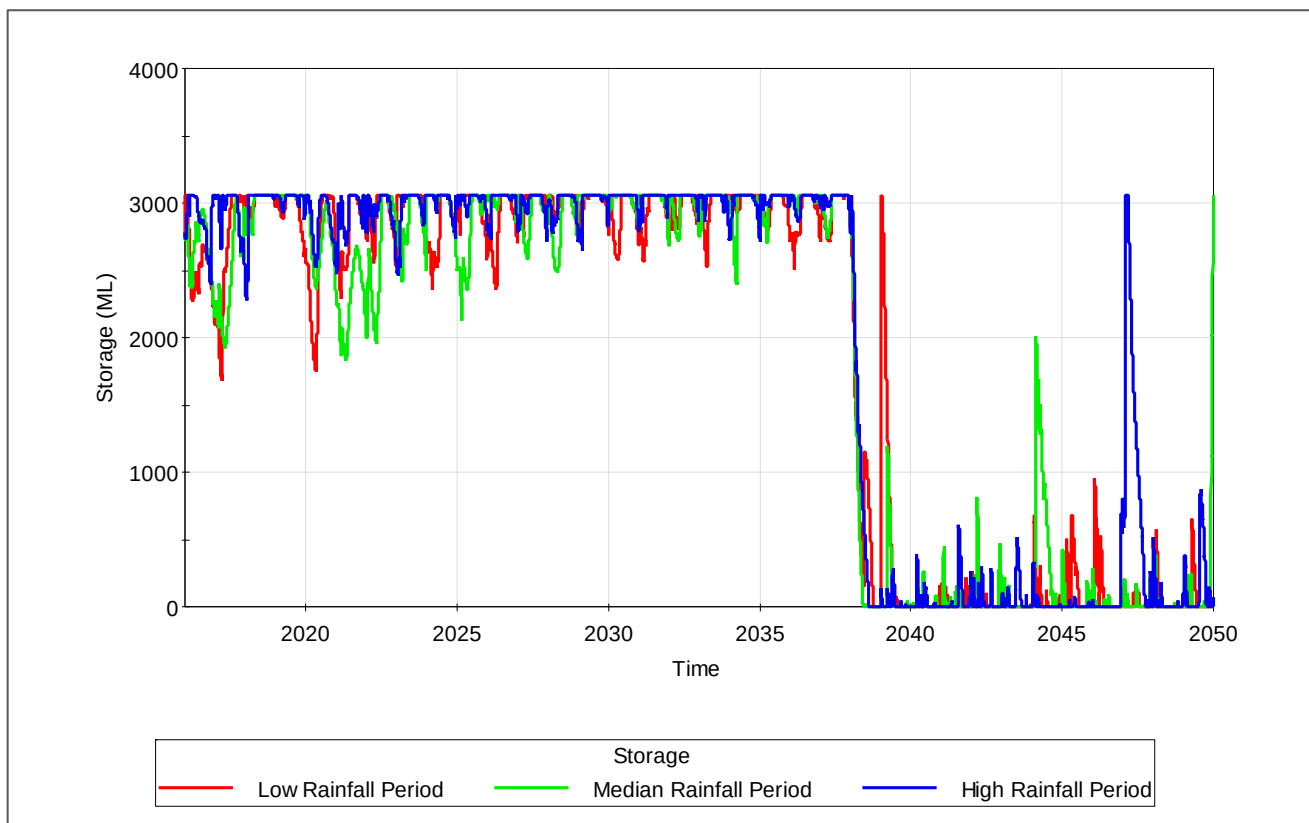


Figure 66: Meandu Creek Dam storage with low flow discharge post closure (Base case)

7.1.1.4 Meandu Creek Dam overflow and low flow discharge

In the scenario where both power station blowdown water and low flow discharges from Meandu Creek Dam are discontinued in 2037, the overflow and low flow discharge (and corresponding EC) are shown in Figure 67. Overflow events continue to occur in the post closure period given median rainfall conditions.

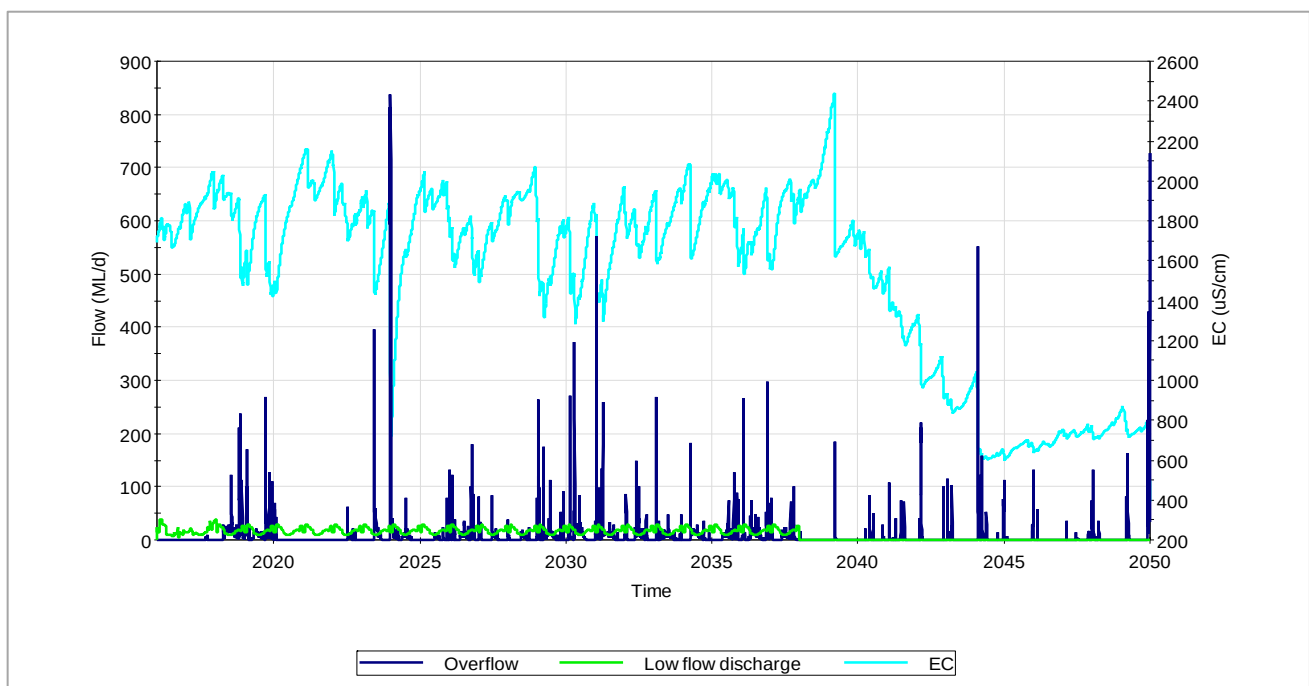


Figure 67: Meandu Creek Dam flow release and EC (Base case, median rainfall period) – without low flow discharge post closure

Where low flow discharge continues in the post closure period, there are no overflows during the closure period given median rainfall conditions as shown in Figure 68.

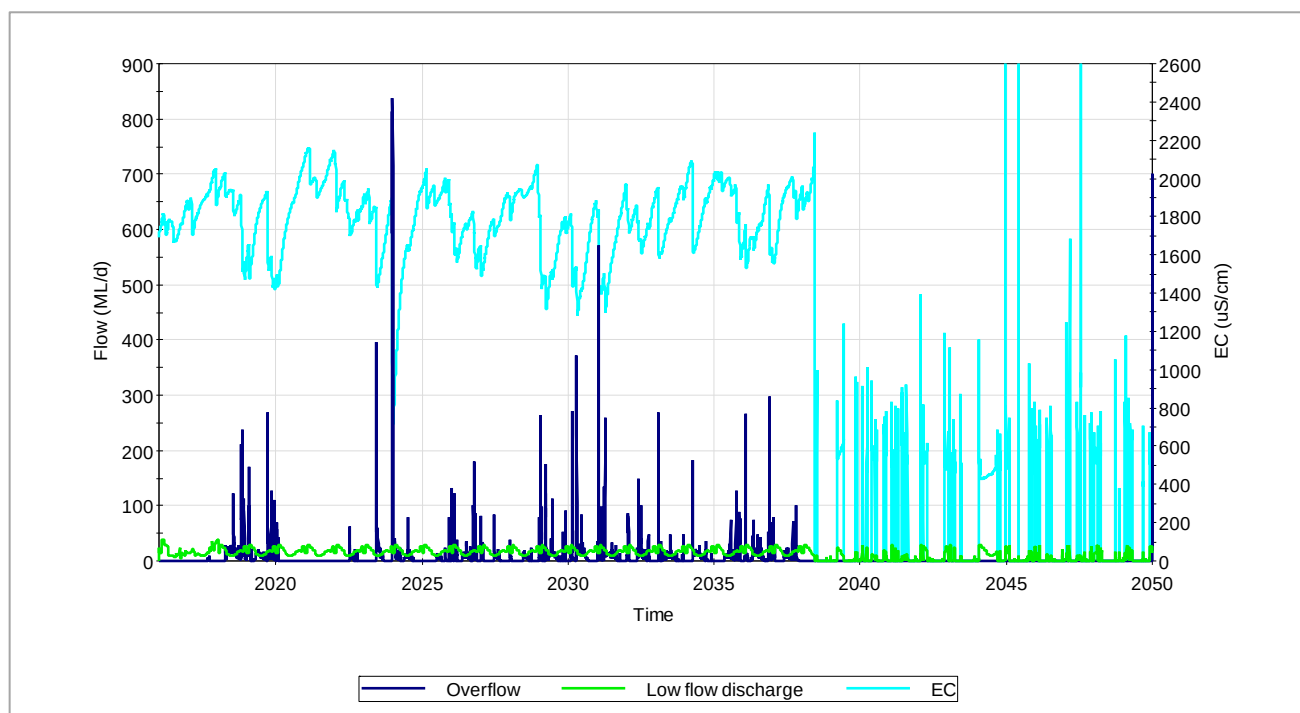


Figure 68: Meandu Creek Dam flow release and EC (Base case, median rainfall period) – with low flow discharge post closure

7.1.1.5 Retained water in pits

Pit water storage includes an estimate of water stored in pit sumps and spoil. Once active mining is completed in a pit, dewatering is discontinued and as a result water is retained in the pit void. Once a pit void is filled during rehabilitation the surface runoff is redirected to the closest retention dam. K4E and K2E remain as voids at closure and retain water during the closure period. At the end of the simulation the water storage is rising in the remaining pit voids with K4E at 20% of capacity and K2E at 6% of capacity.

Retained water in Central, Ramp 5 and K4S are shown in Figure 69 to Figure 71, respectively. Retained water (all rainfall conditions) and EC (median rainfall conditions) in K4E Boundary West and K2E are shown in Figure 72 to Figure 75.

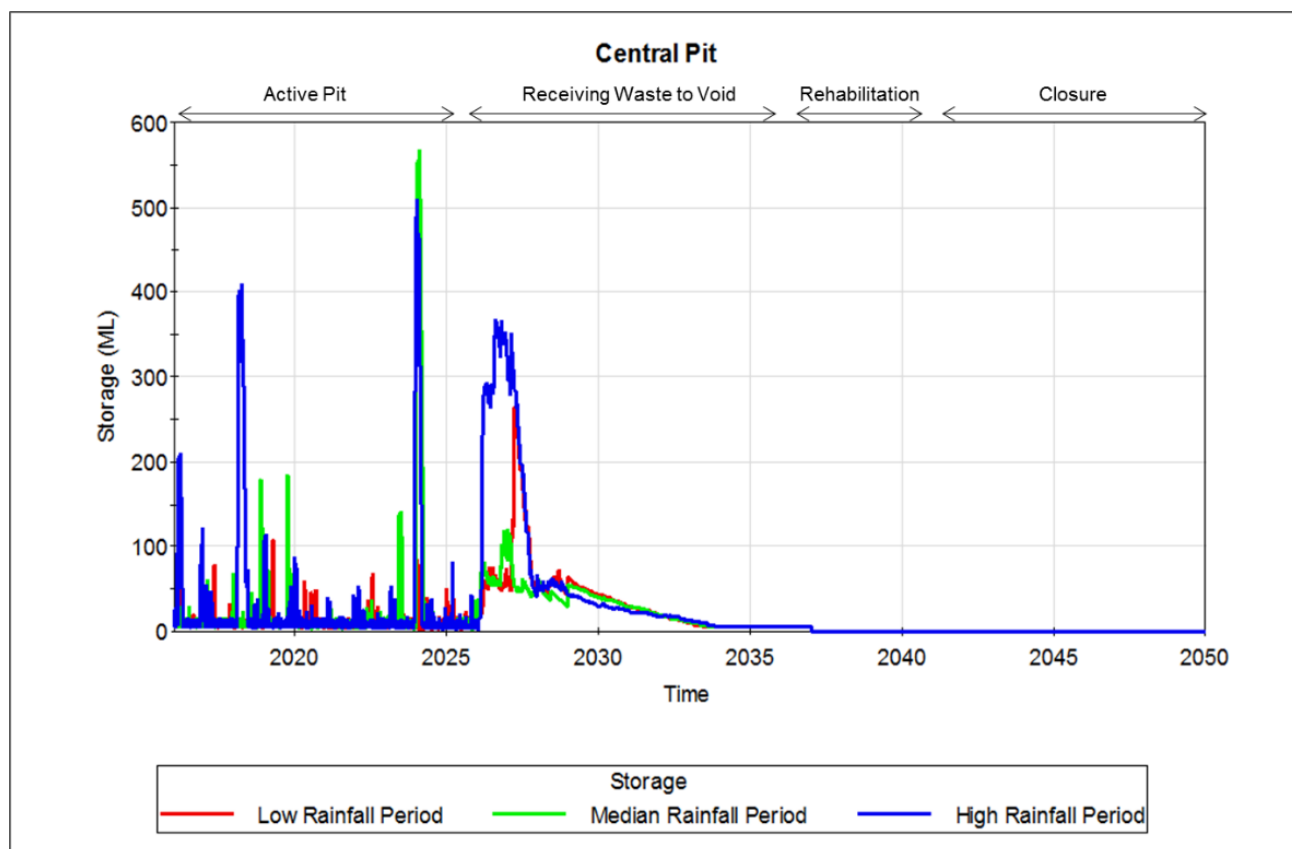


Figure 69: Central Pit retained water volume (Base case)

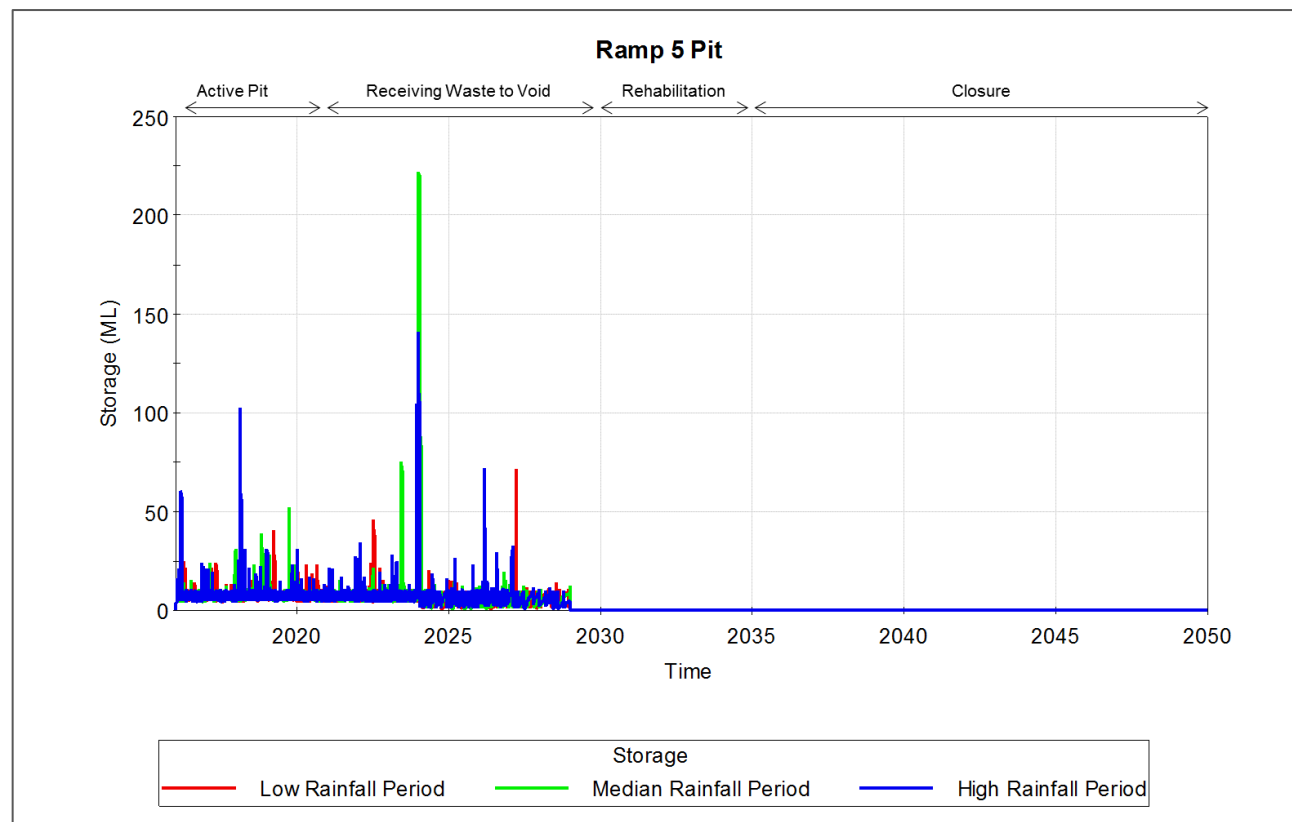


Figure 70: Ramp 5 Pit retained water volume (Base case)

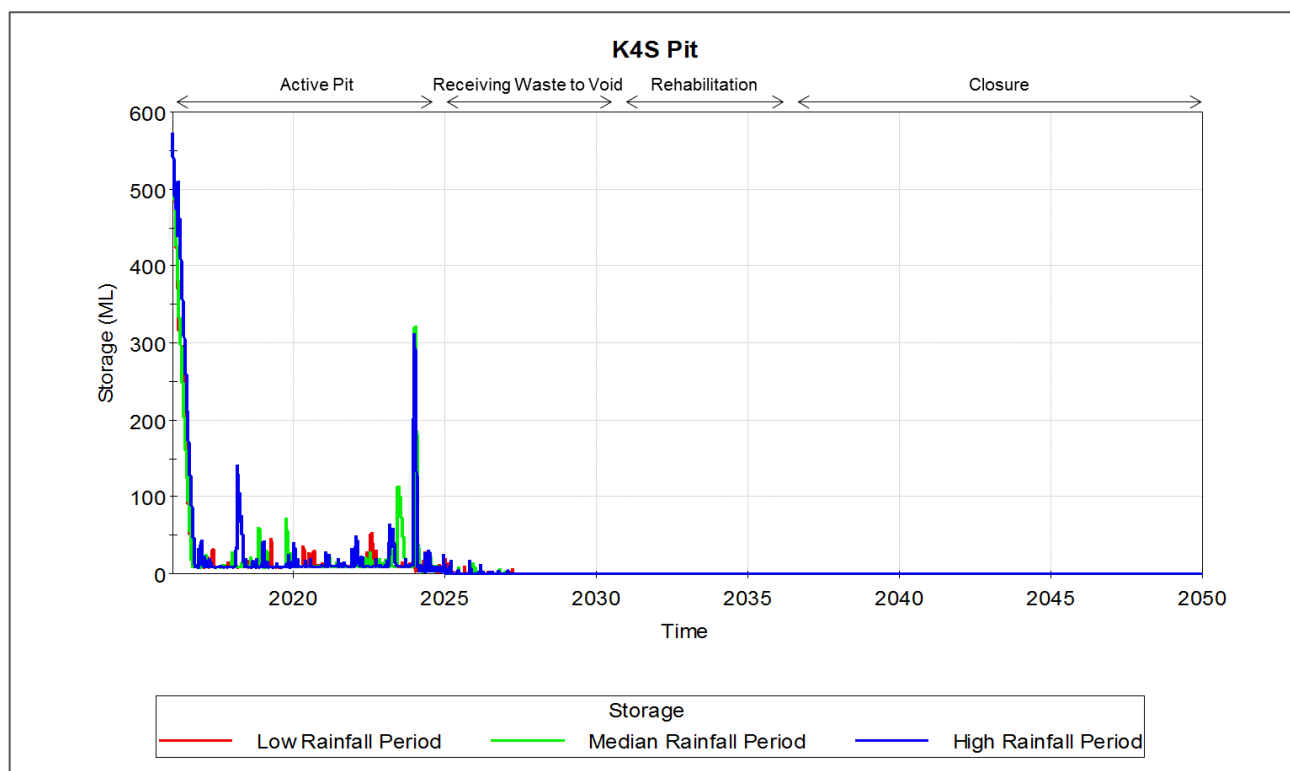


Figure 71: K4S Pit retained water volume (Base case)

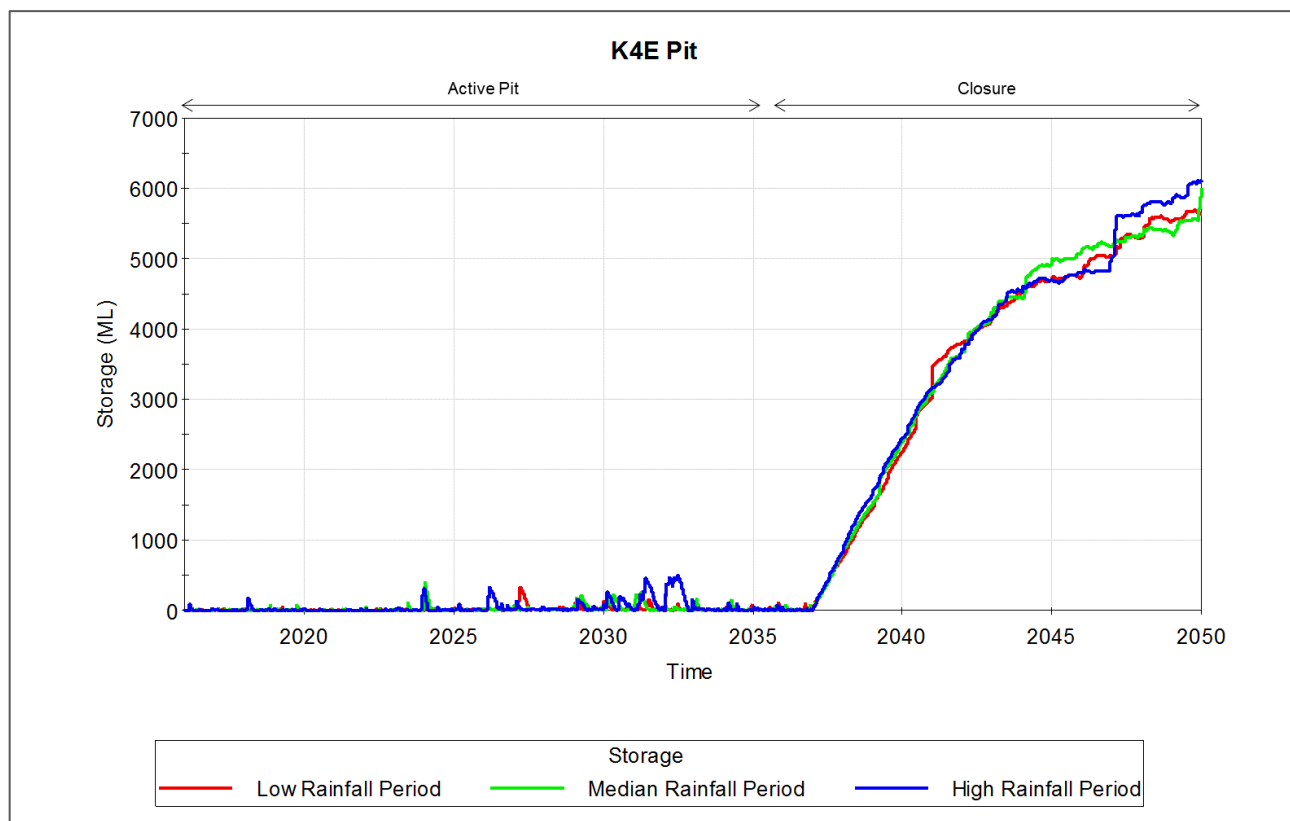


Figure 72: K4E (Boundary West) Pit retained water volume (Base case)

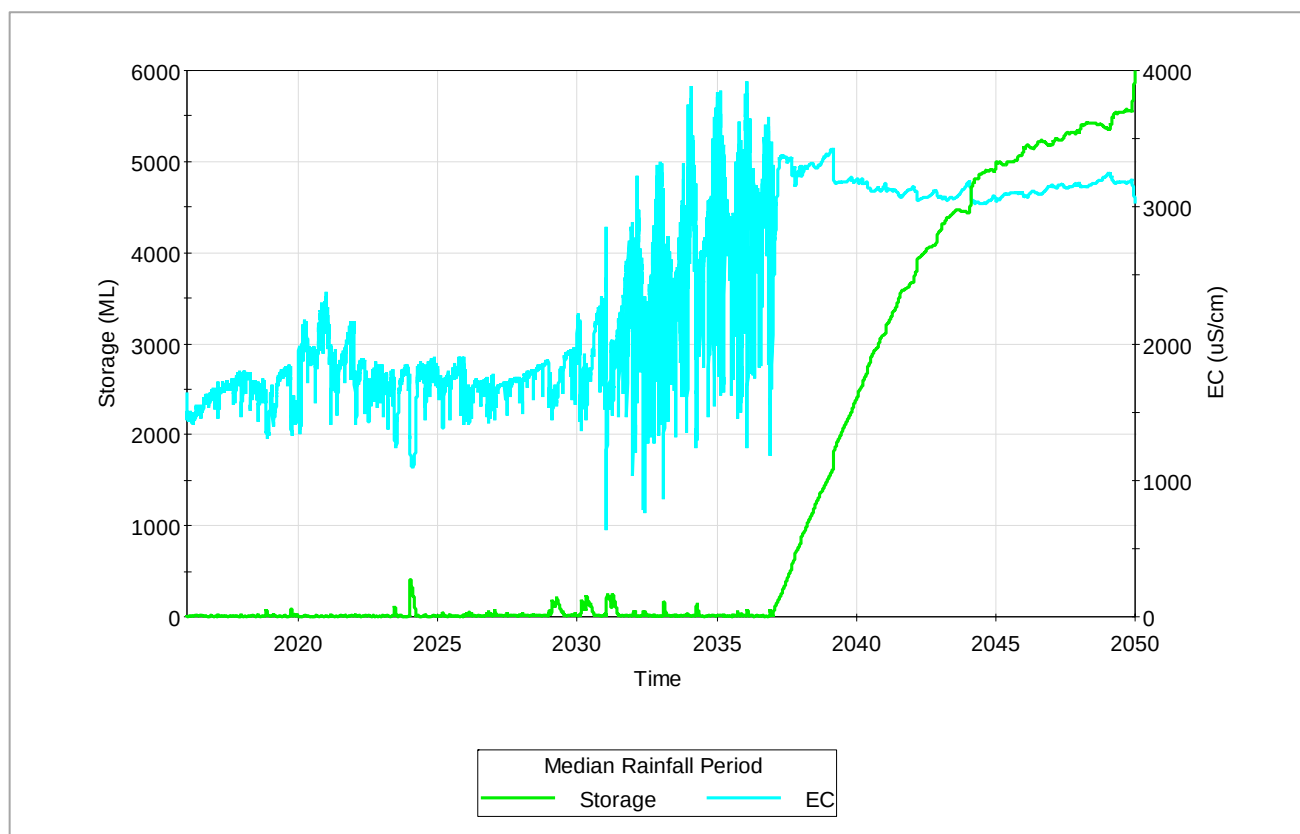


Figure 73: K4E (Boundary West) Pit retained water volume and EC for median rainfall (Base case)

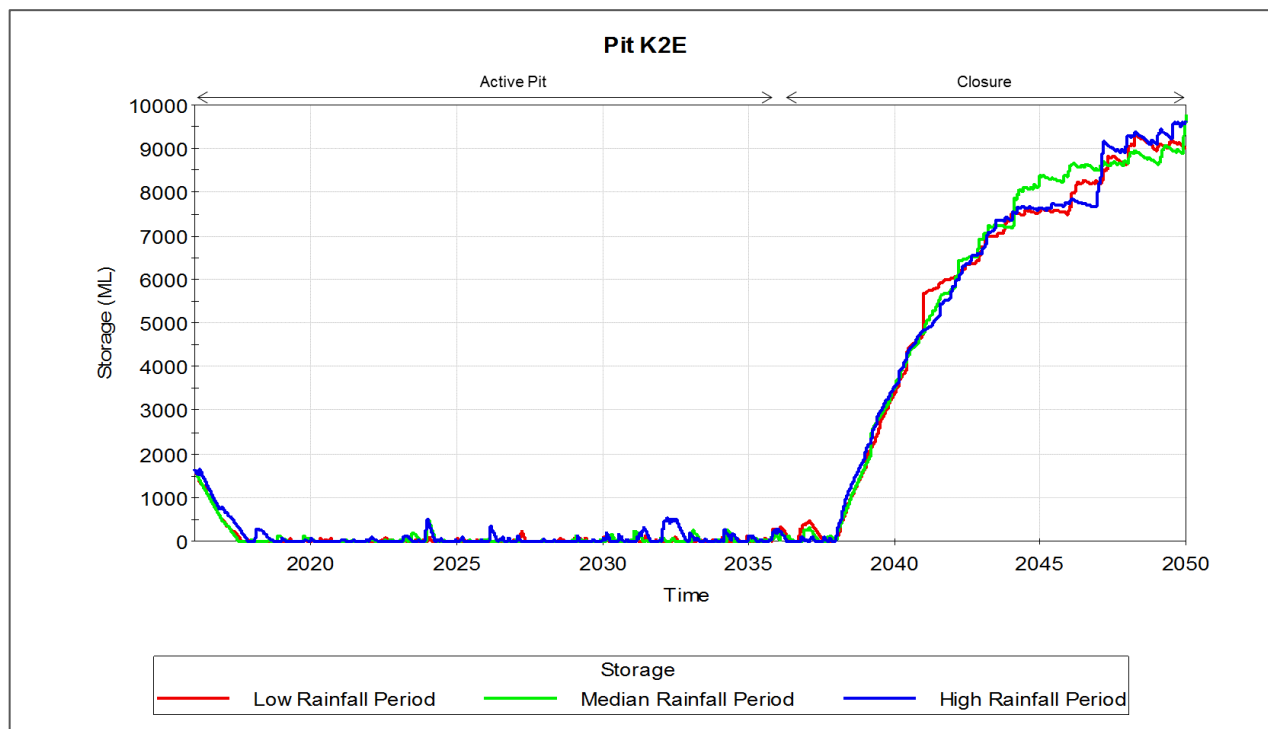


Figure 74: K2E Pit retained water volume (Base case)

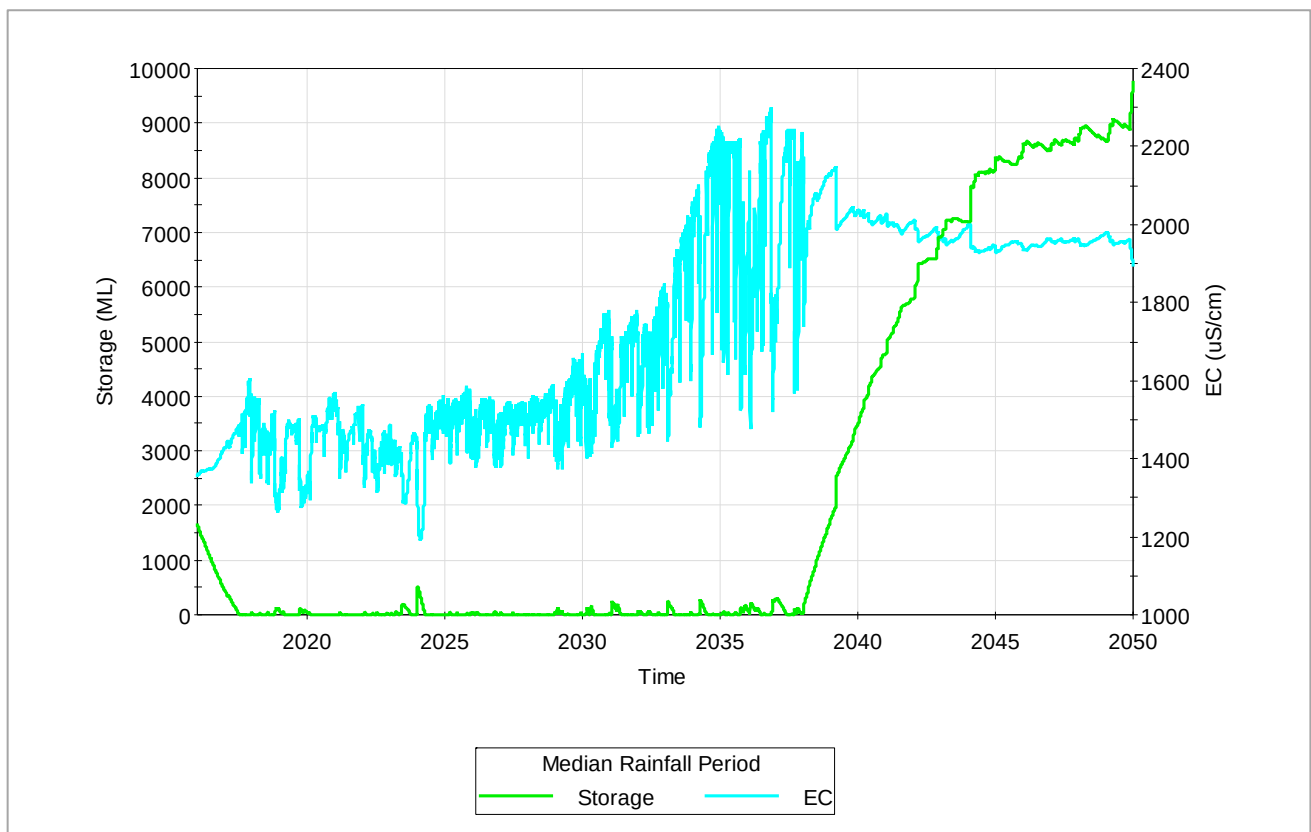


Figure 75: K2E Pit retained water volume and EC for median rainfall (Base case)

7.1.1.6 Water supply – CHPP

Water supply to the CHPP (Figure 76) is higher at the start of the simulation (2016, 2017) prior to the implementation of the solid bowl centrifuge (which became operational in December 2017). Of note to operations, the modelling shows that there may be a period when supply from RD8 and RD2 does not meet demand on some days during 2020 – 2023. In the simulation, this period occurs when relatively high production and corresponding water demand at the CHPP coincides with less water being available from dewatering at Ramp 5 which is closed and K2E which is about to recommence mining). Changes to water management may be required during that period to ensure sufficient water to the CHPP and Stanwell should monitor water requirements and availability prior to that time.

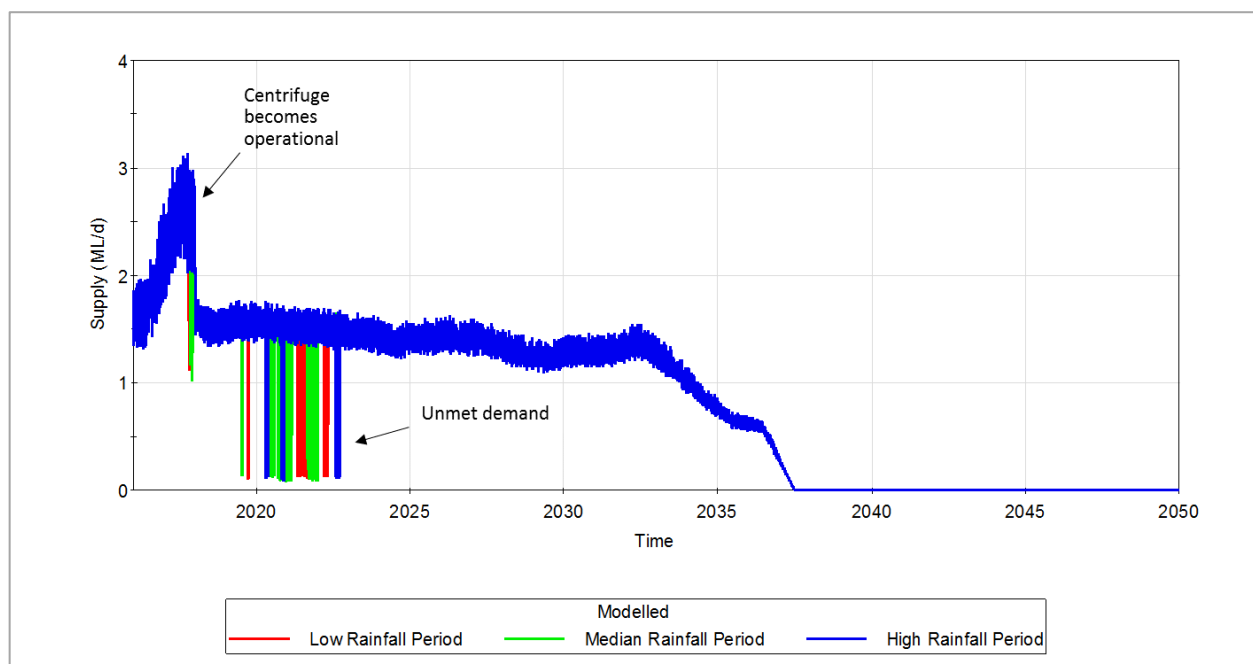


Figure 76: Water supply to the CHPP (Base case)

7.1.1.7 High flow bypass of RD27

Treatment in RD27 is applied to water that enters RD27. However, when flows in excess of the capacity of the RD27 inlet occur these will bypass treatment and flow to RD7 and if not utilised in the CHPP will be discharged at CP3. Some of this high flow will carry with it impacted water from Bullgang Corner and Ramp 7.

Simulations have been run in all climate scenarios to gain an understanding of the occurrence of high flow bypass, to quantify the cumulative water direct to RD27 and RD7 from Bullgang Corner and the water collected in Ramp 7 (including catchment runoff).

Results of this assessment are shown in Figure 77, Figure 78 and Figure 79. The total treated flow exceeds the high flow bypass in all cases.

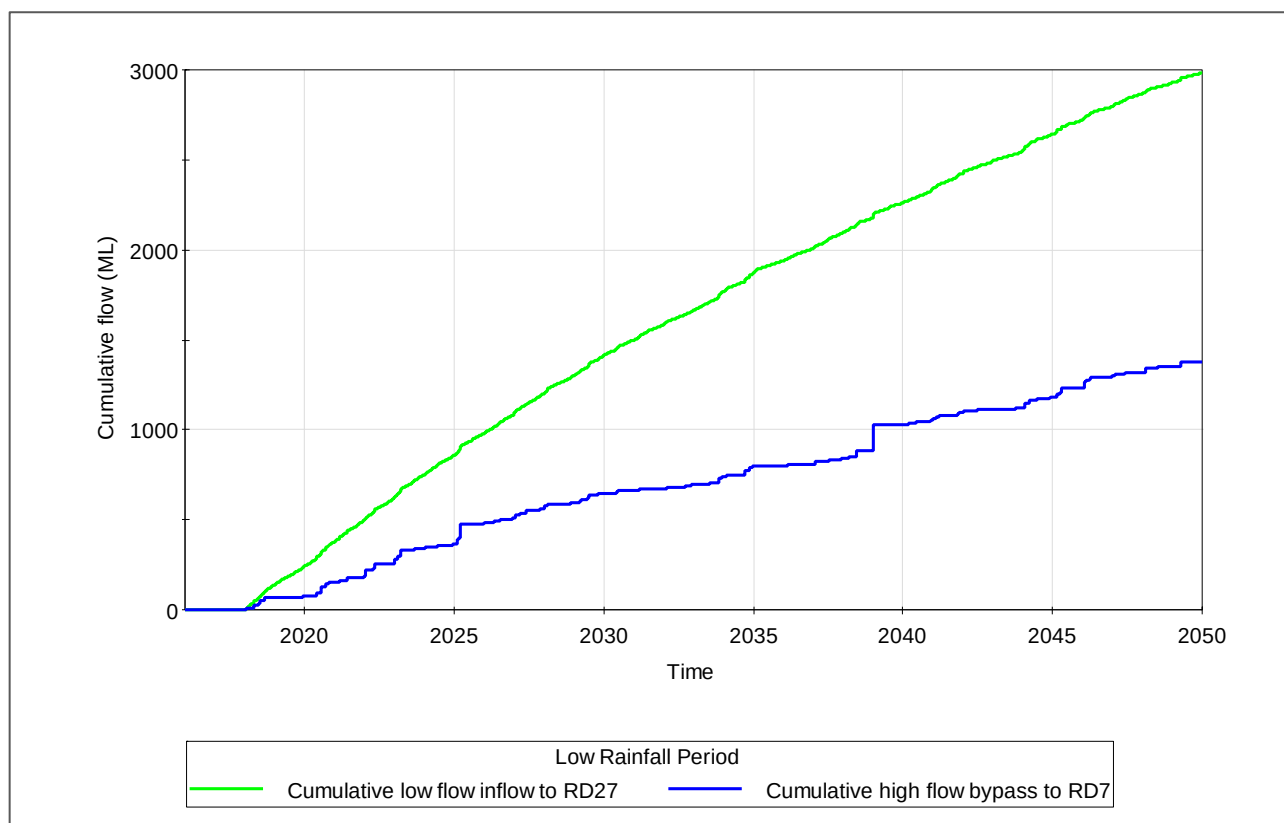


Figure 77: Inflow and bypass flow at RD27 low rainfall scenario (Base case)

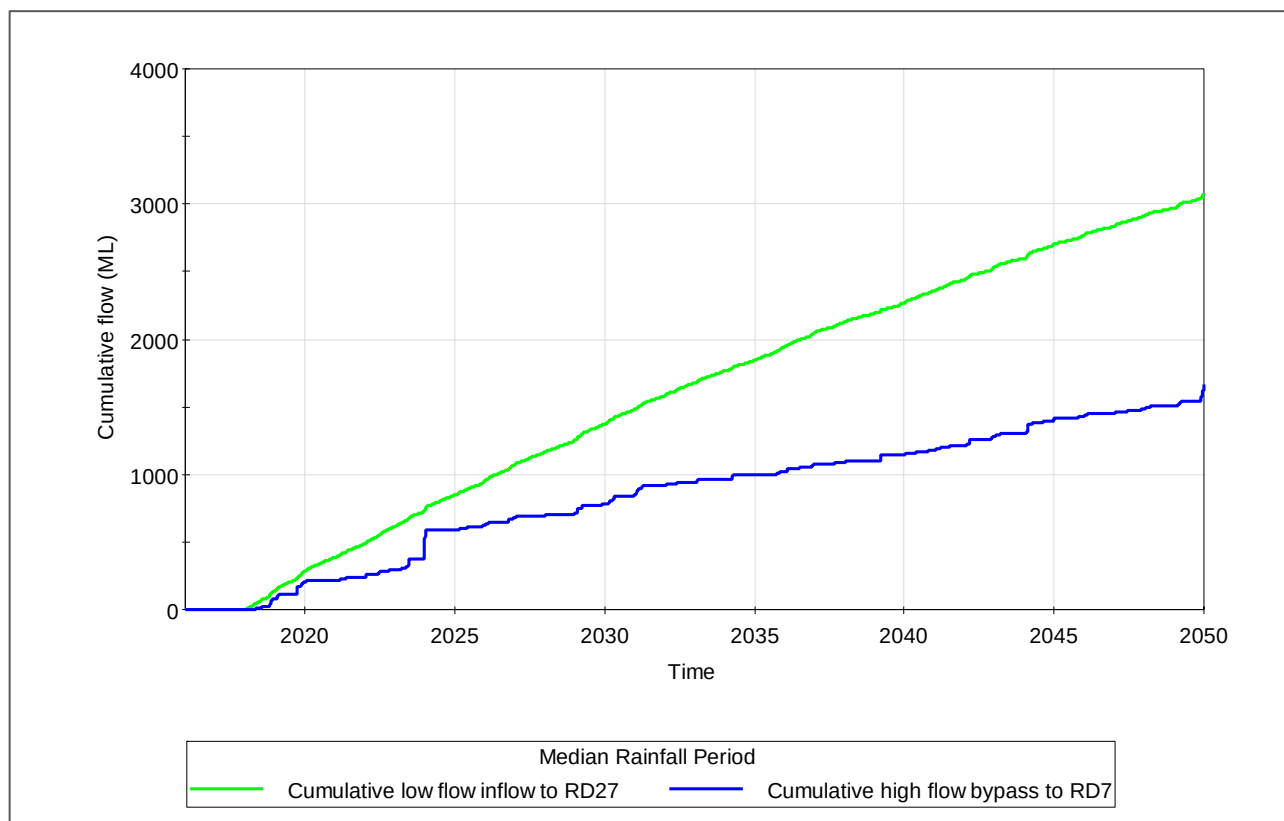


Figure 78: Inflow and bypass flow at RD27 median rainfall scenario (Base case)

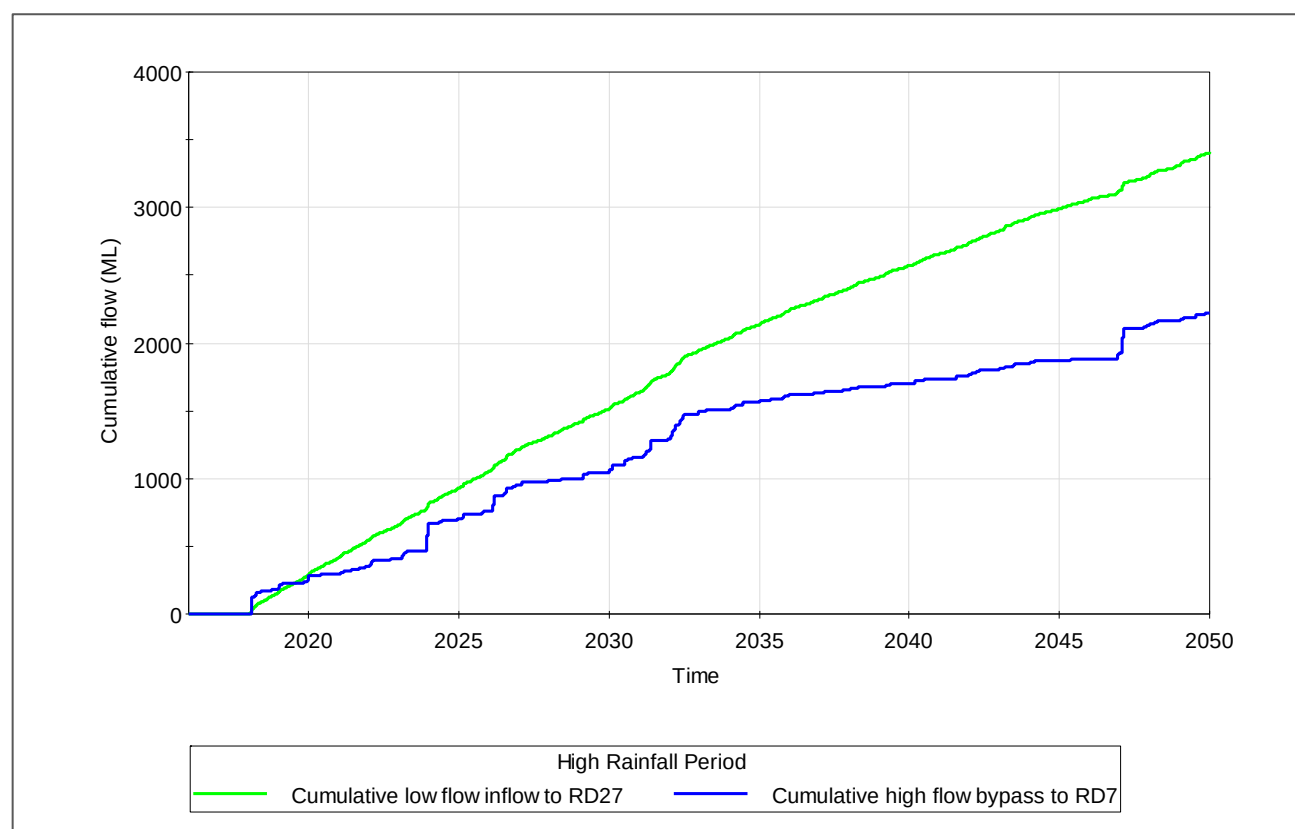


Figure 79: Inflow and bypass flow at RD27 high rainfall scenario (Base case)

7.1.2 Water quality

7.1.2.1 CP3

The EC results at CP3 for low, median and high rainfall scenarios is shown in Figure 80 - Figure 82. In all scenarios for the period 2020 – 2025 there are some instances of modelled exceedances (that is, modelled EC values exceeding 2,500 $\mu\text{S}/\text{cm}$). During operations up until closure there is a very gradual increase in EC that finishes at the end of operations and remains below reportable EC concentrations. In the post closure period there are some exceedances in some simulations.

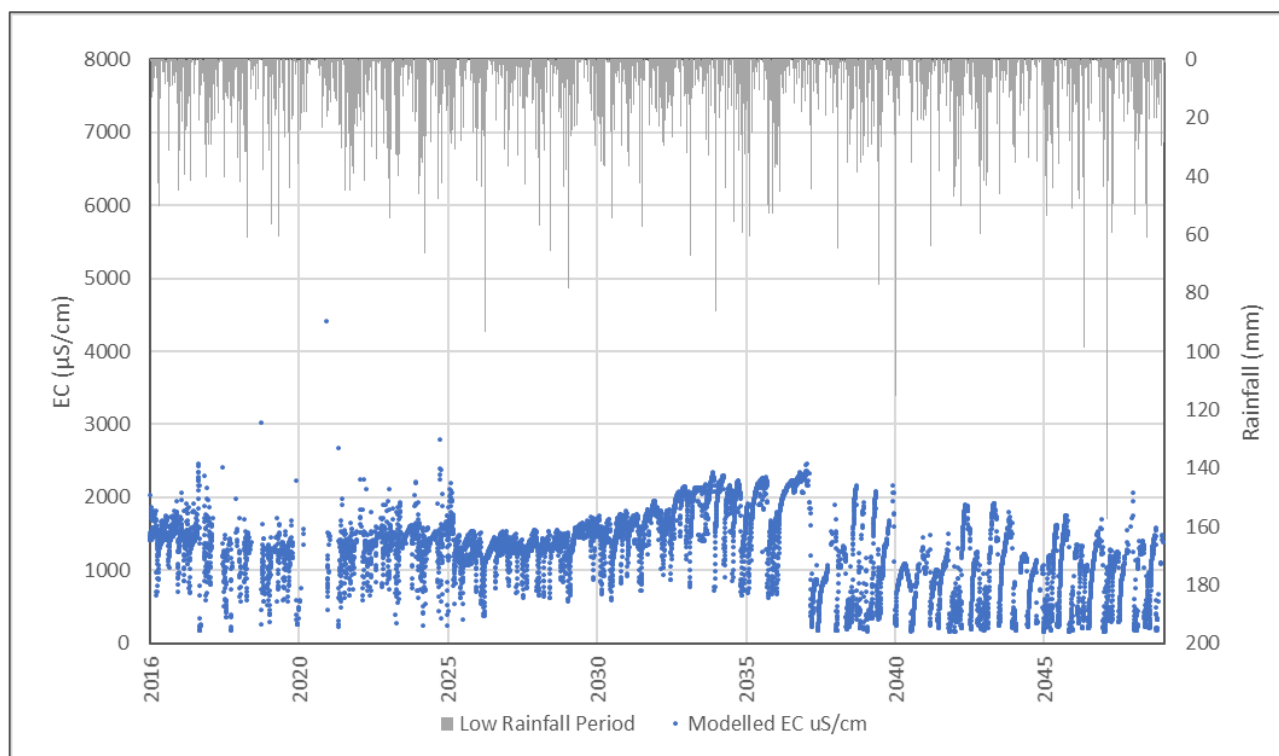


Figure 80: CP3 EC – low rainfall scenario (Base case)

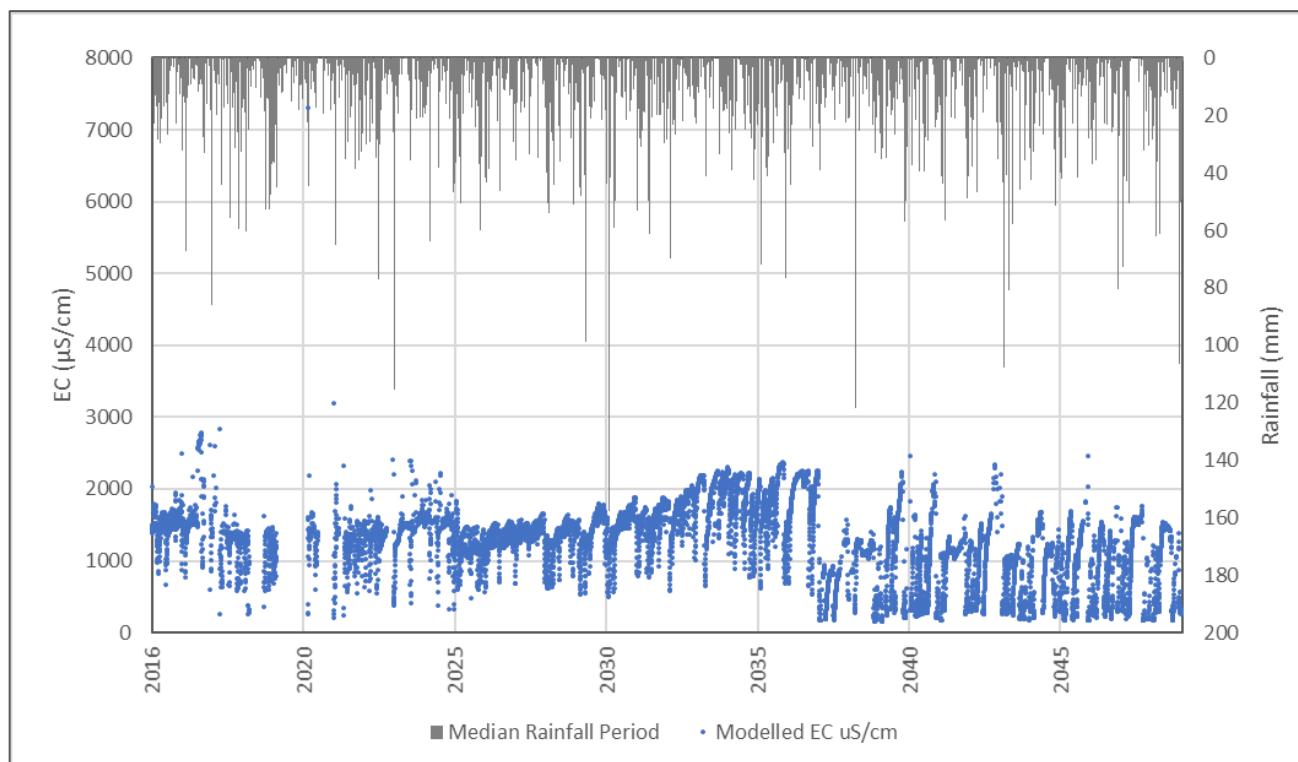


Figure 81: CP3 EC – median rainfall scenario (Base case)

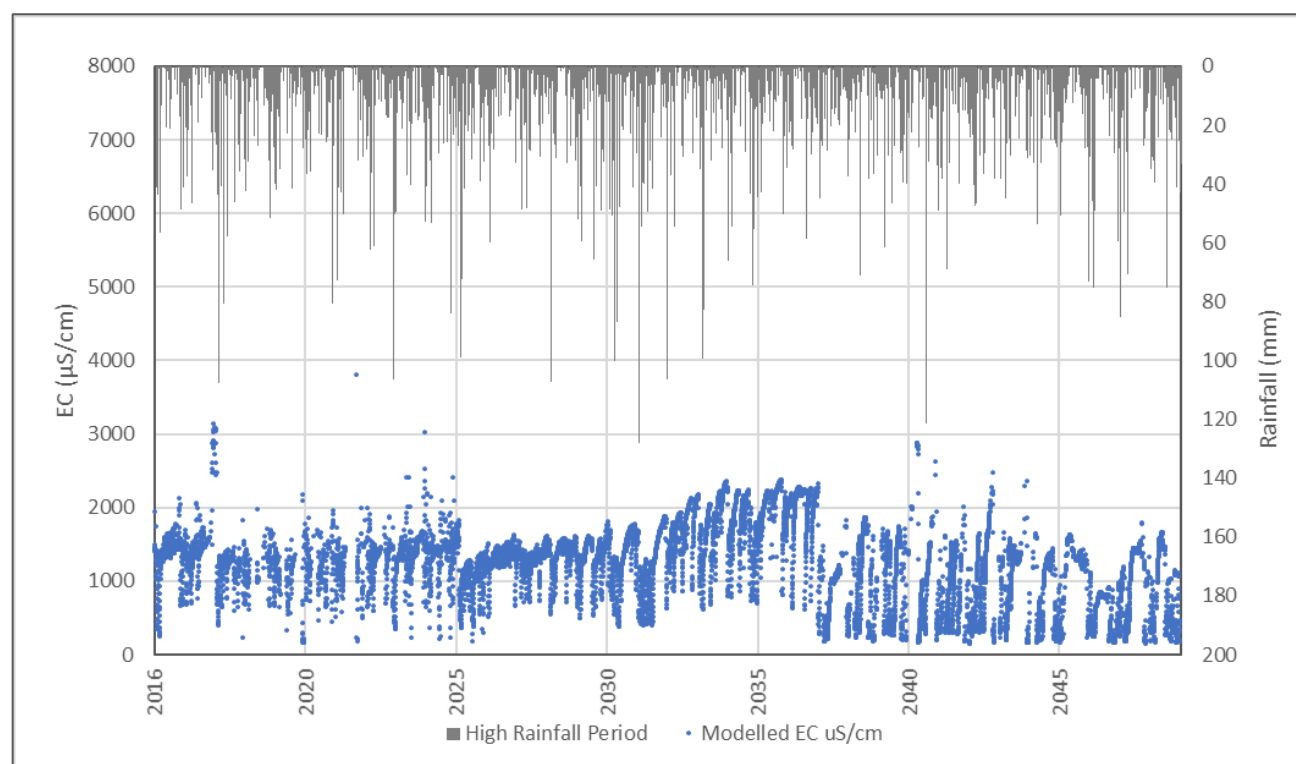


Figure 82: CP3 EC – high rainfall scenario (Base case)

Summary data is provided in Table 18.

Table 18: Summary EC results all simulations

	Low Rainfall Simulation	Median Rainfall Simulation	High Rainfall Simulation
Maximum EC ($\mu\text{S}/\text{cm}$)	4402	7302	3795
Number of exceedances $>2\,500\ \mu\text{S}/\text{cm}$ (34 years)	4	33	39

As discussed previously, between 2020 and 2025 each rainfall scenario uses a different rainfall record, the rainfall records for the median scenario has two consecutive years with annual rainfall totals of less than 450 mm. This is also a modelled period of relatively high production and water demand at the CHPP and when less water is available from dewatering (Ramp 5 is closed and K2E is about to recommence mining). Peak values in EC occur immediately after an extended dry period (as shown in Figure 83).

Each of the modelled exceedances, including those in the post closure period occur with the first flush of runoff through the weir following a dry period.

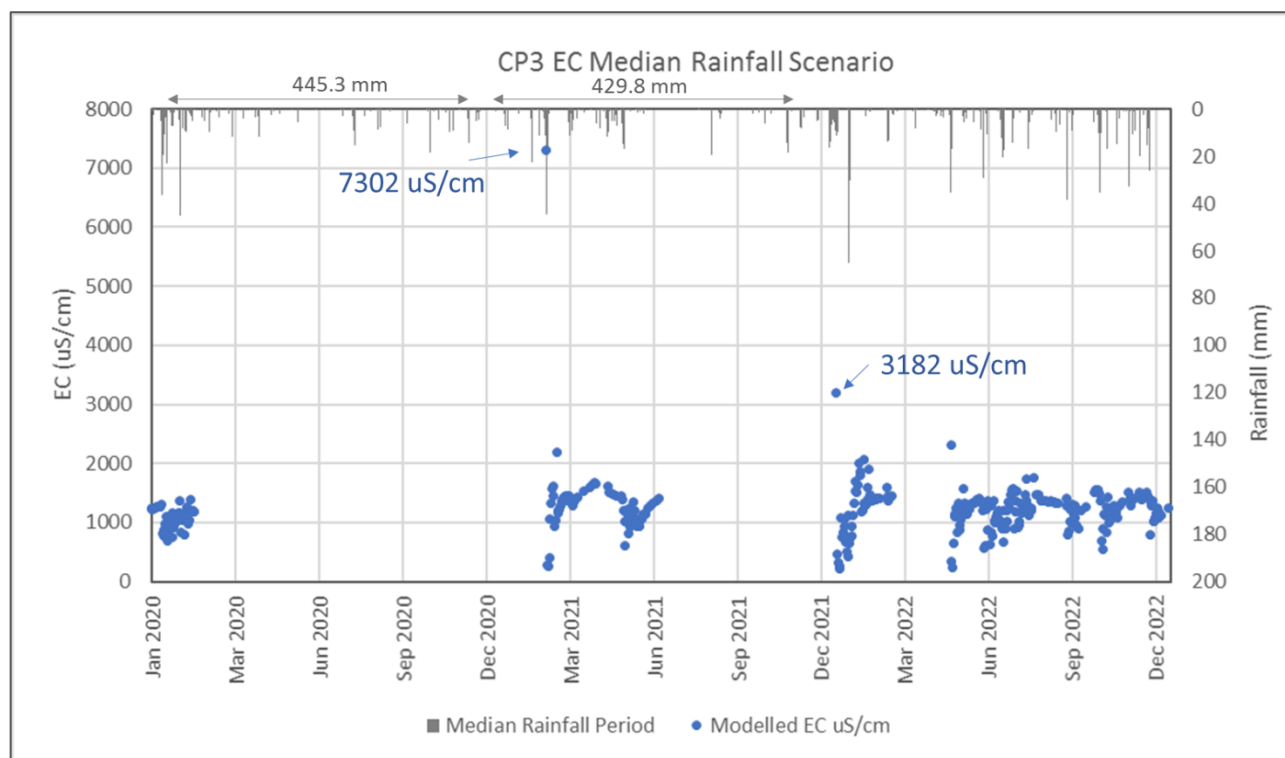


Figure 83: High EC events at CP3 compared to the modelled rainfall record for the period 2020 – 2022

During the same period, there is very little change in seepage from Bullgang Corner. There are small peaks in flow at around the same time as the peaks in EC occur as shown in Figure 84.

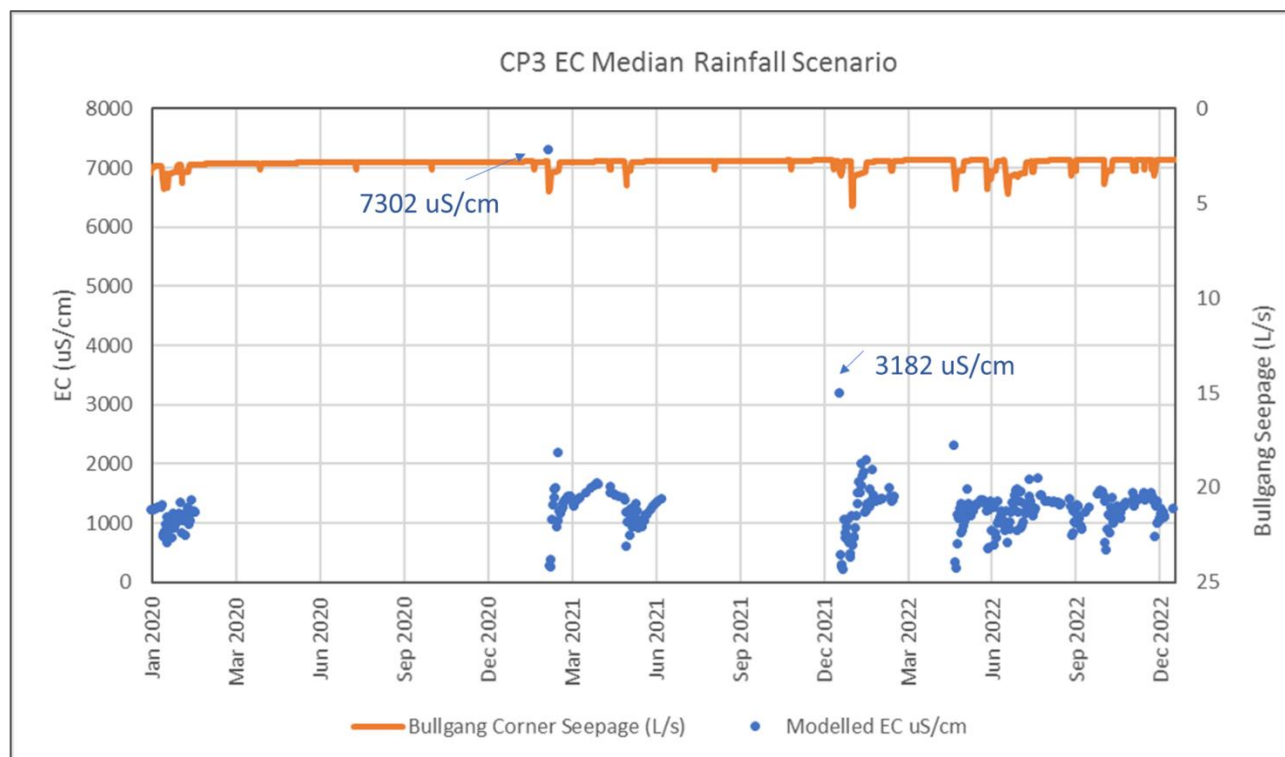


Figure 84: High EC events at CP3 compared to modelled Bullgang Corner seepage for the period 2020 – 2022

Conversely during a period of high flow from Bullgang Corner during 2023 – 2025 there is a small if any response in change in EC (as shown in Figure 85).

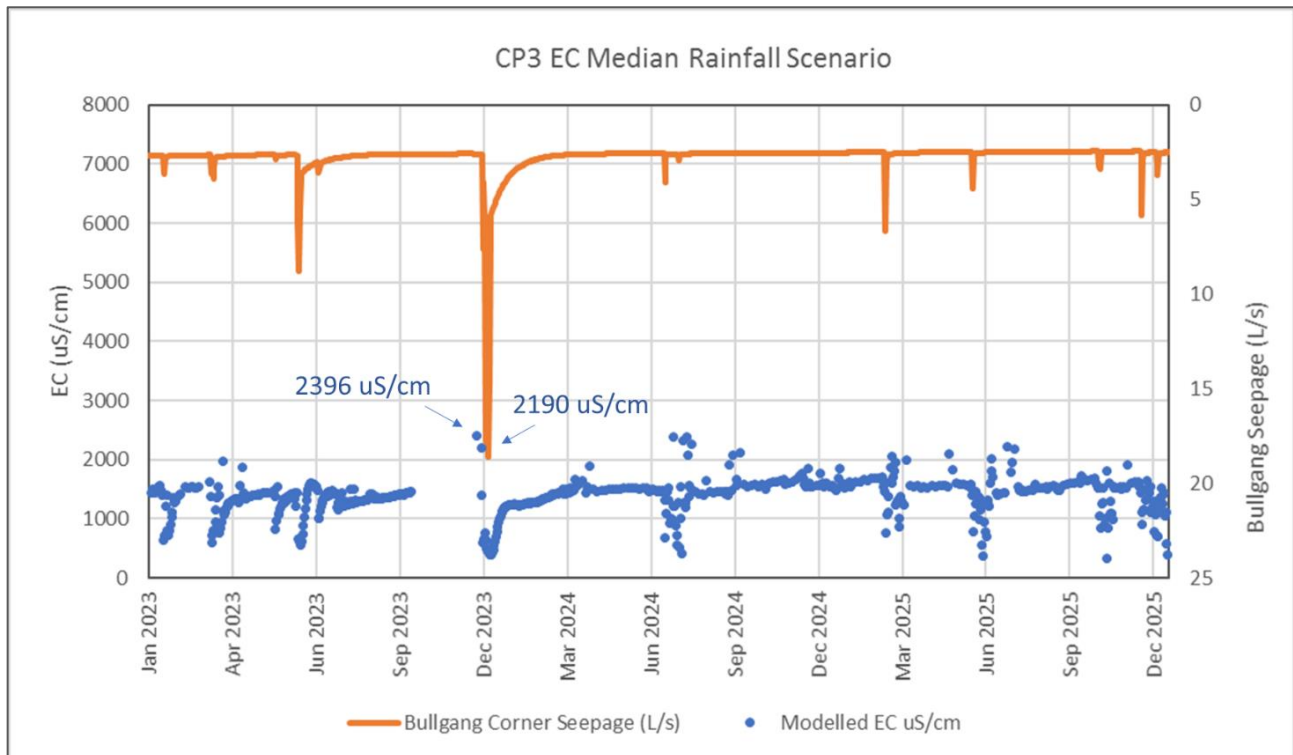


Figure 85: High seepage event at Bullgang Corner compared to EC at CP3 during the period 2023 – 2025

Long-term pH results at CP3 are provided in Figure 86, Figure 87 and Figure 88. Results are very similar in all climate scenarios. The lowest pH occurs in all scenarios in 2025 (range of 4.82 – 4.93) and declines also occur towards the end of operations. Once dewatering of all pits ceases in 2037 the pH returns to near neutral conditions. There was less confidence in the verification of the model for pH and there are limited data records available for in-pit samples; pH is established based on the concentration of hydrogen ions only and may need revision to incorporate hydroxide component. Regular in-pit pH sampling is recommended to assist in further verification of the model. It is also noted that contaminant limits for pH are set in EA (EPML00709113) for releases to receiving waters from Meandu Mine, prohibiting releases of water with low pH (less than 5.5) from the mine.

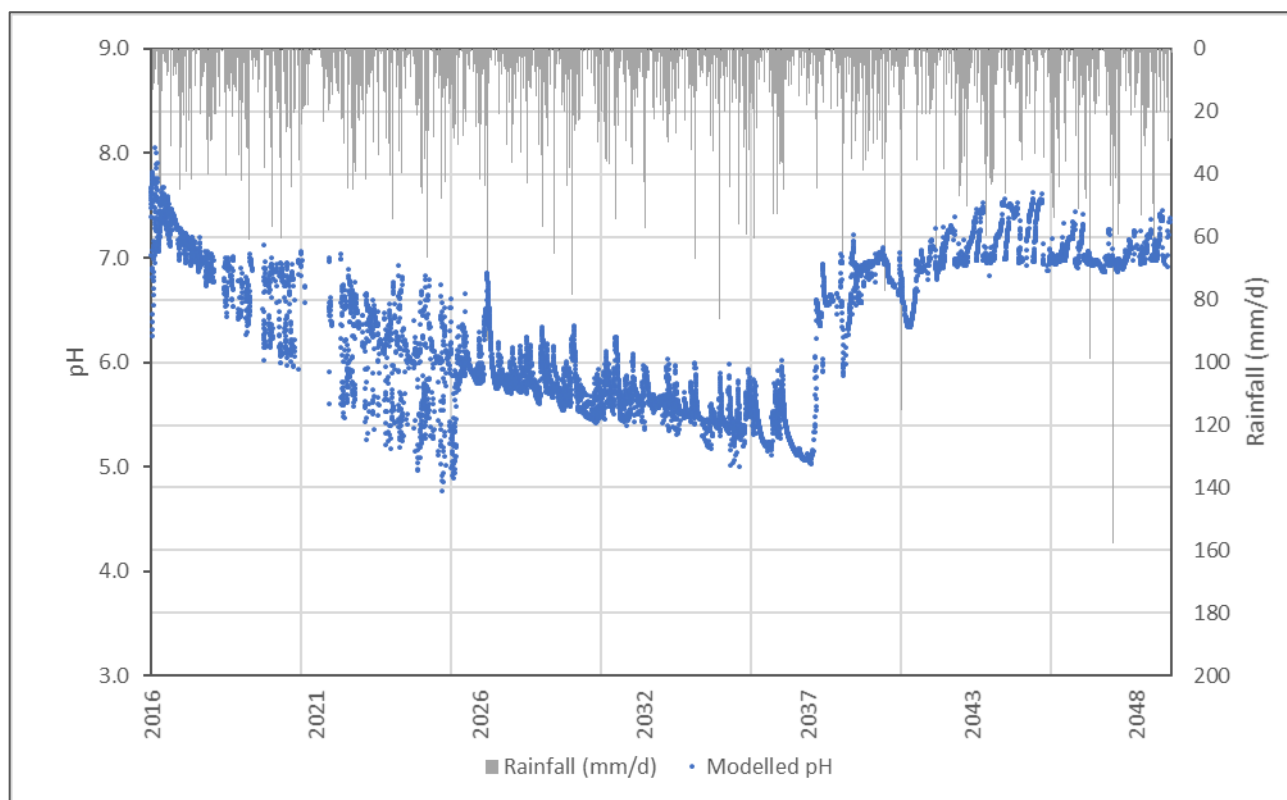


Figure 86: pH at CP3 – low rainfall scenario (Base case)

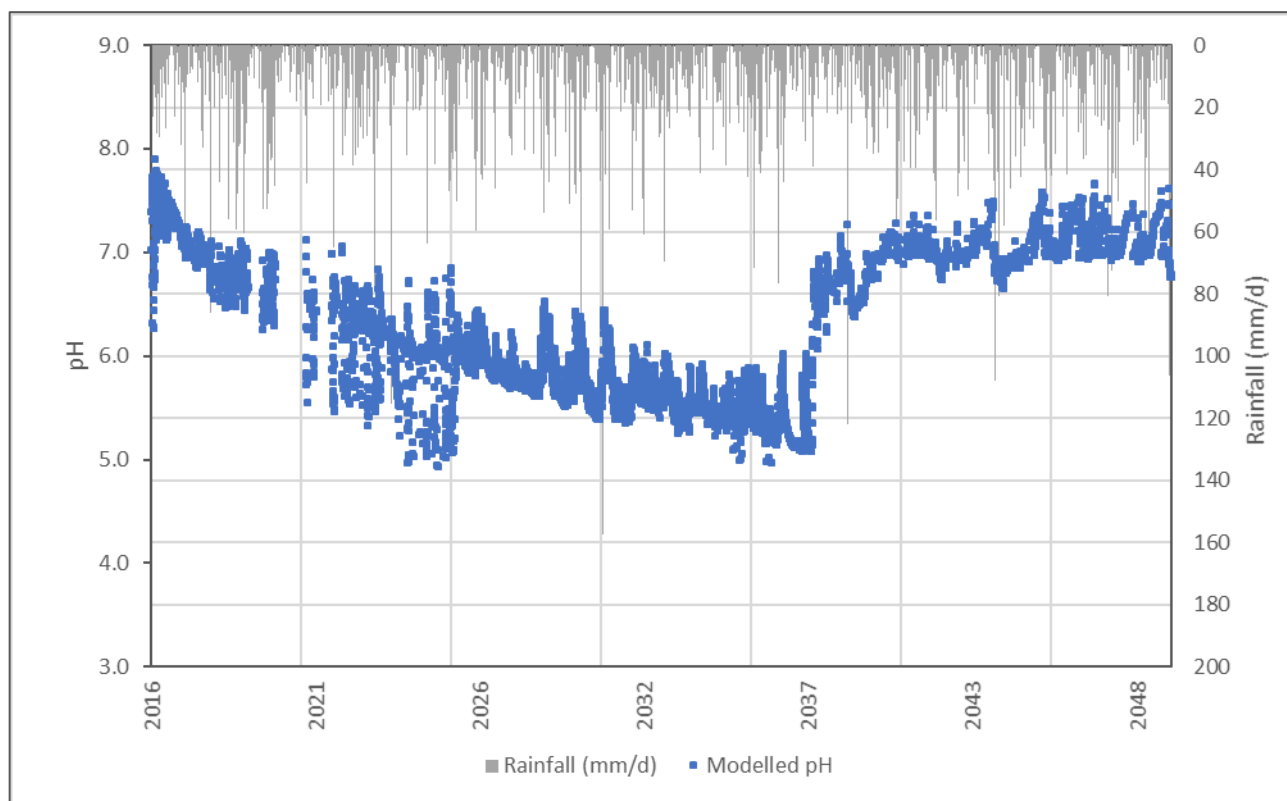


Figure 87: pH at CP3 - median climate scenario (Base case)

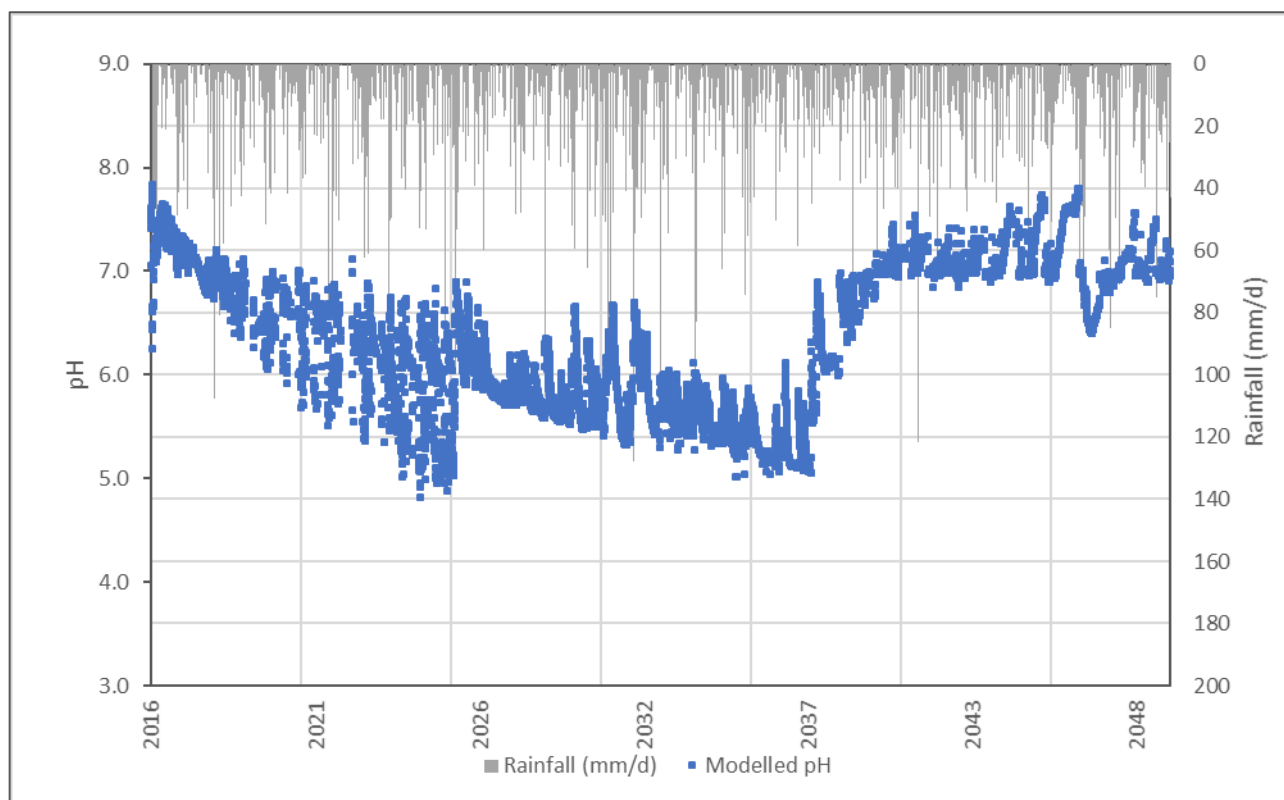


Figure 88: pH at CP3 high rainfall scenario (Base case)

Figure 89 to Figure 91 show zinc, nickel and manganese concentrations (respectively) at CP3 for the base case (without low flow discharge post closure) under all climate scenarios. Post closure, zinc concentrations are typically less than 0.14 mg/l, nickel concentrations are typically less than 0.035 mg/l and manganese concentrations are typically less than 0.25 mg/l.

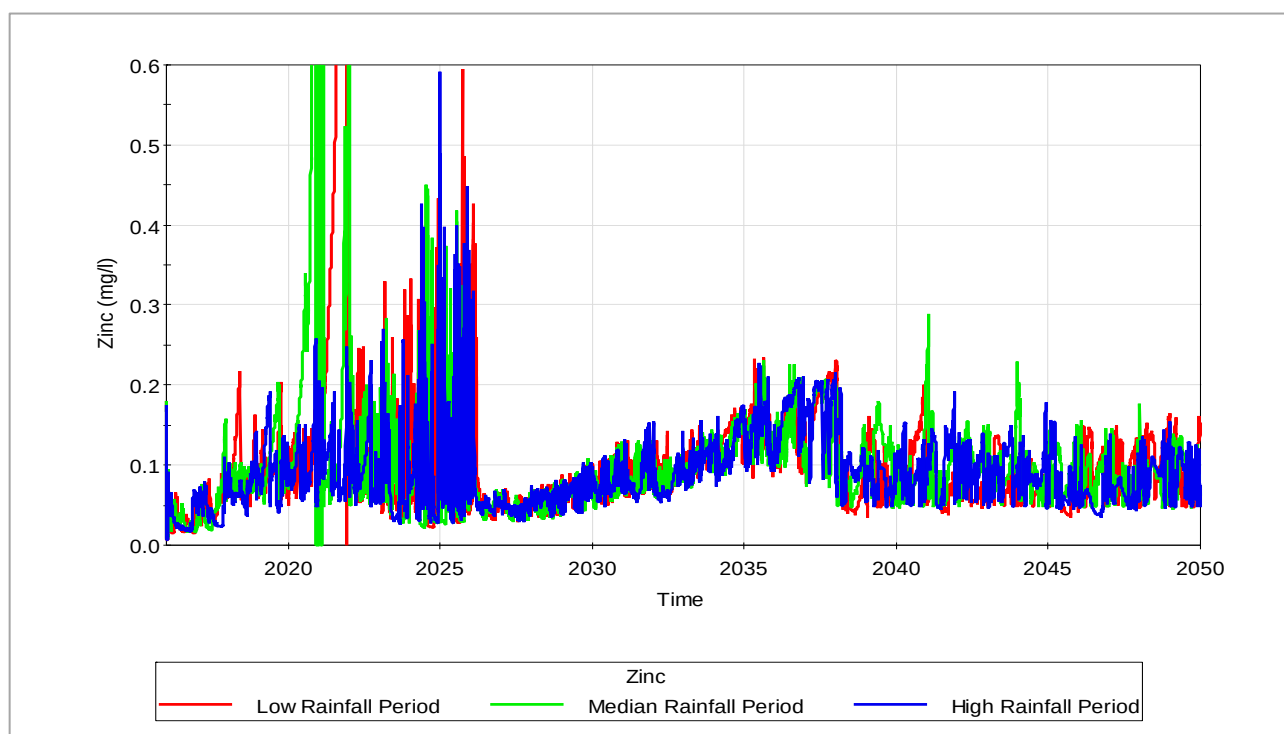


Figure 89: Zinc concentrations at CP3 (Base case) for all climate scenarios

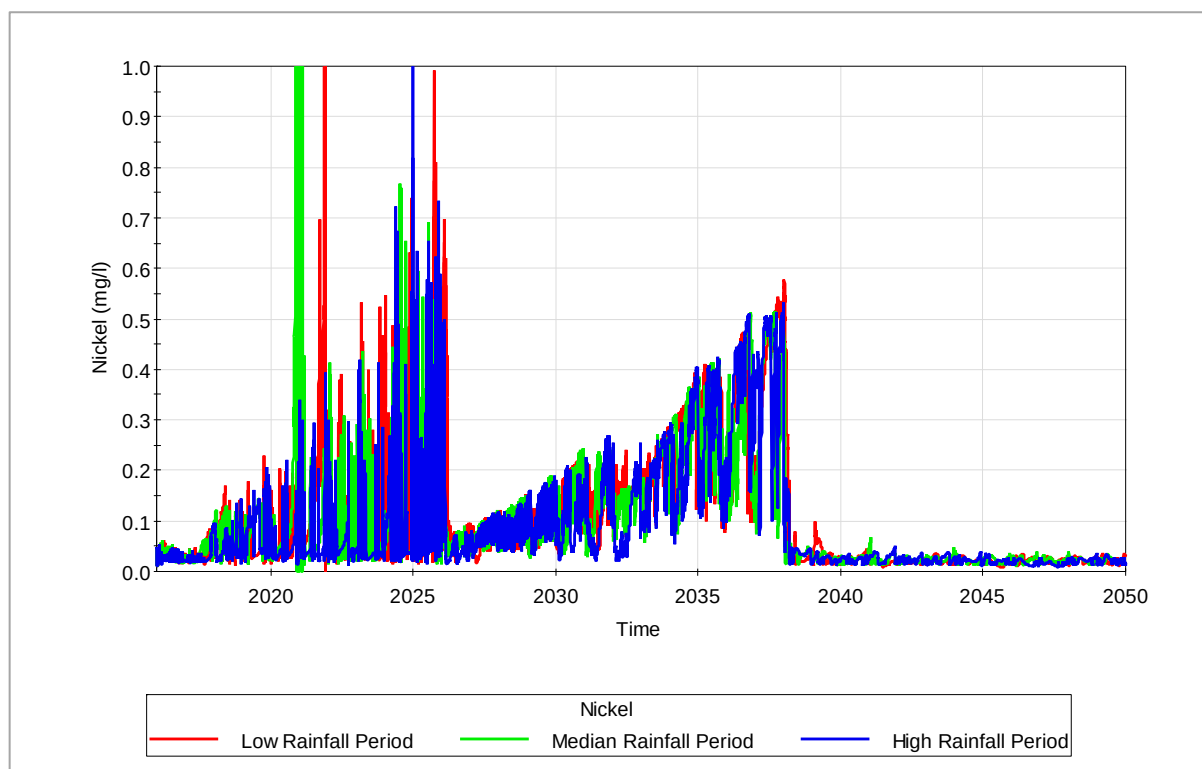


Figure 90: Nickel concentrations at CP3 (Base case) for all climate scenarios

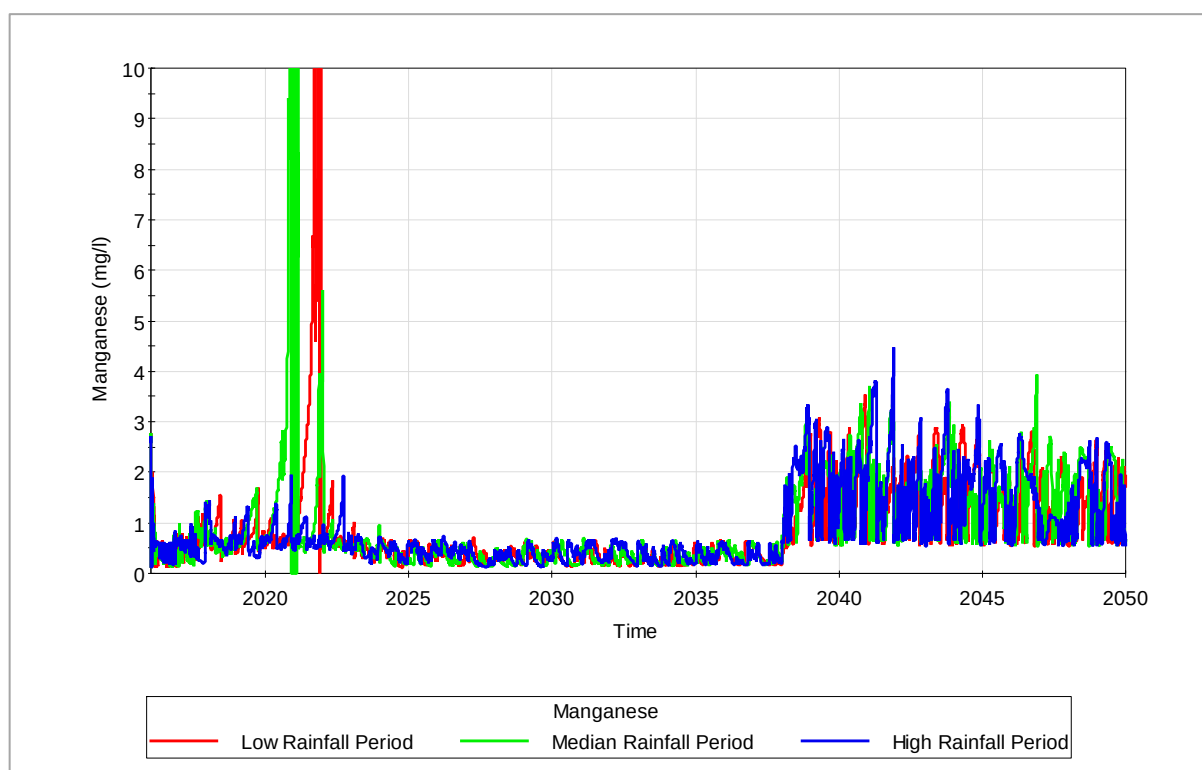


Figure 91: Manganese concentrations at CP3 (Base case) for all climate scenarios

7.1.2.2 Meandu Creek Dam

EC at Meandu Creek Dam is shown in Figure 92 for the median rainfall scenario. This is the case where in the modelled system the low flow outlet is switched off when operations cease. Meandu Creek Dam remains near

to capacity during operations and closure (as described in Section 7.1.1.3 and shown in Figure 65). The EC is generally in the order of 1 500 $\mu\text{S}/\text{cm}$ to 2 000 $\mu\text{S}/\text{cm}$ during operations. At closure EC reduces to around 500 $\mu\text{S}/\text{cm}$.

pH at Meandu Creek Dam is shown in Figure 93. The pH is influenced by inflow pH from CP3 and is in the range of 5.7 to 8.5; increasing after closure to 6.5 to 7.0. As discussed in Section 7.1.2.1 there is uncertainty in the verification of the model representation of pH at CP3.

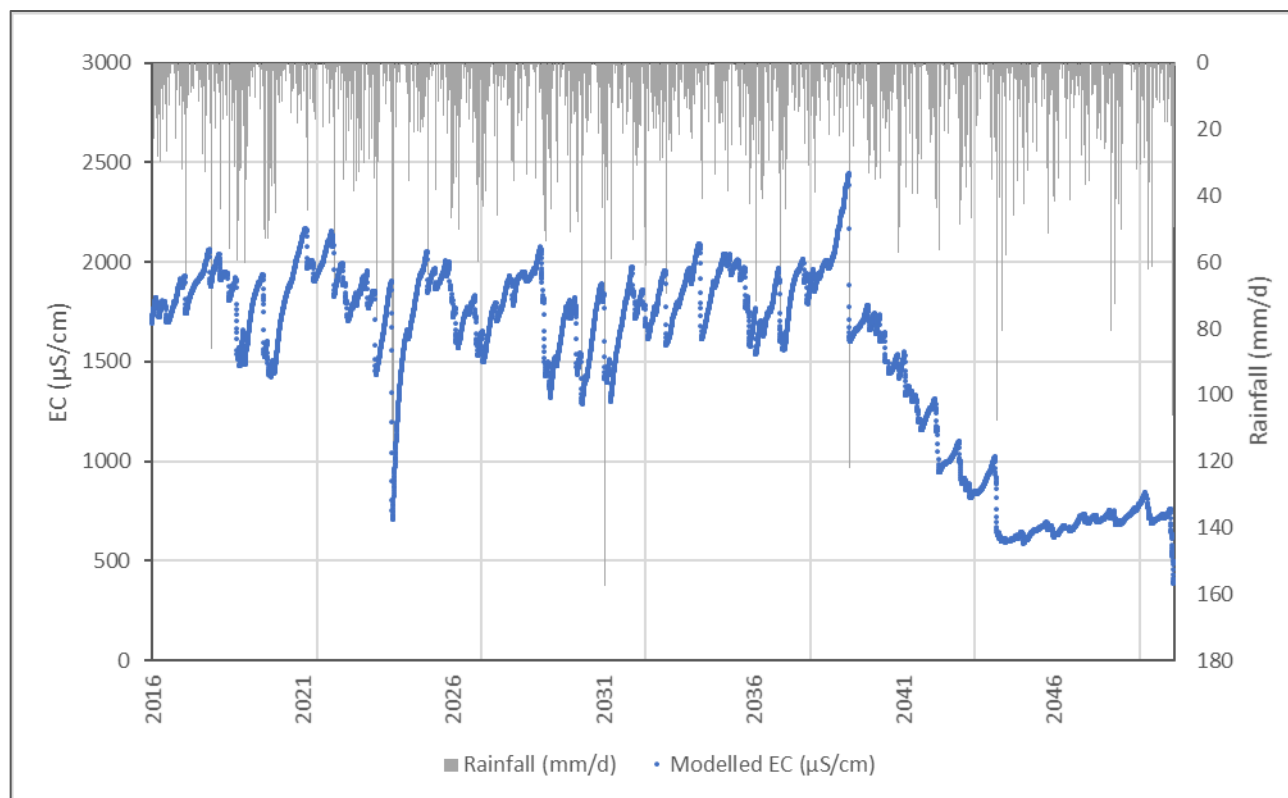


Figure 92: EC at Meandu Creek Dam (Base case, median rainfall scenario)

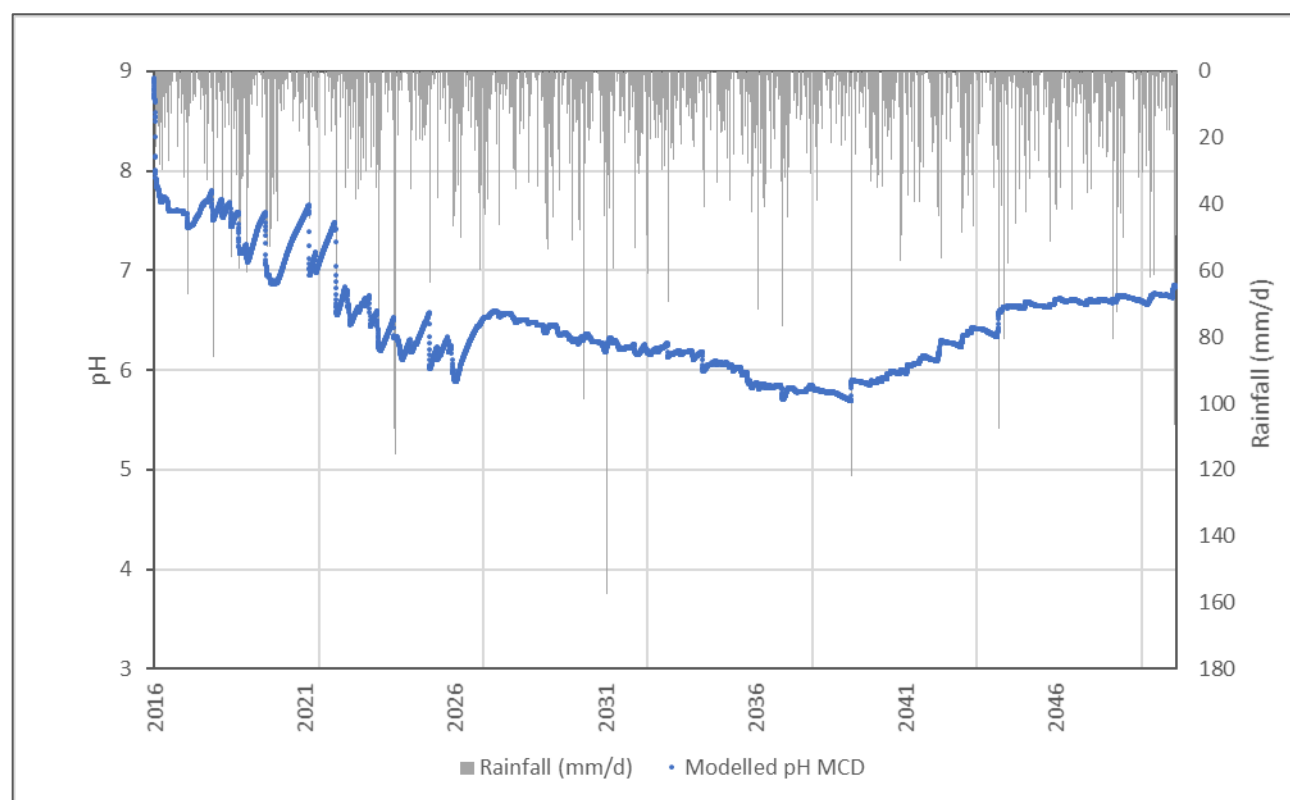


Figure 93: pH at Meandu Creek Dam (Base case, median rainfall scenario)

7.2 Engineering control simulations

7.2.1 Dewatering NWBFP

7.2.1.1 Quantity

An option under consideration for control of resurgent seepage at Bullgang Corner and the diffuse seepage at Ramp 7 is the controlled dewatering of the NWBFP. Two pumping rates have been considered for the full duration of simulations, that is, the installation of one bore with the capacity to dewater the NWBFP at a rate of 6 L/s (Scenario 1a) and the installation of two bores with the combined capacity to dewater the NWBFP at a rate of 12 L/s (Scenario 1b). Due to some changes in water quality identified in the modelled system for the closure period using Scenario 1a and 1b, two additional scenarios have also been considered. That is, Scenario 1c and 1d, where pumping is discontinued in 2037 at the end of mining. The options for pump rate and pumping duration tested using the modelled system are shown in Table 19.

In the modelled scenarios, water extracted during dewatering of the NWBFP was added to the Bullgang Corner seepage flow directed to RD27.

Table 19: Dewatering scenarios.

Scenario	Pump rate (L/s)	Pump start (Year)	Pump end (Year)
1a	6	2019	2050
1b	12	2019	2050
1c	6	2019	2037
1d	12	2019	2037

Results considered the dewatering performance (drawdown potential) of the bores and water quantity and quality implications to RD27 and at the downstream compliance point CP3.

The water level in the NWBFP, simulated using 100 model realisations (stochastically generated rainfall), for the base case, Scenario 1a and Scenario 1b are provided in Figure 94, Figure 95, and Figure 96 respectively. Two different scales of the water level axis are provided in each case; the first showing the water level relative to the spill elevation to Ramp 7 (432 m RL) and the second showing the water level relative to the base of fill in the NWBFP (375.0 m RL).

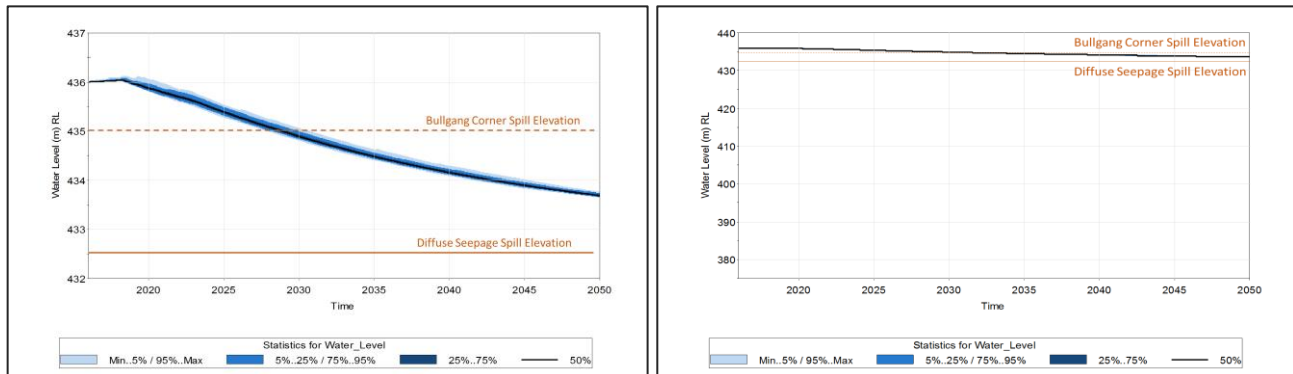


Figure 94: Water level in NWBFP – base case (100 realisations)

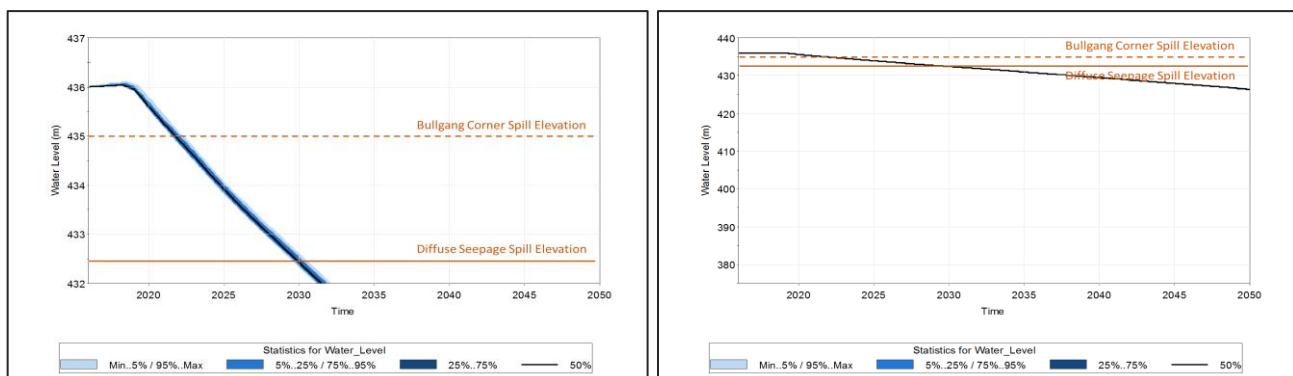


Figure 95: Water level in NWBFP – Scenario 1a (100 realisations)

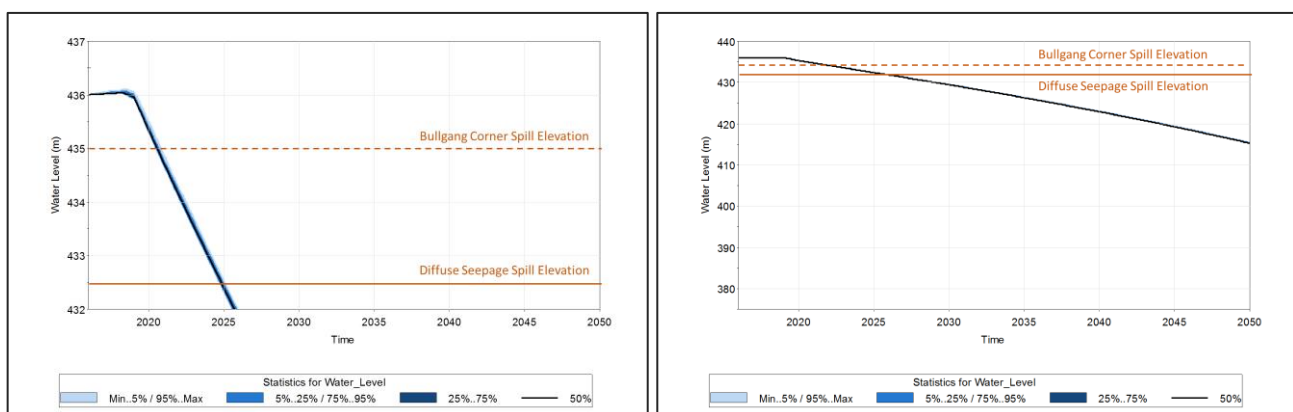


Figure 96: Water level in NWBFP – Scenario 1b (100 realisations)

Table 20 provides the estimated date of effective dewatering of the NWBFP in Scenario 1a and 1b. Without dewatering (the base case) the water level gradually declines to below the spill elevation for resurgent seepage at Bullgang Corner by May 2028 (median of 100 model realisations); but remains above the diffuse seepage to

Ramp 7 spill elevation at closure, indicating that resurgent seepage will continue to occur to Ramp 7 up until and beyond closure.

With dewatering at 6 L/s (Scenario 1a) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by August 2021 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by July 2029 (median of 100 model realisations). With dewatering at 12 L/s (Scenario 1b) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by June 2020 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by September 2024 (median of 100 model realisations).

Table 20: Date of effective dewatering below spill elevations at Bullgang Corner and Ramp 7 (100 model realisations)

Spill Point	Date range	Base case	Scenario 1a	Scenario 1b
Bullgang Corner	Earliest	April 2027	May 2021	May 2020
	Median	May 2028	August 2021	June 2020
	Latest	February 2030	February 2022	October 2020
Diffuse seep to Ramp 7	Earliest	#	March 2029	July 2024
	Median	#	July 2029	September 2024
	Latest	#	March 2030	January 2025

indicates water level does not go below spill elevation during the simulation period

The water elevation in the NWBFP at the end of mining and at the end of the closure period simulated is provided in Table 21. The greater the rate of dewatering the greater the reduction in water surface elevation in the NWBFP. There is a slight rise in water elevation in Scenarios 1c and 1d after dewatering ceases at the end of mining (of less than 0.5 m by 2050 for Scenario 1c and less than 1 m by 2050 for Scenario 1d) as the model assumes (conservatively) that there is no outflow through the floor of the pit

Table 21: Water elevation (RL m) (median of 100 realisation)

Scenario	End of mining 2037 (RL m)	At 2050 (RL m)
Base Case	434.3	433.7
Scenario 1a	430.1	426.4
Scenario 1b	424.3	415.3
Scenario 1c	430.1	430.5
Scenario 1d	424.3	425.1

Seepage from the NWBFP reporting to Bullgang Corner and diffuse seepage at Ramp 7 is comprised of resurgent seepage as well as interflow (as shown in Figure 14). The resurgent seepage is the constant low flow component. Interflow occurs in response to rainfall. The total seepage flow for base case, Scenario 1a and Scenario 1b is shown in Figure 97, Figure 98, and Figure 99 respectively for low, median and high rainfall periods. As can be seen from these figures the low flow component of the seepage ceases to occur with dewatering, however, discharge from the NWBFP will continue due to infiltration and interflow in response to rainfall events.

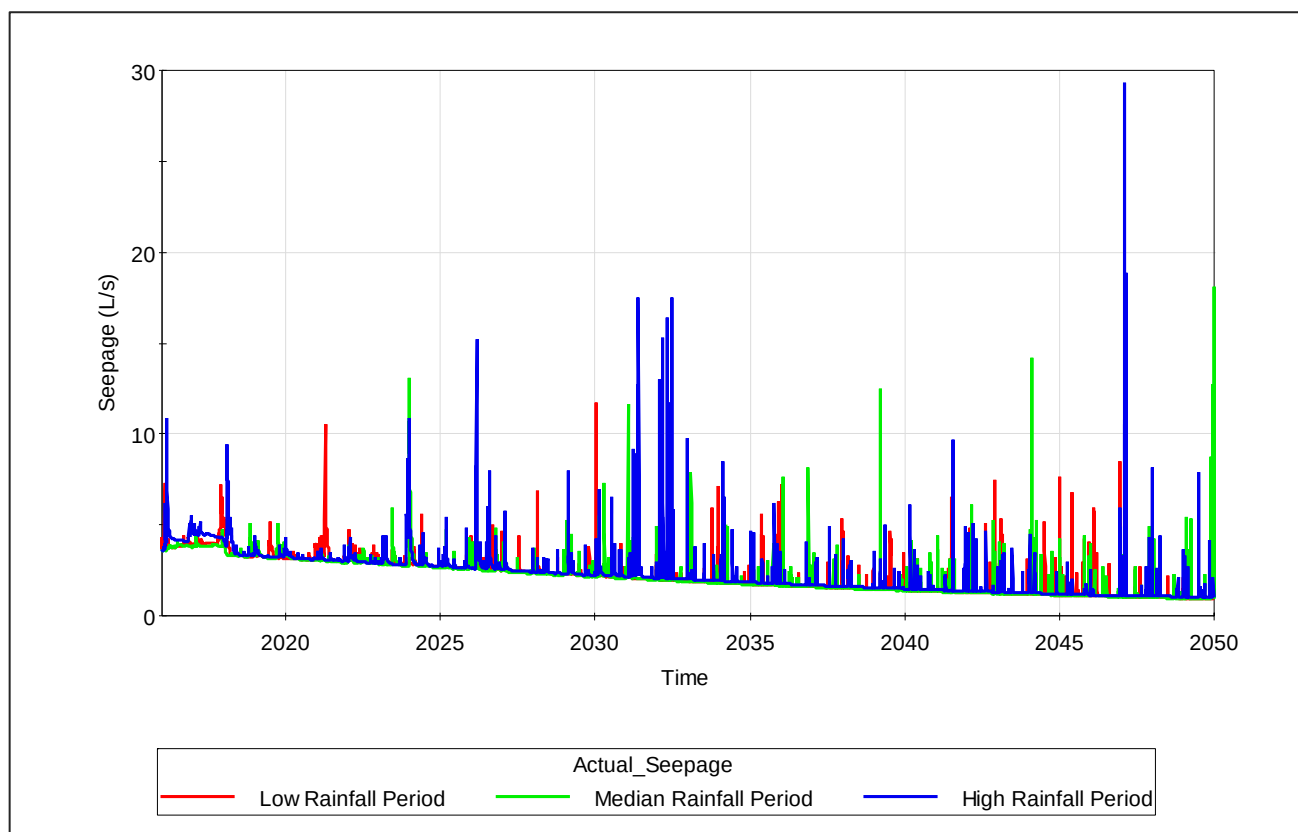


Figure 97: Total seepage (Bullgang Corner and Ramp 7) – base case (low, median and high rainfall periods)

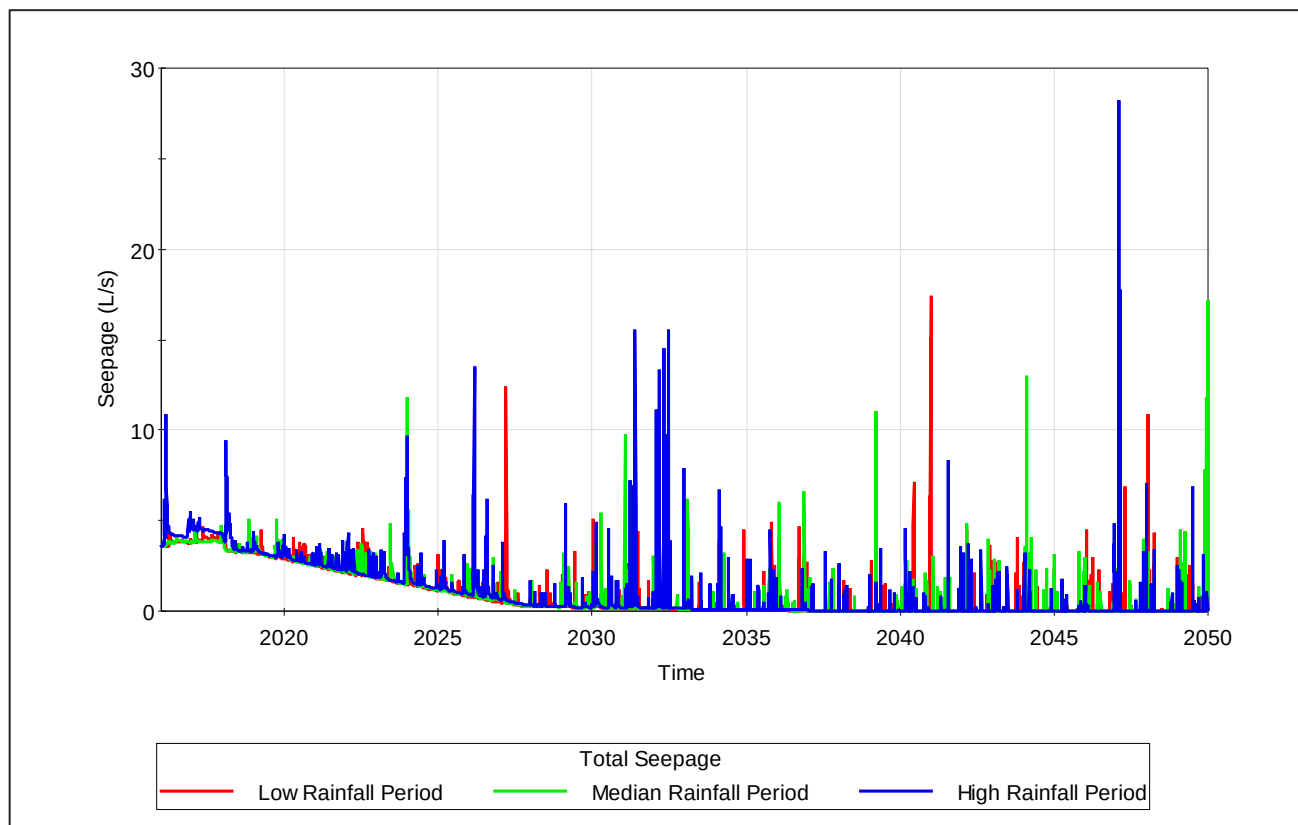


Figure 98: Total seepage (Bullgang Corner and Ramp 7) - Scenario 1a (low, median and high rainfall periods)

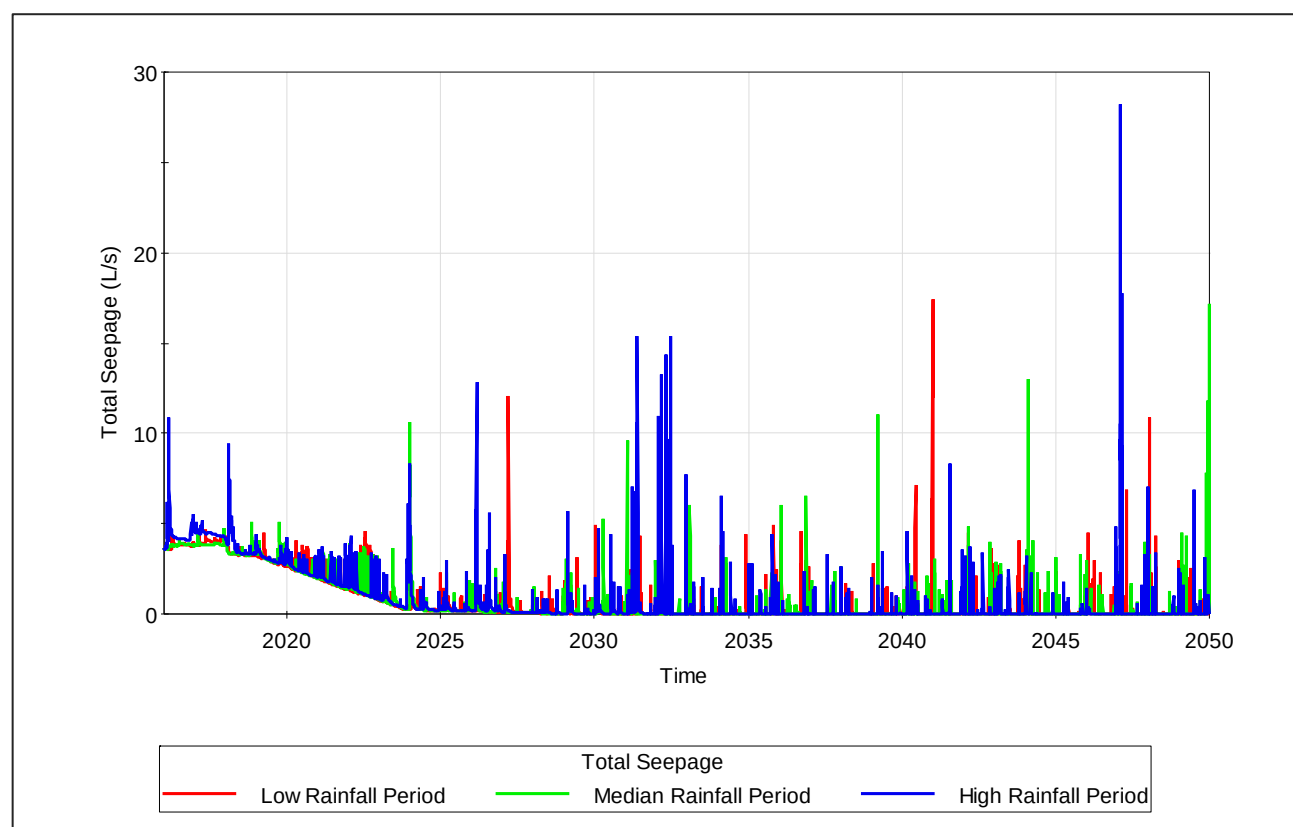


Figure 99: Total seepage (Bullgang Corner and Ramp 7) - Scenario 1b (low, median and high rainfall periods)

The annual average resurgent seepage and interflow is provided in Table 22. As the water level in the NWBFP is drawn down the resurgent seepage rate declines. The faster the drawdown the lower the resurgent seepage rate.

Table 22: Annual average resurgent seepage and interflow (median rainfall simulation)

Year	Base case (L/s)	Scenario 1a (L/s)	Scenario 1b (L/s)
2018	4.49	4.49	4.49
2019	4.53	4.45	4.37
2020	3.40	3.02	2.63
2021	3.35	2.74	2.11
2022	3.99	3.31	2.61
2023 - 2037	3.06	1.37	1.04
2038 - 2050	2.24	1.07	1.07

The low flow inflow to RD27 inclusive of dewatering from NWBFP and Ramp 7 flow (diffuse seepage and RD27 catchment runoff) is shown in Table 23.

Table 23: Annual average inflow to RD27 (median rainfall period)

Year	Base case (L/s)	Scenario 1a (L/s)	Scenario 1b (L/s)
2018	4.49	4.49	4.49
2019	4.53	10.45	16.37
2020	3.40	9.02	14.63
2021	3.35	8.74	14.11
2022	3.99	9.31	14.61
2023 - 2037	3.06	7.37	13.04
2038 - 2050	2.24	7.07	13.07

Water in excess of the low flow inlets to RD27 is sent via a high flow bypass to RD7. The average annual high flow bypass flow rate is provided in Table 24. There is no difference between the scenarios in the quantity of water in excess of what is able to enter RD27 via the low flow inlets.

Table 24: Annual average quantity of water in high flow bypass (median rainfall period)

Year	Base case (L/s)	Scenario 1a (L/s)	Scenario 1b (L/s)
2018	3.00	3.00	3.00
2019	4.56	4.56	4.56
2020	0.50	0.50	0.50
2021	0.54	0.54	0.54
2022	2.14	2.14	2.14
2023 - 2037	1.94	1.92	1.92
2038 - 2050	1.63	1.61	1.61

7.2.1.2 Water quality

EC at CP3 for the base case, Scenario 1a and Scenario 1b is shown in Figure 100, Figure 101, and Figure 102 respectively. The base case scenario has been reported in Section 7.1.2.1 and is reproduced here for comparison purposes.

In both Scenario 1a and Scenario 1b during the post closure period (2038 – 2050) there is a marked increase in EC as seen in Figure 101 and Figure 102. The reason for this increase in the modelled system is that at closure, due to the cessation of use of treated water at fill points and for transfer to RD26 the pond continuously overflows. The primary inflow to RD27 during this period is low flow seepage from the NWBFP that, when treated, has a modelled EC of 3700 $\mu\text{S}/\text{cm}$ (input water quality parameters are provided in Table 12). The overflow from RD27 is routed via RD7 and RD8 to CP3. Also, with the cessation of pit dewatering at closure

there is reduced flow through the eastern retention dam system routing water via RD2 to CP3. As a result, the water quality at CP3 is impacted directly by the water quality of the overflow from RD27.

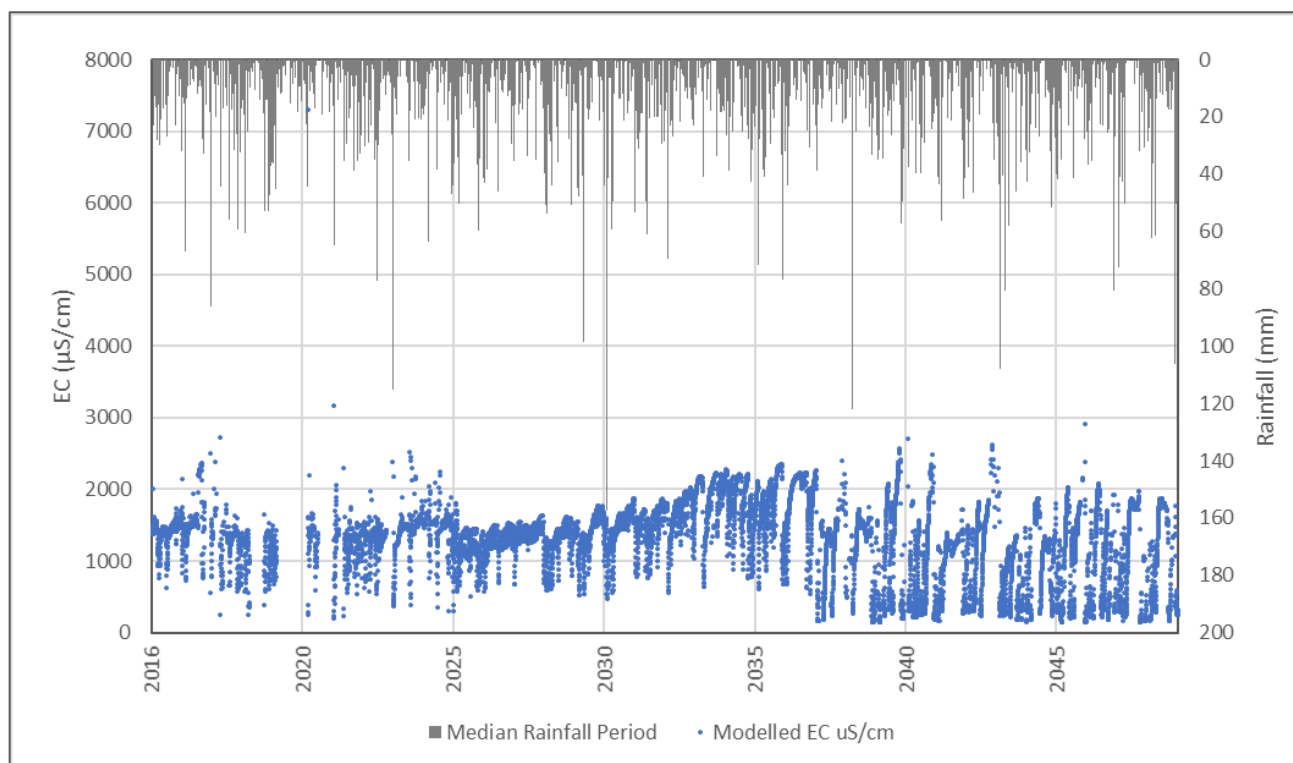


Figure 100: CP3 EC base case (median rainfall simulation).

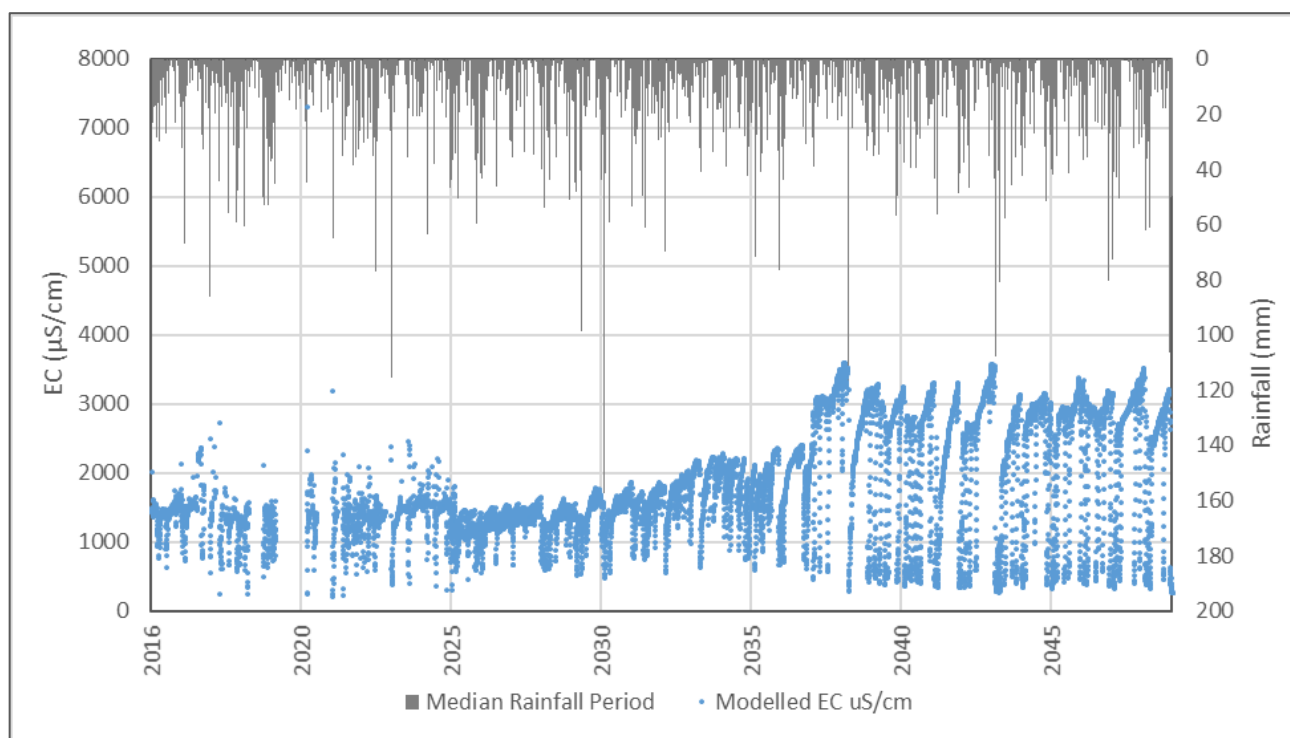


Figure 101: CP3 EC Scenario 1a (median rainfall simulation).

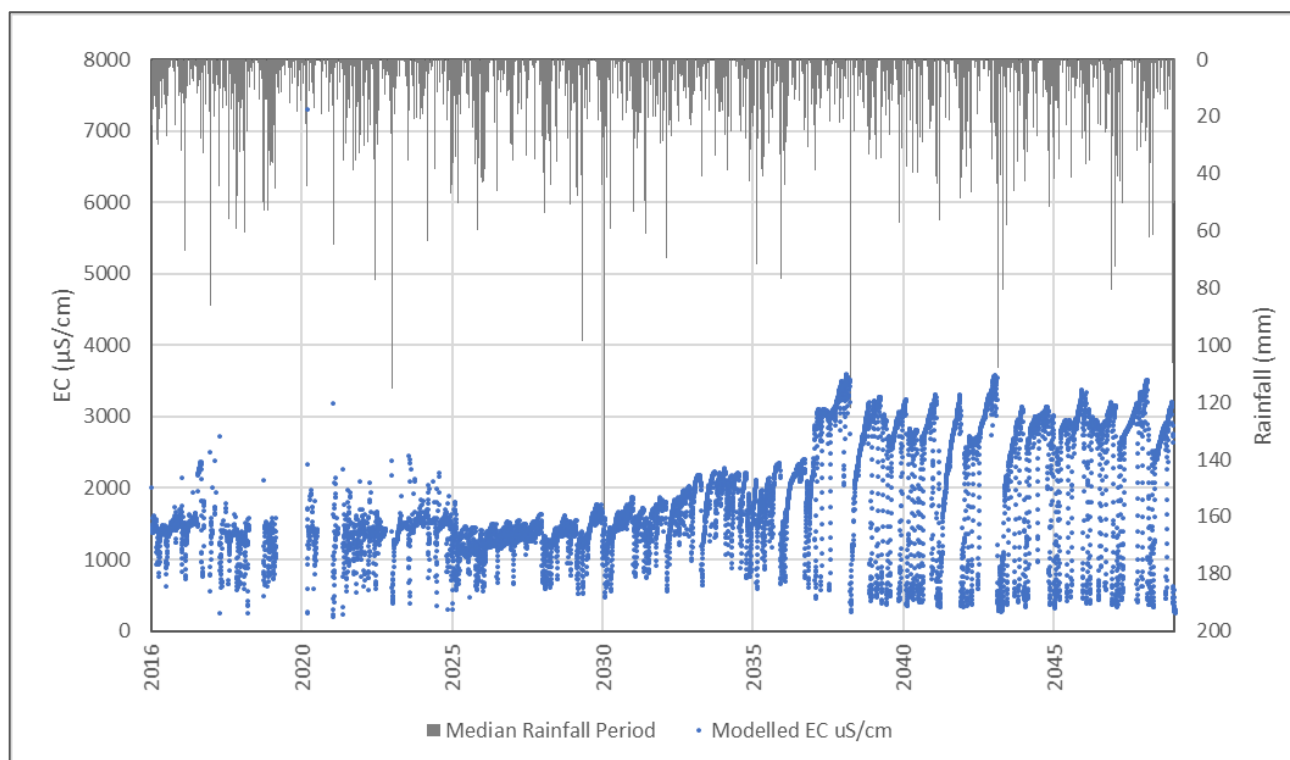


Figure 102: CP3 EC Scenario 1b (median rainfall simulation).

Alternative scenarios (Scenario 1c and Scenario 1d) were simulated where the dewatering pumps were turned off at the end of mining operations in 2037. The resultant EC at CP3 is shown in Figure 103. If water requiring treatment from dewatering is stopped at the start of the closure period, the EC remains below 2100 $\mu\text{S}/\text{cm}$.

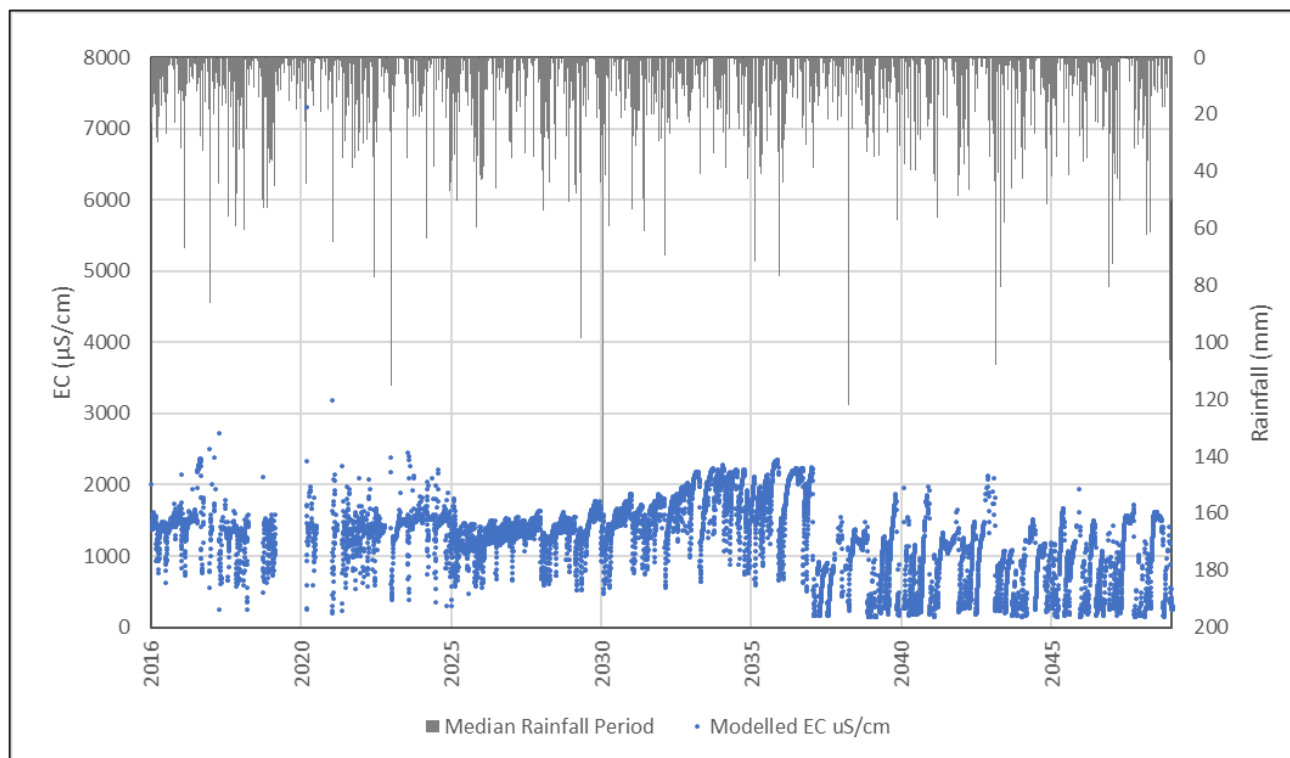


Figure 103: CP3 EC Scenario 1c (median rainfall simulation)

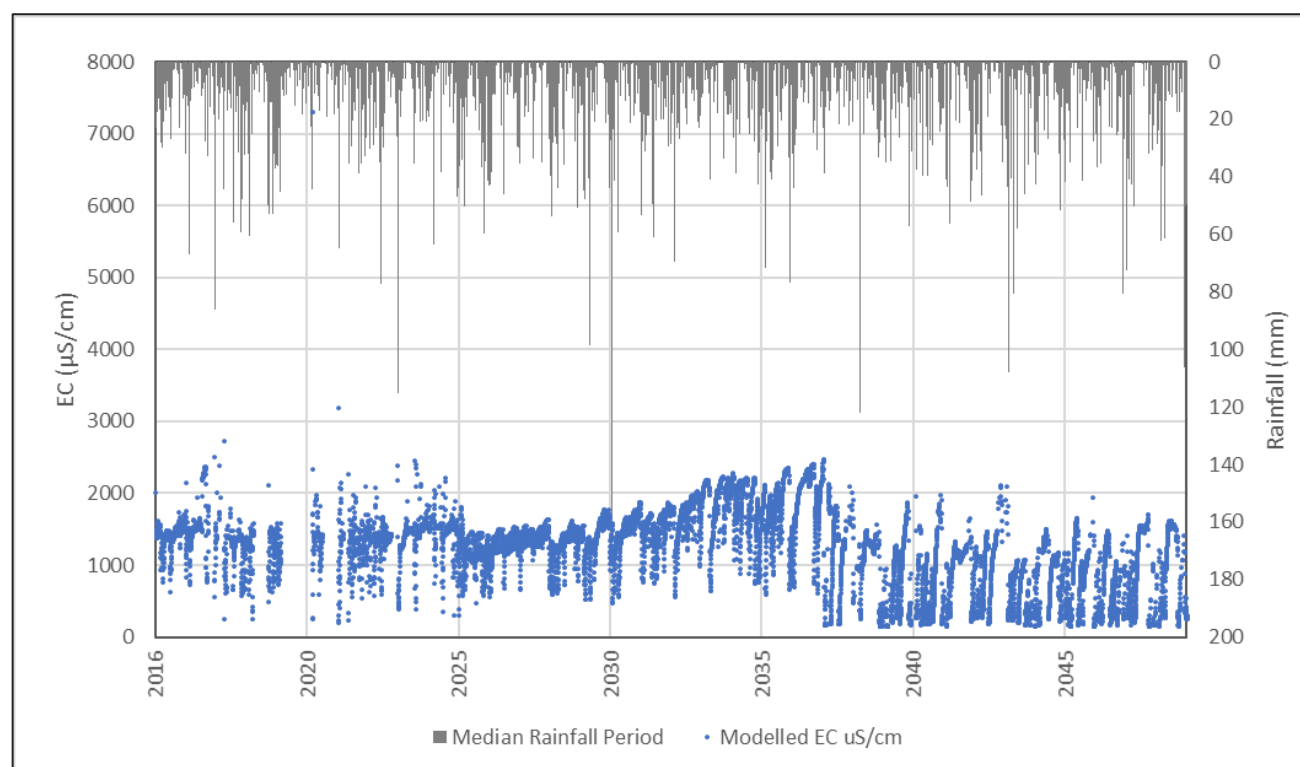


Figure 104: CP3 EC Scenario 1d (median rainfall simulation)

7.2.2 Improved cover to Rejects Storage Area 1

A second engineering control has been simulated using the model, that is, application of an improved cover system to the RSA1. The existing cover (1 m on the western embankment of the NWBFP, termed RSA1-A in the model; and 3 m on the western surface of the NWBFP, termed RSA1-B in the model); is of a reduced thickness compared to the 6 m depth of cover used since 2016 above PAF Material and particularly coarse rejects at Meandu Mine. Surface runoff and baseflow from RSA1-A reports directly to the Ramp 7 haul road drain. Surface runoff from RSA1-B reports to the Ramp 7 haul road drain and baseflow reports as recharge to the NWBFP. Due to the reduced thickness of the existing soil cover in the location of RSA1-A and RSA1-B; in the base case, these areas have been modelled as having the same surface runoff and baseflow characteristics as waste.

The purpose of this simulation trial (Scenario 2) is to determine the impact of the change in cover thickness of RSA1-A and RSA1-B on the quantity of recharge to the NWBFP and quality of water at downstream compliance points in the modelled system. For the Scenario 2 simulation, the relevant areas have been modified from the base case to have the runoff/recharge properties of rehabilitated land.

On average, there is a 13% reduction in infiltration (as shown in Table 25), however, this change is insufficient to make a significant change to the water surface elevation in the NWBFP.

Table 25: Change in surface cover results – quantity (median rainfall simulation)

	Average change in infiltration from base case (2018 – 2026)	Water surface elevation 2037 (RL m)	Water surface elevation 2050 (RL m)
Base case	0%	434.3	433.7
Scenario 2	13% reduction	434.3	433.7

There is also minimal change from base case (Figure 100) in the modelled EC at CP3 for the duration of the simulation as shown in Figure 105.

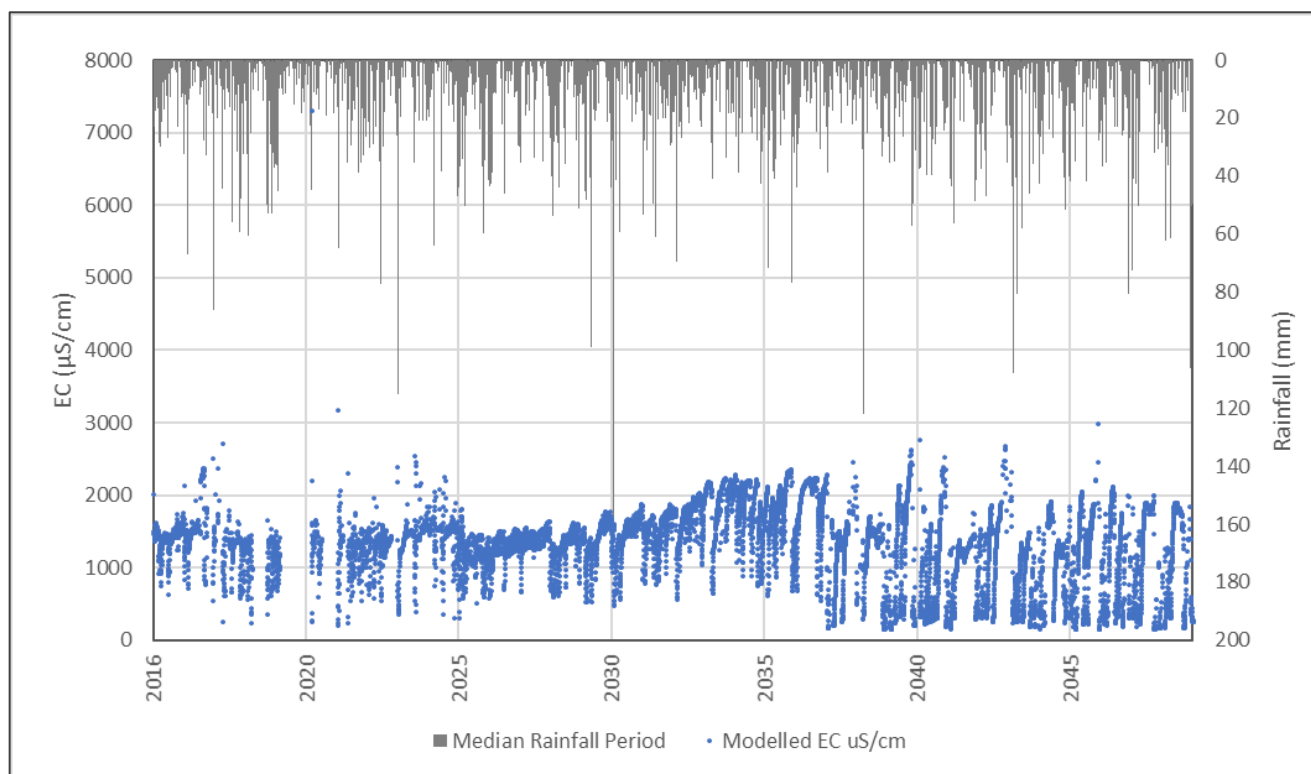


Figure 105: CP3 EC Scenario 2 (median rainfall simulation)

8.0 CONCLUSIONS

8.1 Base case

The base case has been modelled with the AMD and mine water controls to be implemented from 2018. The modelled network has components that represent each of the mine water management elements at Meandu Mine, including surface water quantity, groundwater quantity and water quality.

The sensitivity of modelled seepage at Bullgang Corner to NWBFP hydraulic parameters was examined by varying the hydraulic conductivity values of the materials in the groundwater (Seep/W) model. Discharge from the NWBFP continues to be released, in all cases trialled, for the duration of the simulation period that includes operations and post closure period, without further controls in place.

Flow at CP3 was simulated using three climate scenarios. There are periodic high and low flows in both operational and closure periods in all scenarios, as well as periods of no flow. Periods of no flow are more frequent during mining operations, but there is also an increase in background low flow during operations when compared to the post closure period.

Two scenarios were simulated for the operational and post closure period at Meandu Creek Dam.

- The first, stops continuous low flow discharge when operations cease, and Meandu Creek Dam remained close to capacity during operations and the post closure period.
- The second, allowed a continuation of low flow discharge at current rates which resulted in a marked decline in storage volume.

Once K2E Pit is dewatered, despite lower water demand using the solid bowl centrifuge at the CHPP, the model indicates there may be periods of insufficient water supply available to the CHPP; particularly during extreme dry periods. It is recommended that Stanwell monitor water requirements and availability in the lead up to this period and adjust water management practices.

In all climate scenarios simulated there are frequent high flow bypasses of inflow to RD27. In total, approximately half of the catchment and other flow to RD27 will bypass RD27 and go to RD7. This occurs during high flow events and does not appear to impact on water quality at CP3.

There is good confidence in the representation of EC at CP3 in the modelled system. Exceedances of EC occurred in the modelled system at periods of low flow. There was only a small, if any, change in EC at CP3 in response to high flows of resurgent seepage from Bullgang Corner and Ramp 7 haul road drain.

Post-closure, modelling indicates that metal concentrations typically remain between stable upper and lower limits, though may exhibit sharp and temporary increases when water volumes are very low (that is, during extremely dry conditions). EC behaviour post-closure typically remains below reportable concentrations, with some exceedances occurring in some simulations (during dry conditions).

There is less confidence in the representation of pH at CP3 and subsequently at Meandu Creek Dam (CP1) in the modelled system. Low pH events appear to be related to pit dewatering activities. Once pumping from pits ceases at closure, the pH as modelled returns to neutral conditions. pH is represented in the model based on the concentration of hydrogen ions only and may need revision to incorporate a hydroxide component. Frequent in-pit pH sampling is recommended to assist in further verification of the model. It is also noted that contaminant limits for pH are set in EA (EPML00709113) for releases to receiving waters from Meandu Mine, prohibiting releases of water with low pH (less than 5.5) from the mine.

8.2 Engineering controls

Dewatering of the NWBFP was applied in the model for four scenarios, Scenario 1a and 1b were simulated with dewatering in place for the entire period of simulation, that is, for the period 2019 – 2050 (post closure). In Scenario 1a the NWBFP was dewatered at a rate of 6 L/s. In Scenario 1b the NWBFP was dewatered at a rate of 12 L/s. In Scenario 1c and 1d, dewatering of the NWBFP was applied during the period of mining up until 2037, then discontinued for the closure period to 2050. In Scenario 1c the NWBFP was dewatered at a rate of 6 L/s. In Scenario 1d the NWBFP was dewatered at a rate of 12 L/s.

Without dewatering (the base case) the water level gradually declines to below the spill elevation for resurgent seepage at Bullgang Corner by May 2028 (median of 100 model realisations); but remains above the diffuse seepage to Ramp 7 spill elevation at closure, indicating that resurgent seepage will continue to occur to Ramp 7 up until and beyond closure. With dewatering at 6 L/s (Scenario 1a) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by August 2021 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by July 2029 (median of 100 model realisations). With dewatering at 12 L/s (Scenario 1b) the water level declines to below the spill elevation for resurgent seepage at Bullgang Corner by June 2020 (median of 100 model realisations) and below the diffuse seep spill elevation to Ramp 7 by September 2024 (median of 100 model realisations). The water level may be reduced to 424.3 m RL, that is more than 8 m below the diffuse seepage spill point by 2037, if two bores are used for dewatering.

However, with NWBFP dewatering bores in operation (to reduce water levels in the NWBFP), there was a marked increase in EC at CP3 during the closure period due to continuous overflow of treated water from RD27. The primary inflow to RD27 during this period is low flow seepage from the NWBFP that, when treated, has a modelled EC of 3700 $\mu\text{S}/\text{cm}$. Alternatively, if dewatering is discontinued at the end of mining (as shown in Scenario 1c and Scenario 1d) the EC at CP3 remained below 2100 $\mu\text{S}/\text{cm}$.

Seepage from the NWBFP reporting to Bullgang Corner and diffuse seepage at Ramp 7 is comprised of resurgent seepage as well as interflow. The resurgent seepage is the constant low flow component and interflow occurs in response to rainfall. The low flow component of the seepage ceases to occur with dewatering, however, discharge from the NWBFP will continue due to infiltration and interflow in response to rainfall events.

In the dewatering scenarios trialled, as the water level in the NWBFP is drawn down the resurgent seepage rate declines. The faster the drawdown the lower the resurgent seepage rate. The quantity of high flow diverted around RD27 does not change between scenarios, because there is capacity in RD27 low flow inlets sufficient to manage the constant rate dewatering flow.

A second engineering control has been simulated using the model, that is, application of an improved cover system to the RSA1. On average, there is a 13% reduction in infiltration to the NWBFP; however, this change is insufficient to make a significant change to the water surface elevation in the NWBFP and should not be considered as an engineering control on its own. Based on the performance monitored from the dewatering program, additional improvements to the cover thickness may be considered as a long-term control measure.

9.0 RECOMMENDATIONS

9.1 NWBFP

The following recommendations are made from the NWBFP scenarios simulated:

- Install dewatering system bores to effectively reduce the water level in the NWBFP to well below the spill elevation for resurgent seepage.
- Switch off the NWBFP dewatering bores at the end of mining in 2037.

9.2 RSA1

Based on the effectiveness of the dewatering system bores, the following additional improvements to the cover system of RSA may need be considered:

- Increase the thickness of rehabilitation cover to the embankment of the NWBFP and area of cover on the surface of the NWBFP in the area known as the RSA1 to reduce infiltration to the NWBFP.
- Monitor the performance of the dewatering program to determine whether the cover thickness needs to be increased further.

9.3 Modelling predictions

The following recommendations are made to assist in improving the reliability of modelling predictions:

- Monitor water use in the CHPP following installation of solid bowl centrifuge, including separate monitoring of water from retention dams and raw water use.
- Monitor the water quality of water stored in pits either directly or indirectly via dewatering lines
- Install instrumentation for measuring rainfall infiltration to the NWBFP.
- Monitor water level in the NWBFP (to validate or refine parameters used for determining interflow and recharge in the pit).
- Monitor flow rate and water quality at the Bullgang Corner and Ramp 7 intakes to RD27 to validate head-seepage relationships and interflow parameters in the model.

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Signature Page

Golder Associates Pty Ltd



Scott Weeks
Senior Numerical Modeller



Mike Gowan
Principal

MH/MG

A. B. N. 64 006 107 857

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ATTACHMENT A

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ATTACHMENT B

Catchment Areas

Appendix B: Catchment Areas and Sub-Catchment Land Use

Catchment Areas (ha)

Model Ref	RD	2016	2018	2019	2020	2022	2024	2027	2029	2032	2037	2050
1	RD 01	77	77	77	77	77	77	77	77	77	77	77
2	RD 02	4	4	4	4	4	4	4	4	4	4	4
3	RD 03	46	46	46	45	40	30	29	29	29	29	28
4	RD 04	20	20	16	16	14	10	9	9	9	9	9
7	RD 07	145	12	12	12	12	12	12	12	12	12	12
8	RD 08	6	6	6	6	6	6	6	6	6	6	6
9	RD 09	3	3	3	3	3	3	3	3	3	3	3
10	RD 10	82	82	82	81	82	82	82	82	82	82	82
14	RD 14	82	82	82	82	82	82	82	82	82	82	82
15	RD 15	14	14	14	14	14	14	14	14	14	14	14
16	RD 16	161	161	155	159	98	80	140	140	140	140	140
17	RD 17	108	108	108	108	108	108	96	89	85	85	85
18	RD 18	39	39	39	39	39	39	39	39	39	39	38
21	RD 21	7	7	7	7	7	7	7	7	7	7	7
22	RD 22	145	145	145	145	271	271	271	271	271	271	270
24	RD 24	54	54	54	53	222	185	437	437	437	437	437
25	RD 25	3	3	3	3	3	3	152	152	152	152	152
26	RD 26	128	130	126	126	126	70	0	0	0	0	0
27	RD 27	0	132	132	131	132	141	141	141	141	141	140
28	RD28	0	0	0	0	0	0	106	106	106	106	106
29	RD29	0	0	0	0	0	0	25	26	26	26	26
30	Central	235	235	239	241	232	258	31	16	1	0	0
31	Ramp 5	90	90	97	90	31	11	12	0	0	0	0
32	K4E	144	144	150	149	140	92	92	92	92	92	92
33	K4S	119	119	118	127	139	149	11	0	0	0	0

Appendix B: Catchment Areas and Sub-Catchment Land Use

Model Ref	RD	2016	2018	2019	2020	2022	2024	2027	2029	2032	2037	2050
34	Boundary West	0	0	0	0	0	145	147	161	161	161	161
36	K2E	202	202	202	201	202	211	219	234	278	341	341
37	SW Void	127	127	127	126	0	0	0	0	0	0	0
38	K2N-W	85	86	86	85	85	85	85	85	86	86	85
39	NWB	33	34	33	33	0	32	32	32	32	32	32
44	MCD	610	610	610	609	610	610	610	610	610	610	609
45	MC9	1717	1717	1717	1717	1717	1717	1717	1717	1717	1717	1717
46	MC4	1144	1144	1144	1144	1144	1144	1144	1144	1144	1144	1144
47	MC6	102	102	102	102	102	102	102	102	102	102	102
48	MC2	51	51	51	51	51	51	51	51	51	51	51
49	MC5	43	43	43	43	43	43	43	43	43	43	43
50	CP3	7	7	7	7	7	7	7	7	7	7	7

Appendix B: Catchment Areas and Sub-Catchment Land Use

Sub-catchment land use total areas (ha)

Year	Natural (ha)	Hardstand (ha)	Waste (ha)	Rehab (ha)	Pit Void (ha)	Reservoir Area (ha)	TOTAL (ha)
2016	3942	257	716	488	399	92.2	5895
2018	3935	302	623	546	333	92.2	5832
2019	3930	262	649	585	314	92.2	5833
2020	3935	292	608	624	353	92.2	5904
2022	3916	247	590	724	307	92.2	5875
2024	3845	220	563	883	278	92.2	5881
2027	3851	208	487	924	387	92.7	5950
2029	3808	222	402	1035	375	92.7	5934
2032	3800	227	345	1086	409	92.7	5959
2037	3789	169	115	1540	316	92.7	6021
2050	3789	169	0	1655	310	92.7	6016



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